INTERNATIONAL REGISTER OF SHIPPING

RULES AND REGULATIONS FOR CLASSIFICATION OF STEEL VESSELS 2021

Part 2
Materials and Welding

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CHANGES HISTORY

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1.1 Testing and Inspection

1.1.1 General

Testing and inspection of all materials intended for use in the ship's hull construction and equipment that are classed or proposed for Classification, are to be to the Surveyor's satisfaction and as per the following requirements or their equivalent. Materials, test specimens and mechanical testing procedures having characteristics different from those detailed herein may be approved upon request, and considering the established practices in the country where material is produced, purpose for which the material is intended, such as the parts for which it is to be used, the type and nature of the vessel and its intended service and the nature of the vessel construction.

Additional requirements as determined by the Society may be applicable for particular ship types based on the vessel type assigned in the Class Notation.

1.1.2 Manufacturer Approval

1.1.2.1. All materials for hull construction are to be manufactured at INTLREG approved plants for the type and grade of steel envisaged. The aptness of these products intended for welding and assumed forming is to be demonstrated in the initial approval test at the steel plant. The approval of the steel plant for rolled products is to be as specified in Ch 5, Sec 2 & 3.

1.1.2.2. During the production, manufacturer has to ensure that effective procedures and production controls are implemented and that the manufacturing specifications are strictly adhered to. If some controls and procedures are not followed and consequently result in an inferior product, the manufacturer is required to probe the cause of this and take remedial measures to prevent its recurrence. Later, a comprehensive investigation report is to be prepared and submitted to the Surveyor. INTLREG reserves the right to request a closer survey until the issue is resolved wherein each affected piece is tested to the satisfaction of the attending Surveyor before it can be distributed from the steel plant. For subsequent products that will be manufactured in the steel plant, frequency of testing may be increased to gain manufacturer's confidence in the product quality.

1.1.2.3. In cases where steel is not manufactured at the rolling mill, procedures given in [1.4.3] are to be followed.

1.1.2.4. Manufacturer to ensure that the raw materials (used/semi-finished/finished cast) or wrought steel products produced in their plant are within radioactive contamination limits as permitted by the concerned regulatory body/agency, as applicable to the place of manufacture. Reference to the allowed limits and radiation level are to be specified and documented in manufacturer's QA/QC procedures.

1.1.3 Test and Test Data

1.1.3.1 Witnessed Tests

The designation (**W**) indicates the testing of the product is to be witnessed by the Surveyor, unless the plant is enrolled under INTLREG's Quality Assurance Program and manufactures the product as per their standards.

1.1.3.2 Manufacturer's Data

The designation (M) indicates that test data is to be furnished by the manufacturer and the procedure and the results does not have to be verified by a Surveyor.

1.1.3.3 Other Tests

The designation (A) indicates tests for which test data is to be furnished by the supplier and audited by the Surveyor so that the procedures and random tests witnessed are in conformance with the Rule requirements.

Refer to Ch 5, Sec 1 for a complete list of designations for the various tests discussed in Pt 2, Ch 1 and Pt 2, Ch 2 of this Part.

1.1.4 Certification on the Basis of the INTLREG Quality Assurance Program for Rolled Products

Rolled products such as plates, bars and shapes will be accepted and considered upon application without their mechanical tests being witnessed by the Surveyor on the basis of compliance with INTLREG's Quality Assurance Program.

1.1.5 Rejection of Previously Accepted Material

Any certificate of satisfactory testing issued earlier can be rejected in the event that material while being worked upon yields unsatisfactory results.

1.1.6 Calibrated Testing Machines

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition and that the manufacturer has to maintain a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out by competent personnel to a recognized National or International Standard.

1.1.7 Structural Pipe

Pipes intended for structural use are to be tested to the physical requirements of Ch 2, Sec 17.

1.1.8 ASTM References

For Testing and Materials specification designations without year notations, frequent references will be found within Pt 2, Ch 1 and Pt 2, Ch 2 to various American Society for Testing and Materials (ASTM). Unless if otherwise noted, the current issue of the ASTM specification is to be used.

1.2 Defects

All materials used in the construction of ship's hull are to be free from all sorts of defects including cracks, injurious surface flaws, injurious laminations and similar defects. Unless specified for some specific materials and sanctioned by the Surveyor, remedial measures such as welding or dressing are not allowed. Where sanction is required to treat some materials, the Surveyor may further probe and prescribe some heat treatment or other procedures; whichever if found satisfactory, are to be followed. The part which is treated is to be stamped with Surveyor's identification mark and is surrounded by a ring of paint.

1.3 Identification of Materials

Surveyor is to be provided every facility so that all the materials can be traced to its original heat. The manufacturer is to adopt an identification system wherein the ingots, slabs, finished plates, shapes, castings and forgings could be easily traced to its original heat.

1.4 Manufacturer's Certificates

1.4.1 Form of Certificate

The attending Surveyor of INTLREG is to be furnished with four (4) copies of the certified mill test reports and shipping information (may be separate or combined documents) of all accepted material indicating the grade of material, heat identification numbers, test results and weight shipped, unless requested otherwise. One of its copy is to be endorsed by the Surveyor and forwarded to the Purchaser, and rest are to be retained for the use of INTLREG. Before the distribution of the copies of certified mill tests reports and shipping information to the local INTLREG office, the manufacturer is to issue a certificate stating that the material has been made by an approved process and has satisfactorily undergone and withstood the prescribed tests. Moreover, the following form of certificate will be accepted only if printed on each certified mill test report with the name of the manufacturing firm and initialed by the authorized representative of the manufacturer:

"We hereby certify that the material described herein has been made to the applicable specification by the ________________ process (state process) and tested in accordance with the requirements of _____________________(the International Register of shipping Rules or state other specification) with satisfactory results".

The form of certificate may be changed only upon request of manufacturers, provided it indicates compliance with the requirements of the Rules to no less degree than indicated in the foregoing statement.

1.4.2 Electronic Certification System

An electronically generated, electronically signed and stamped certified mill test reports may be issued, by the attending Surveyor, subject to the following conditions:

- All relevant information regarding the customer order, including the electronic certification request, is to be furnished to the attending Surveyor by the manufacturer.
- Handling and distribution of certified mill test reports among the manufacturer, INTLREG, and the purchaser should be carried out as per established procedures.
- Electronic certification system is implemented only in those steel mills which are under mandatory INTLREG QA program.

1.4.3 Other Certificates

If the plant where steel is produced and where it is rolled or forged are different, a certificate is to be supplied to the Surveyor stating the process by which it was manufactured, the number of the heat from which it was made, the name of the manufacturer who supplied it and the ladle analysis. The identification heat number is to be marked on each ingot, bloom, slab or billet.

1.5 Marking and Retests

1.5.1 Identification of Specimens

When Surveyor is required to identify and select the test specimens, specimens are not to be detached until stamped with his identification mark and until the material has been given its final treatment.

1.5.2 Defects in Specimens

Any test specimen showing defective machining or develops defects, it may be discarded and different specimen substituted. The forgings are not allowed to be retested if a defect develops in them during testing causing rupture, cracks or flakes in the specimen.

1.5.3 Retests

A retest is permitted subject to the following:

- If the percentage of elongation of any tension test specimen is less than that specified; or
- If any part of the fracture is more than 19 mm (0.75 in.) from the center of the gauge length of a 50 mm (2 in.) specimen, or
- Is outside the middle half of the gauge length of a 200 mm (8 in.) specimen, as indicated by scribe scratches marked on the specimen before testing.

1.5.4 Rejected Material

Any set of test specimens are unable to meet the requirements, the lot of material from which such specimens have been taken is to be rejected and the required markings withheld or removed.

1.6 Standard Test Specimens

1.6.1 General

Unless specified otherwise, the tension test specimens are to be of the full thickness or section of material as rolled. The specimens have to undergo only prescribed preparation and similar and simultaneous processes of the material from which they are cut. Straightening of specimens that are distorted by shearing is to be carried out in while the piece is cold. The accuracy of the tensile test machines is to be within ±1% of the load applied.

1.6.2 Orientation of Test Specimens

For shapes and bars tension test specimen are to be taken longitudinal to the final direction of rolling. The tension test specimens are to be taken longitudinal to the final direction of rolling for plates equal to or less than 600 mm (24 in.) in width and transverse to the final direction of rolling for plates wider than 600 mm (24 in.).

1.6.3 Tension Test Specimens, Plates and Shapes

1.6.3.1 Flat Specimens

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to given dimensions and form as shown in Figure 1.1.2 or to dimensions other than described herein may be approved by the Society at the request of the manufacturer.

1.6.3.2 Round Specimens

Material with thickness or diameter over 19 mm (0.75 in.), tension test specimens may be machined to dimensions depicted in Figure 1.1.2. The axis of each round specimen is to be located as near as the midway between the center and the surface of the material. Tension test specimen with dimensions other than described herein may be approved by the Society at the request of the manufacturer.

1.6.4 Tension Test Specimens for Castings (other than Gray Cast Iron) and Forgings

Tension test specimens for castings and forgings are to be machined to the form and dimensions depicted in alternative C in Figure 1.1.2 for the round specimen or as per Figure 1.1.3.

1.6.5 Bend Test Specimens, Castings and Forgings

The bend test specimens for castings and forgings may be machined to 25 mm x 20 mm (1 in. x 0.790 in.) in section. The length is not significant, provided that it is adequate to perform the bending operation. The edges on the tensile side of the bend test specimens may have the corners rounded to a radius of 1–2 mm (0.040–0.080 in.).

1.6.6 Impact Test Specimens

An impact test is to comprise of three (3) specimens taken from a single test coupon or test location. These are to be machined to the form, dimensions and tolerances illustrated in Figure 1.1.4. Full size standard specimens are to be used unless the section thickness of the product is below 11 mm (7/16 in.) or the absorbed energy is expected to exceed 80% of the test machine full scale capacity. For plates, flats and bars, the specimens are to be located at their edges within 2 mm (0.08 in.) from the surface, except that where the thickness exceeds 40 mm (1.57 in.), the longitudinal axis of the specimen is to be located at a point midway between the surface and the center of the thickness. Unless otherwise specified, these test specimens are to be cut with their longitudinal axes either longitudinal or transverse to the final direction of rolling of the material at the option of the steel manufacturer. The length of the notch is to be perpendicular to the original rolled surface. Also refer to Sec 2, [2.6.1] and Sec 4, [4.3.], as applicable.

1.6.7 Tolerances

The tolerances of the tension test specimen dimensions are to be in accordance with a recognized National standard.

1.7 Definition and Determination of Yield Point and Yield Strength

1.7.1 Yield Point

The yield point of a material is the first stress in a material, less than the maximum obtainable stress and at which an increase in strain occurs without an increase in stress. The value of stress is measured at the point when plastic deformation begins 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. Yield point may be determined by the halt of the pointer, or autographic diagram. Under load method, 0.5% total extension will also be considered acceptable.

The test is to be performed with an elastic stress within the limits as in Table 1.1.1.

Table 1.1.1

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

1.7.2 Yield Strength

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. When definite yield phenomenon does not exist, yield strength is to be determined by the 0.2% (*Rp 0.2*) offset method. Also, for material whose stress-strain characteristics are established from previous tests in which stress-strain diagrams were plotted, a 0.5% extension under load method may be used. When agreed upon by the supplier and purchaser for austenitic and duplex stainless steel products, the 1% proof stress may be determined in addition to *Rp 0.2.*

The rate of loading is to be as provided in the limits above (Ref Table 1.1.1)

1.7.3 Tensile Strength

For ductile material, after reaching the yield or proof load, during the tensile test, the machine speed is not to exceed that corresponding to a strain rate of 0.008 per second. In the case of brittle materials, such as gray cast iron, the elastic stress rate is not to surpass 10 N/mm^2 per second.

1.8 Elongation

The elongation value is valid only if the distance between the fracture and the nearest gauge mark is not less than 1/3rd of the original gauge length. However, the validity remains, irrespective of the location of the fracture, provided the percentage elongation after fracture is equal to or greater than the required value.

The elongation A_s, is, determined on a proportional gauge length of $5.65\sqrt{S_o} = 5d$, but may also be given for other specified gauge lengths.

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

$$A_0 = 2\,A_s\left(\frac{\sqrt{S_0}}{L_0}\right)^{0.4}$$

where,
A_0 = Required elongation for the non-proportional test specimen
As = Specified elongation on a gauge length of $5.65\sqrt{S_o}$
S_0 = Cross-sectional area of the test specimen
L_0 = Gauge length of the test specimen

1.9 Permissible Variations in Dimensions

1.9.1 Scope

The minimum material certification requirements is also based on the under tolerances specified below and is to be considered as the lower limit of the usual range of variations (+/-) from the specified dimension.

The manufacturer bears the responsibility for meeting the tolerances and maintains a procedure acceptable to the Surveyor. INTLREG is to be advised before presenting the steel for acceptance to ensure that wherever any tolerances (including over thickness tolerances) to be used are more stringent than the normal commercial tolerances, by the appropriate thickness measuring procedure.

Nevertheless, the thickness of the steel is to meet the under tolerances specified below and the steel mill is to consider the effect of mill scale on the resulting measurement. For classification purposes and also while making the assessment of deterioration at future thickness gauging, the thickness indicated on the approved plan is to be used.

1.9.2 Plates and Wide Flats

These requisites apply to the tolerance on thickness of steel plates and wide flats with widths of 600mm (14 in.) or greater (hereinafter referred to as: product or products) with thicknesses of 5 mm (0.2 in.) and over, covering the following steel grades:

a) Normal and higher strength hull structural steel.

b) Higher strength quenched and tempered steels for welded structure as given in Section 4 of this chapter.

For products below 5 mm (0.2 in.) the thickness tolerances may be specifically agreed.

Note: Tolerances for length, width, flatness and over thickness may be taken from National or International standards.

Class C of ISO 7452 may be applied in lieu of [1.9.2.2], in which case the requirements in [1.9.2.3] and [1.9.2.4] need not be applied. If Class C of ISO 7452 is to be used, the portion of the footnote of ISO 7452, Table B.2, which reads “Also a minus side of thickness of 0,3 mm is permitted.” is not to be applied.

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

1.9.2.1 Responsibility

The manufacturer holds the responsibility for verification and maintenance of the production within the required tolerances. The Surveyor may witness some measurements. Shipyard has to bear the responsibility for storage and maintenance of the delivered product(s) with acceptable level of surface conditions prior to their use in fabrication.

1.9.2.2 Thickness Tolerances

a) Thickness tolerances of a given products are defined as:
   (i) Plus, tolerance is the upper limit of the acceptable range above the nominal thickness.

   (ii) Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

   Note: Purchaser defines nominal thickness at the time of enquiry and order.

b) Minus tolerance on thickness of products in the scope of [1.9.2] is 0.30 mm (0.012 in,) irrespective of nominal thickness.

c) Plus, tolerances on nominal thickness are to be in accordance with National or International standard like ASTM A6.

d) Thickness tolerances are not applicable to areas repaired by grinding done as in line with Sec-2, [2.8.2].

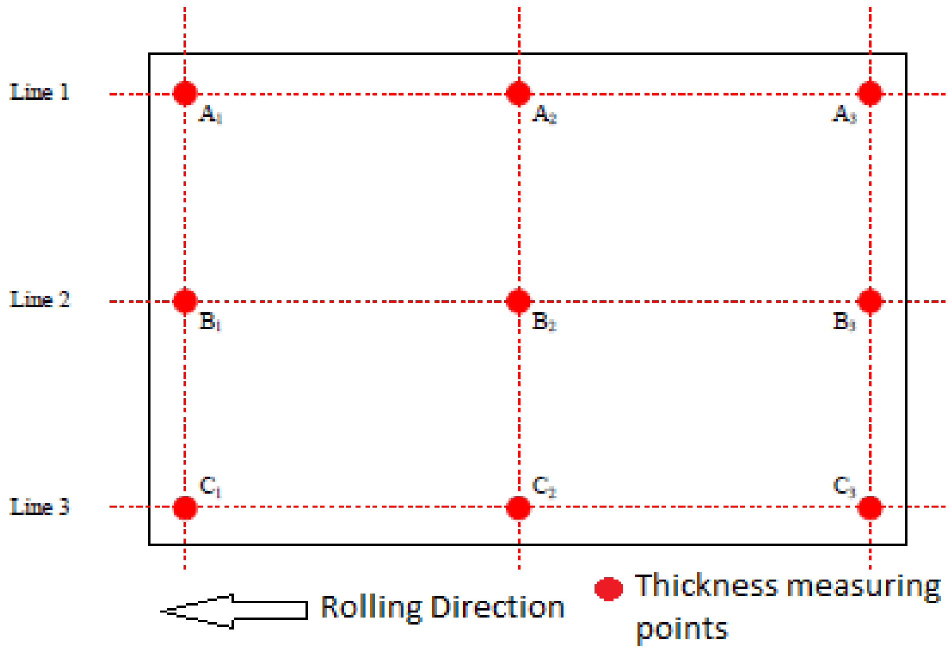
1.9.2.3 Average Thickness

a) The average thickness of a product is defined as the arithmetic mean of the measurements made in accordance with the requirements of [1.9.2.4].

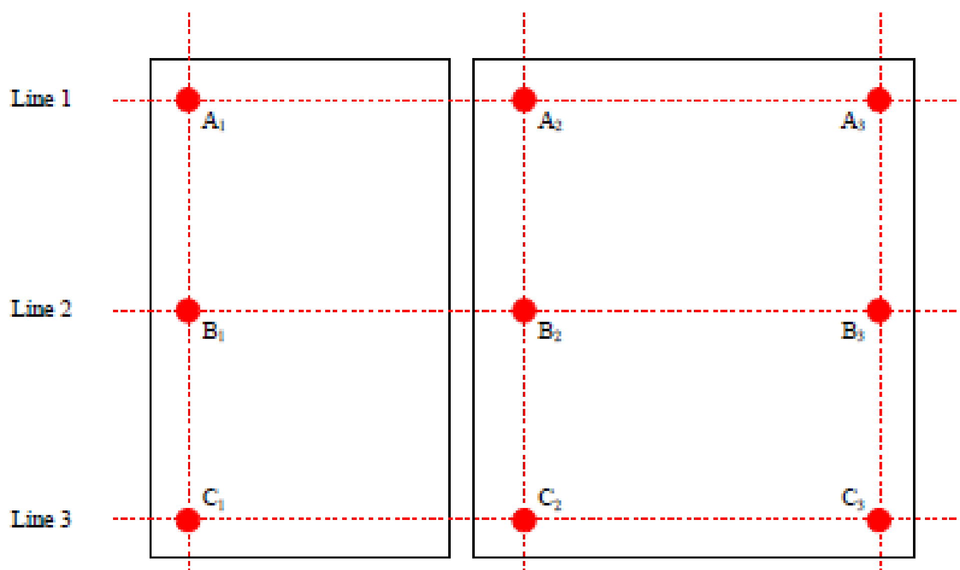
b) The average thickness is not to be less than the nominal thickness.

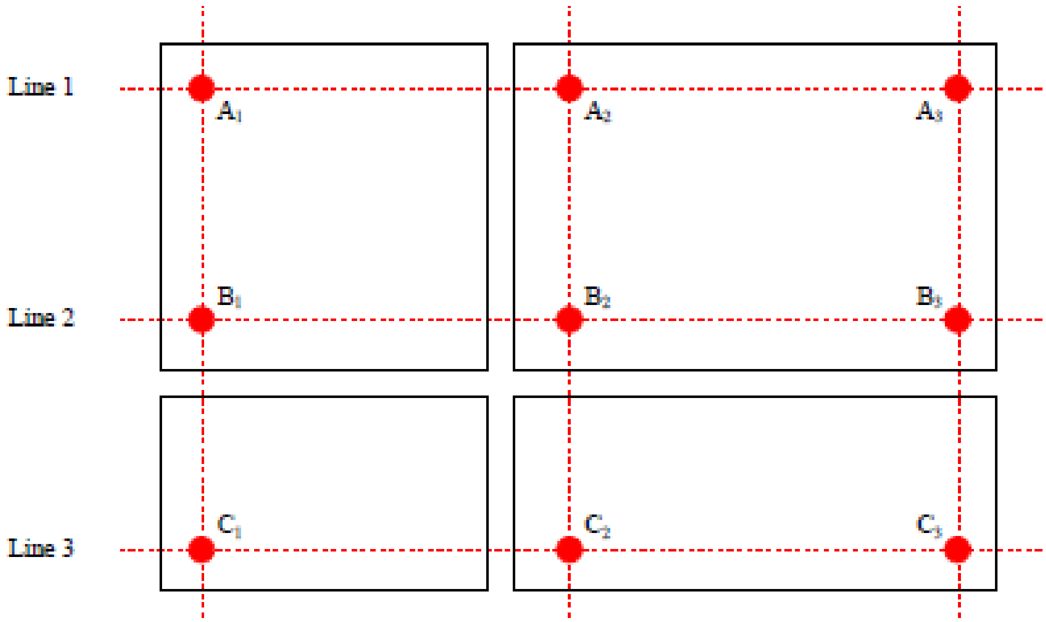
1.9.2.4 Thickness Measurements

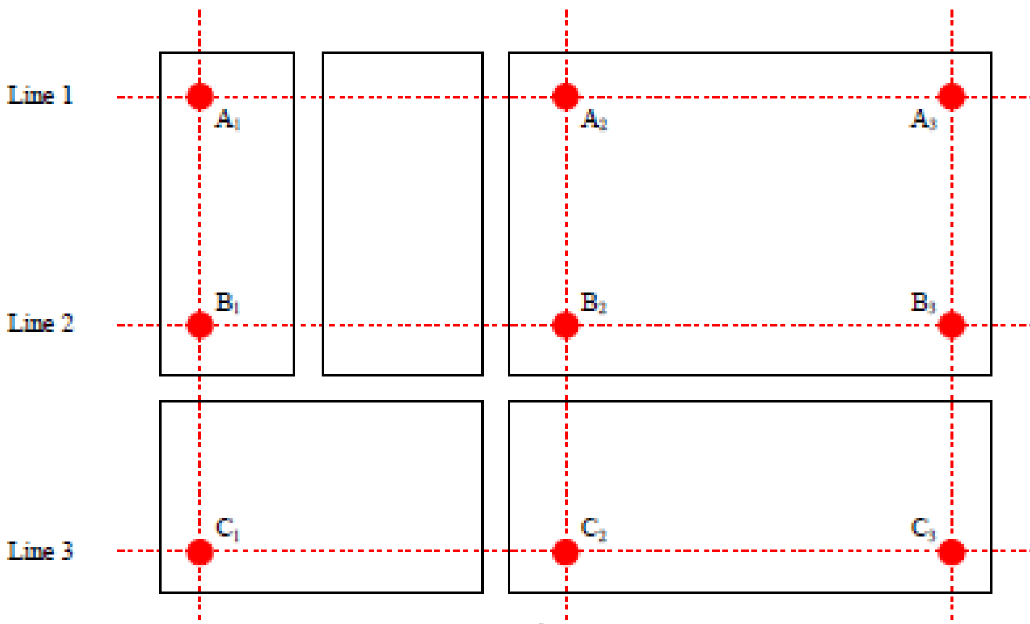
Thickness is to be measured at locations illustrated in Figure 1.1.1 below. Automated or manual method is applied to the thickness measurements and respective procedure and records of measurements are to be made readily available to the Surveyor and upon request, copies are also to be provided.



(a) Thickness Measuring Point locations for Original Steel Plates







(b) Thickness Measuring Point locations for Cut Steel Products
(Rolling direction same as in (a) above)

Figure 1.1.1

Notes: (Refer Figure 1.1.1)

1. Two lines, as a minimum, are to be selected from Lines 1, 2, or 3, and on each of them, three points are to be selected for thickness measurement. If more than three points are taken on each Line, same number of points on each line is to be taken.

2. Peripheral points are to be chosen 10-300 mm (0.375-12.0 in.) from the edge in the case of automated measuring.

3. Peripheral points are to be chosen at 10-100 mm (0.375-4.0 in.) from the edge in the case of manual measuring.

4. Rolling direction and thickness measuring points same for each figure above as shown for the Original Steel Plate (a).

1.9.3 Shapes and Bars

For shapes and bars, the under tolerance of cross-sectional dimensions are to be based on the ordered dimensions and are to be in compliance with ASTM A6 or other recognized standards, as specified by the purchaser.

1.10 Rolled Plates over 100 mm (4 in.) Thickness

Where INTLREG and non-INTLREG grade rolled plates of over 100 mm (4 in.) thickness are used for vessel hull structural application, the test data given below is to be obtained at one-quarter and mid thickness locations in addition to chemical analysis:

- Tensile properties

- Impact properties in the longitudinal or transverse directions.

Also, each plate is to be UT inspected in accordance with either ASTM A 578 Level B or other equivalent recognized standard to evaluate the internal soundness.

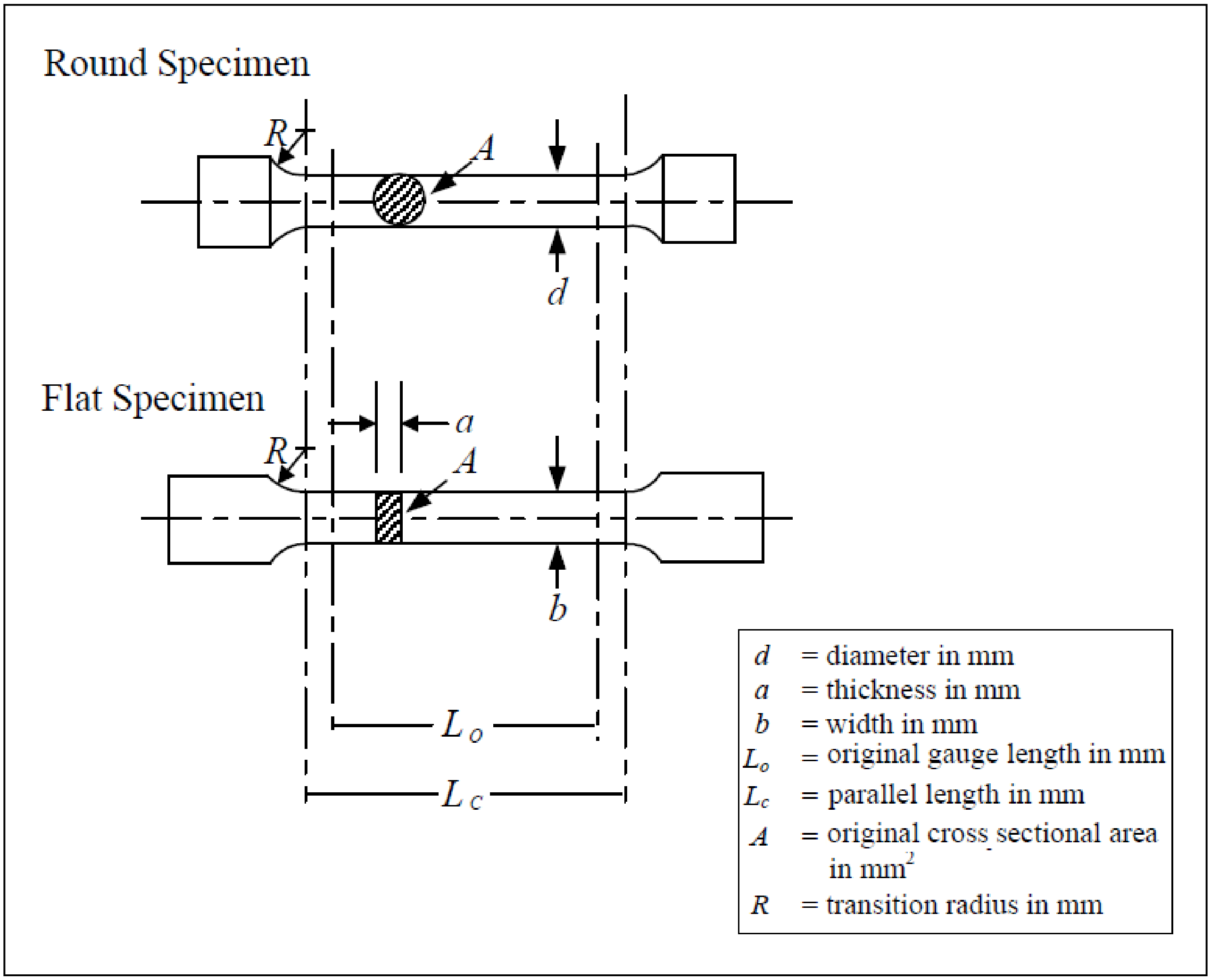

Round Specimen
R
A
d
Flat Specimen
a
R
A
b
L o
L c
d = diameter in mm
a = thickness in mm
b = width in mm
Lo = original gauge length in mm
Lc = parallel length in mm
A = original cross sectional area in mm2
R = transition radius in mm

Figure 1.1.2: Standard Tension Test Specimen (Refer Table 1.1.2 for the values)

	d	A	b	L_o	L_c	R
Flat specimen Alternative A	-	t(2)	25	$5.65\sqrt{A}$	$L_o + 2\sqrt{A}$	25
Flat specimen Alternative B	-	t(2)	25	200	225	25
Round specimen Alternative C	14	-	-	70	85	10

Notes:

1. Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in Table 1.2.3 or Table 1.3.2.
2. ‘t’ is the full thickness of the material as produced. If the capacity of the testing machine does not allow full thickness specimens to be broken, the thickness may be reduced by machining one surface only.
3. L_o, the proportional gauge length, is to be greater than 20 mm.

Table 1.1.2

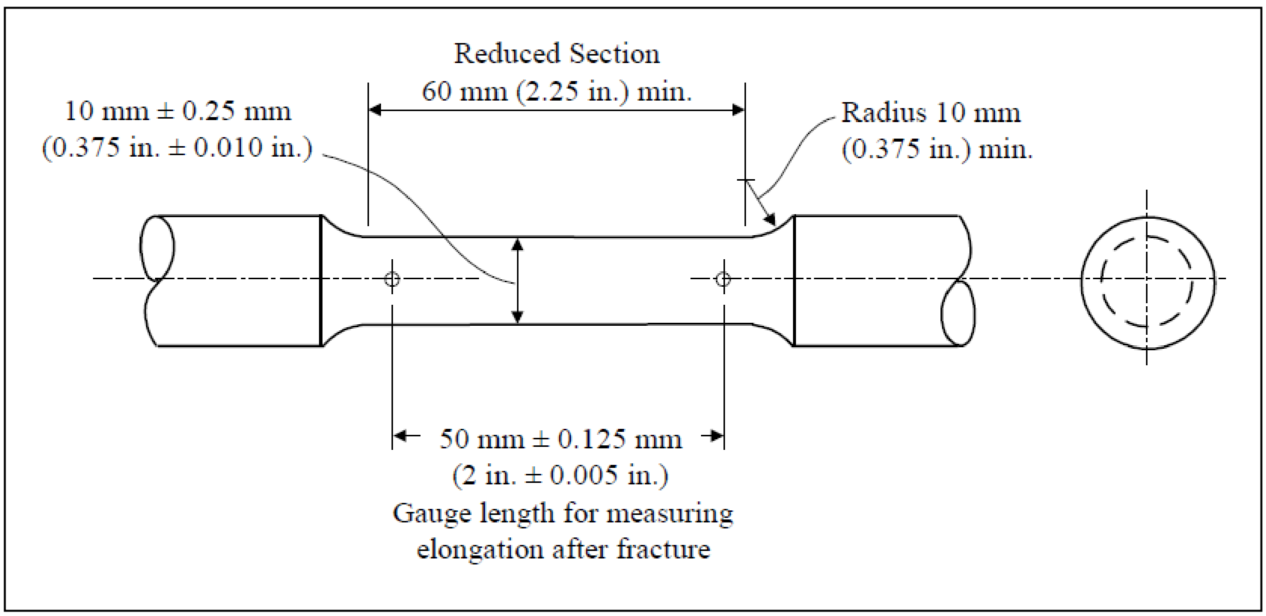


Figure 1.1.3: Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length

Note:

The gauge length and fillets are to be as illustrated. However, their ends may be of any shape to fit the holders of the testing machine to maintain the load in axial direction. The reduced section may gradually taper from the ends towards the center, with the ends not more than 0.13 mm (0.005 in.) larger in diameter than the center.

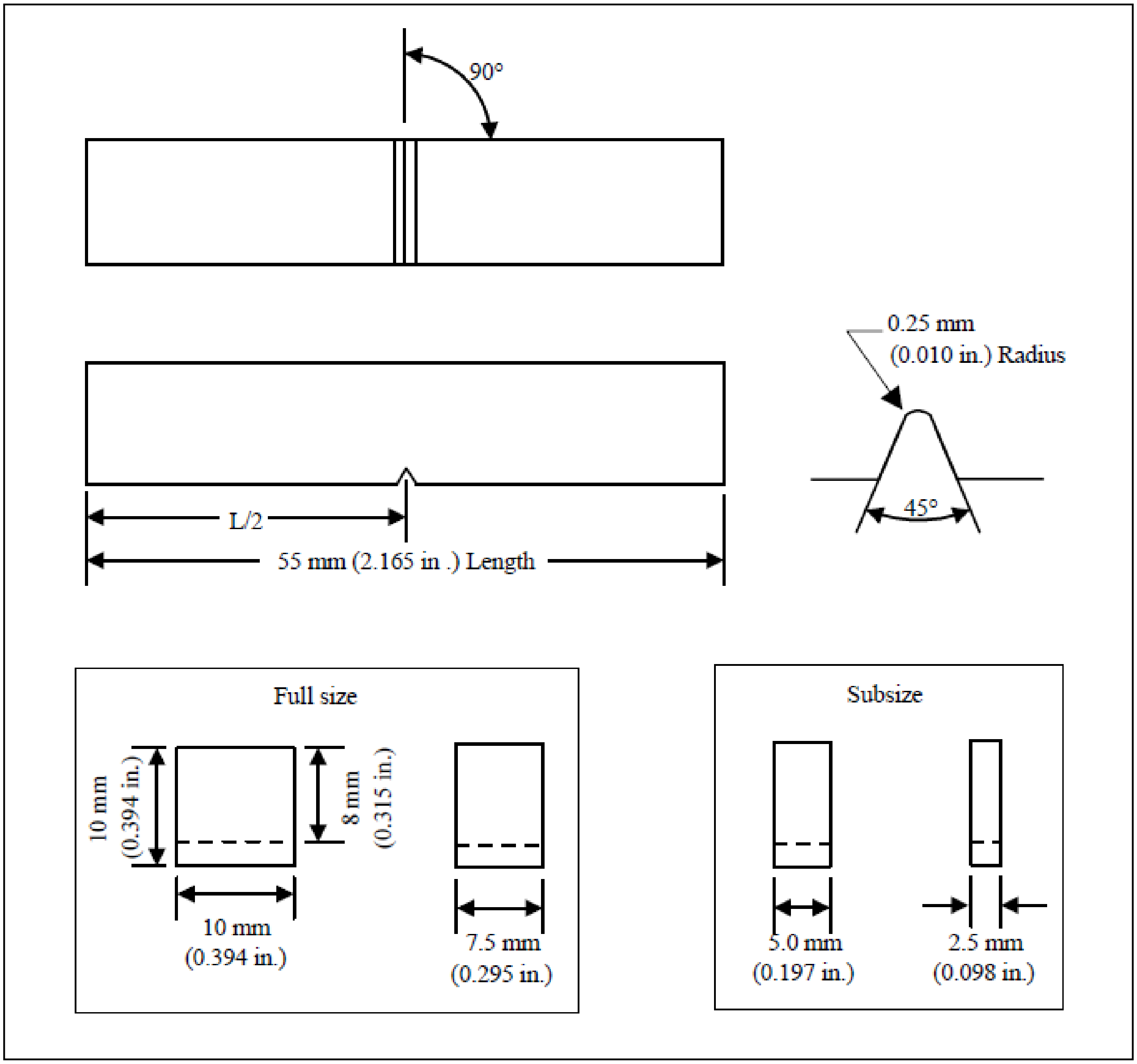


Figure 1.1.4: Charpy V-notch Impact Test Specimens

<u>Tolerances</u>: (Refer Figure 1.1.4)

- Adjacent sides are to be at 90 Deg ± 10 min.
- Centering of notch ± 1 mm (0.039 in.)
- Width:

Standard Specimen	10 mm ± 0.11mm (0.004 in.)
Sub size Specimen	7.5 mm ± 0.11 mm (0.004 in.)
sub size Specimen	5 mm ± 0.06 mm (0.0024 in.)
sub size Specimen	2.5 mm ± 0.06 mm (0.0024 in.)

- Thickness ± 0.06 mm (0.0024 in.)
- Angle of Notch ± 2 degrees.
- Angle between plane of symmetry of notch and longitudinal axis of test specimen is to be at 90 deg. ± 2 deg.
- Radius of Notch ± 0.025 mm (0.001 in.)
- Length of specimen ± 0.60 mm (0.024 in.)
- Dimension to Bottom of Notch ± 0.06 mm (0.0024 in.)
- Surface finish requirements on:
  Notched surface and opposite face: 2 µm (63 µin.)
  Other surfaces: 4 µm (125 µin.)

Charpy machines complying with ISO 148 (or other equivalent National or International recognized standards) are to be used to carry out all the impact tests, and having a striking energy of not below 150 J.

The temperature of the test specimen at the moment of breaking shall be the specified temperature within ± 2°C (± 3.6°F). where the test temperature is other than ambient.

1.11 Steel Plates and Wide Flats with Specified Minimum through Thickness Properties ("Z" Quality)
"Z" quality steel is in use in those structural details that are subject to strains in the through thickness or "Z" direction to minimize the possibility of lamellar tearing either during fabrication or erection.

Although these requirements are projected for material with thicknesses greater than or equal to 15 mm (0.60 in.) provided a specified minimum ductility in the through thickness or "Z" direction is specified. Products with a thickness less than 15 mm (0.60 in.) may also be included

Two "Z" quality steels are for normal and severe applications respectively are:

- Z25 (for normal ship application)
- Z**35** (for more severe application)

The characteristic of through thickness properties are the specified values for reduction of area in a through thickness tension test.

The steel plants are to be approved by INTLREG for the manufacture of "Z" quality steels, as specified in Ch 5, Sec 2 & 3. Furthermore, maximum sulfur content determined by ladle analysis is to be 0.008%.

When steels with improved through thickness properties are specified, following special steel-making processes are to be used, either alone or in combination:

a) Low sulfur practices

b) Electro-slag or vacuum arc re-melting

c) Addition of elements known to control the shape of non-metallic inclusions.

d) Control of centerline segregation during continuous casting.

1.11.1. Sampling

One test sample for steel plates and wide flats is to be taken close to the longitudinal centerline of one end of each rolled piece representing the batch. Refer Table 1.1.3 and Figure 1.1.5.

Table 1.1.3: Batch Size Depending on Product and Sulphur Content

Product	Sulphur > 0.005%	Sulphur ≤ 0.005%
Plates	Each piece (parent plate)	Maximum 50t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm (1.0 in.)	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 > 25 mm (1.0 in.)	Maximum 20t of products of the same cast, thickness and heat treatment	Maximum 50t of products of the same cast, thickness and heat treatment

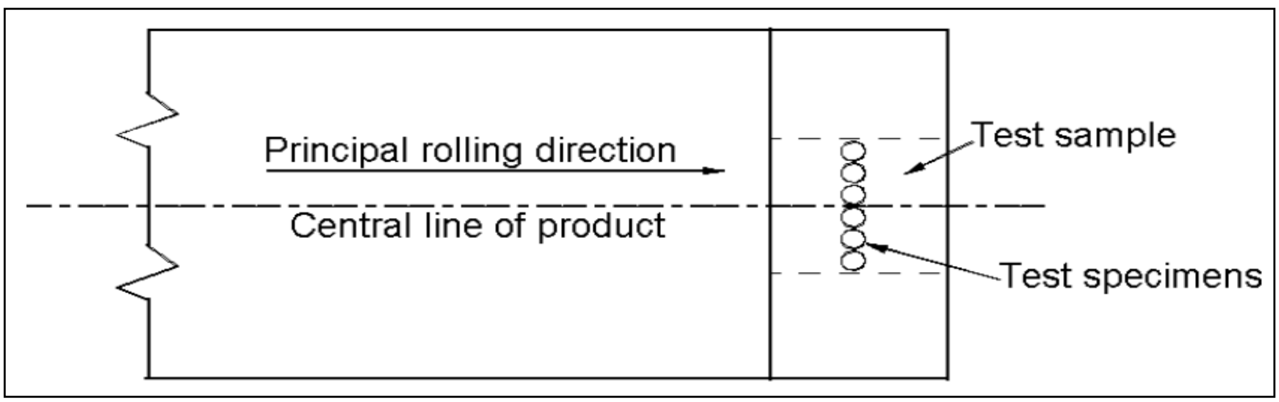


Figure 1.1.5: Plate and Wide Flat Sampling Position

1.11.2. Number of Tensile Test Specimens

The test sample must be large enough to accommodate six (6) specimens out of which three (3) test specimens are to be prepared while the rest are set aside for possible retest.

1.11.3. Tensile Test Specimen Dimensions

Round test specimens, including built-up type by welding, shall be prepared in accordance with a recognized National / International standard.

1.11.4. Tensile Test Results

The minimum average value for the reduction of area of at least three (3) tensile test specimens taken in the through thickness direction must be as mentioned for the appropriate grade in Table 1.1.4. Only one individual value may be below the minimum average but not less than minimum individual value given for the appropriate grade. Refer Figure 1.1.6.

If a value is less than the minimum individual value, this is a cause for rejection. The test is considered invalid and a further replacement test is to be carried out if the fracture occurs in the weld or heat-affected zone.

Table 1.1.4: Reduction of Area Acceptance Values

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

1.11.5. Retests

Figure 1.1.6 illustrates three cases where retest is permitted. For the purpose of which three more tensile tests are to be taken from the remaining test sample. The average of all six (6) tensile tests is to be greater than the required minimum average with not more than two results below the minimum average. If after retest, one encounters failure, either the whole batch represented by the piece is rejected or each piece within the batch is required to be tested.

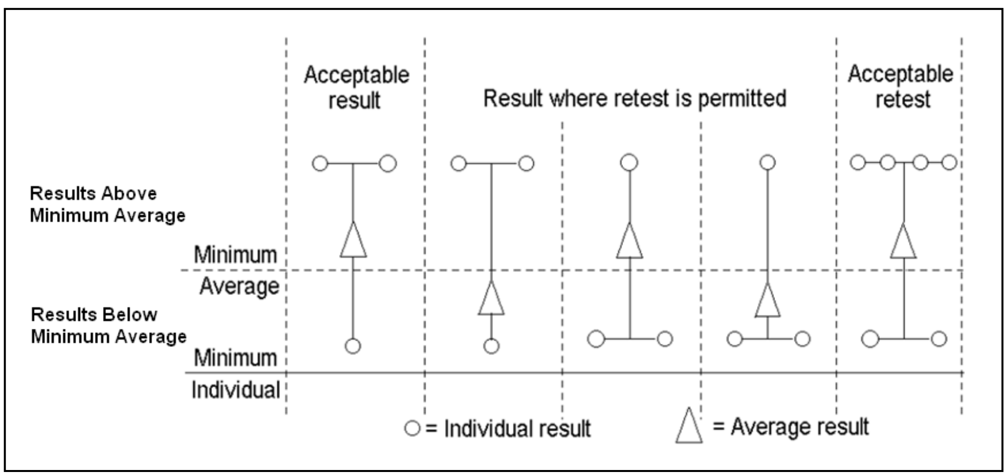


Figure 1.1.6: Diagram Showing Acceptance/Rejection and Retest Criteria

1.11.6. Ultrasonic Inspection

In accordance with either EN 10160 Level S1/E1 or ASTM A578 Level C Ultrasonic inspection is required to be carried out. All ‘Z’ grade plates are to be tested in the final supply condition with a probe frequency of 2 or 2.25 MHz. While carrying out UT on material less than 20 mm (3/4 in.) thick, frequency up to 5 MHz may be considered acceptable if satisfactorily documented and qualified

1.11.7. Marking

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

1.11.8. Certification

In addition to the appropriate steel grade requirements, following information is required to be included on the certificate:

(i) Through thickness reduction in area (%)

(ii) Steel grade with Z25 or Z35 notation.

(iii) Ultrasonic Inspection result of each plate

1.12 Formed Materials

As per the requirement given in Ch3,Sec 1,[1.2.7] confirmatory mechanical tests are to be carried out when material is hot or cold formed.

1.13 Ultrasonic Examination of Plate Material

For being specially marked as given in paragraph Sec 2, [2.7.7], INTLREG steels are to be ultrasonically examined in accordance with a recognized specification such as ASTM A435 or equivalent.

1.14 Fracture Toughness Testing

Where specified fracture toughness testing of materials and weldment is to be carried out. It may involve tests for properties such as plane strain fracture toughness parameter, K_{IC}; elastic-plastic fracture toughness parameter, J_{IC}; or critical crack-tip opening displacement (CTOD) parameter, for mode-I type of deformation.

Testing as per BS 7448 Parts 1 & 2/ASTM E1820 specification or another recognized standard is acceptable. It is deemed to be valid and acceptable, provided post-test data analyses meets all validity criteria of BS 7448 Parts 1 & 2/ASTM E1820 or any other recognized standard, and the fracture toughness value determined is equal to or greater than the minimum specified value in the INTLREG-approved specification. Specific aspects that are to be taken into considerations before testing are as detailed below:

1.14.1 Load type (bend or tension), specimen geometry and notch orientation etc. are to be selected as per the specification and in line with the recognized standards detailed in BS 7448 Parts 1 & 2 / ASTM E 1823 or equivalent.

1.14.2 As specified in the material specification for plates, and for welds, and as provided in the manufacturing procedure specification, cut samples for machining test specimens are to be extracted from test coupons or from locations with proper orientation identified. On the basis of the manufacturer's evolved traceability system using a template and paint, local chemical etching or mechanical means, the orientation mark, plate number, heat number, etc., are to be transferred onto the samples. There should not be any plastic deformation or distortions during this process. Before the initiation of the test program, this process is to be repeated on the finished, inspected and accepted specimens. Mix-up of specimens without proper identification will result in rejection of the test results.

1.14.3 When samples are to be straightened, it is to be carried out between the platens of a suitable press (mechanical or hydraulic) under the slowest possible loading rate, and the compressive load applied is not to exceed the compressive yield stress of the material. It is the manufacturer's responsibility to ensure complete safety to personnel and the witnessing Surveyor during the operation.

1.14.4 In case of weldment testing, the residual stresses are not to be altered in any way by pre-compression crack front straightening method(s), unless permitted in the INTLREG-approved material and product manufacturing procedure specifications separately.

1.14.5 The specimen dimensions, side grooving, machined notch root radius and other fine details (such as specimen surface finish, centerline offset of loading pins, etc.) in the test specimens shall be in accordance with the approved specimen drawing and in compliance with ASTM E1820 or to any other recognized standard.

1.14.6 Calibration certificates for load cells, transducers, servo-mechanical/hydraulic universal testing machines, and recording equipment used in testing are to be provided to the Surveyor by the testing lab for verification and record. Selection of the loading roller diameter and its alignment with the crack plane of the specimen in the case of bend specimen testing and proper alignment of the clevis for compact tension testing are to be ensured by the Surveyor prior to the beginning of a test.

1.14.7 In the presence of the attending Surveyor, crack opening displacement (COD) gauges are to be calibrated once per batch of testing.

1.14.8 Fatigue pre-cracking loads and cyclic loading rates (applied stress intensity level/time) are to be as per BS7448/ASTM E1820 or any other recognized standard, and the surveyor is to witness at least one specimen in a batch of specimen being tested. For the rest, the test lab has to provide the loading history and certify that these were done in accordance with BS7448/ASTM E1820 or any other recognized standard.

1.14.9 Crack length measurement may be carried out by using electrical potential technique and may be supplemented by optical means of measurements. The calibration method employed is to be verified by the Surveyor and is to be validated by nine (9) point measurements made on the broken specimen after the test as per BS 7448/ASTM E1820 or to any other recognized standard. Heat tinting/etching or other appropriate method(s) that are used to disclose the crack front to estimate the final crack length in post-test analysis is to be carried out to the Surveyor's satisfaction. For each specimen that is tested, photo-macrographs of the broken samples are to be captured and documented along with the valid test report.

1.14.10 The acceptance criteria for CTOD tests as given below are to be applied whenever these tests are performed:

- If from a set of three tests, the scatter in CTOD (δ_c, δ_u or δ_m) data is such that the minimum value is greater than or equal to 70% of the average value of the set, then that minimum value is to be taken as the characteristic CTOD value for a specified location (base metal, weld metal, or HAZ) and is to be equal to or higher than the specified minimum CTOD value for the material at the specified location.

- If from a set of three tests, the minimum value is less than 70% of the average value of the set, or it fails to meet the specified minimum CTOD value, then three additional specimens are to be machined and tested from the same previously tested plate, product, or weldment. Then, the reported characteristic CTOD value is the second lowest of all six values and which has to be equal to or greater than the specified minimum CTOD value as stipulated in INTLREG-approved material and fabrication specifications for the material at the specified location.

SECTION 2 ORDINARY STRENGTH HULL STRUCTURAL STEEL

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2.1 General

In this section the requirements are intended for products with the following thicknesses.

- Sections and Bars up to and including 50 mm (2.0 in.)
- Plates and Wide Flats up to and including 100 mm (4.0 in.)

2.2 Process of Manufacture

2.2.1 The steel is to be produced using processes such as: basic-oxygen, open-hearth, electric furnace, vacuum-arc remelt, electro-slag remelt, or other processes which are specially approved. The steel may be cast in ingots or may be strand (continuous) cast. The ratio of reduction of thickness from a strand (continuous) cast slab to finished plate is to be a minimum of 3:1, unless specially approved.

2.2.2 The steel manufacturer has to submit data in support of mechanical properties, weldability and compliance with the Rules for review and approval when new steel mills begin production or when new or special steels produced or new production methods are proposed.

2.2.3 Plates Produced from Coils

For plates produced from coils or coiled plate, the manufacturer is to submit supporting data for review and approval to establish that the manufacturing, processing, and testing will produce material which is in compliance with the Rules.

2.3 Chemical Composition

2.3.1 **Ladle Analysis**

The chemical properties of the grades of steel listed in Table 1.2.2 are applicable for compliance with the chemical composition determined by the steel manufacturer on samples taken from each ladle of each heat.

2.3.2 **Product Analysis**

The chemical tolerances of ASTM A6 or of other nationally recognized standards are to be applied where product (check) analysis is required.

2.3.3 **Special Compositions**

Materials differing in chemical composition, de-oxidation practice, mechanical properties or heat treatment from that given in Table 1.2.2 will be subject to special approval.

2.3.4 **Fine Grain Practice**

Where fine grain practice is used in making steel, adding aluminum helps in meeting the requirements, unless some other method is specifically approved. The fine grain requirement may be determined using one of the methods given below:

2.3.4.1 A McQuaid-Ehn austenite grain size of 5 or finer in accordance with ASTM E112 for each ladle of each heat, or

2.3.4.2 Minimum Acid-soluble Aluminum content of 0.015% or minimum total Aluminum content of 0.020% for each ladle of each heat.

2.4 Condition of Supply

The conditions of supply are to be as per the requirements in Table 1.2.6 and those given below. For each plant and combination of grade and thickness limit, controlled manufacturing processes require approval. The applicable rolling procedures are defined as follows:

2.4.1 **As Rolled – AR**

The AR procedure involves the rolling of steel at high temperature and subsequent air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalizing temperature. The resultant steel generally has strength and toughness properties less than steel heat treated after rolling or than steel produced by advanced processes.

2.4.2 **Heat Treatment**

2.4.2.1 Normalizing Heat Treatment

Normalizing heat treatment is to comprise of heating plates, bars, wide flats, or shapes from a suitable temperature below the transformation range to the proper temperature above the transformation range, holding for enough time to effect the desired transformation and then cooling the individual material in air.

This drastically improves the mechanical properties of as-rolled steel by refining the austenitic grain size, in case that the steel is produced to fine austenitic grain size practice. These treatments are usually conducted at the steel manufacturer’s plant though they may also be carried out at a shipyard or fabricator’s plant, provided the Surveyor is satisfied with the heat-treating facilities and procedures. In such cases, the shipyard or fabricator is to specify on the purchase order that the mill tests are to be made on normalized coupons. Otherwise tests on the normalized material will be required at the shipyard or fabricator’s plant.

2.4.2.2 Special Heat Treatment

Special heat treatments are to be specifically approved.

2.4.3 **Controlled Manufacturing Process**

2.4.3.1 **Controlled Rolling – CR** (Normalized Rolling – NR)

In this procedure, the final rolling temperature is generally controlled within the range used for normalizing heat treatments so that the austenite entirely re-crystallizes and results in a material condition generally equivalent to that obtained by normalizing.

2.4.3.2 **Thermo-mechanical Rolling – TM** (Thermo-mechanical Controlled Processing – TMCP)

Thermo-mechanical controlled rolling procedure comprises of the stringent control of the steel temperature and the rolling reduction. Usually, a high proportion of the rolling reduction is carried out close to or below the Ar3 transformation temperature and may involve rolling towards the lower end of the temperature range of the inter critical duplex phase region, thus permitting little recrystallization of the austenite, if there is any. Unlike controlled rolling, the properties produced by TM (TMCP) cannot be reproduced by subsequent normalizing or other heat treatment.

On attaining special approval of INTLREG, the use of accelerated cooling on completion of rolling may also be accepted.

Accelerated cooling (AcC) is a process by which the mechanical properties are improved by controlled cooling with rates higher than immediate air cooling after the final TM (TMCP) operation. Direct quenching is excluded from accelerated cooling.

Where controlled manufacturing processes (CR and TM) with/without AcC are applied, the programmed rolling schedules are to be verified by INTLREG at the time of approval of steel plants. Surveyor shall have easy and ready access to these schedules whenever required and it is the manufacturer's responsibility to adhere to them during the rolling operation. Refer to Ch 1, Sec 1, [1.1.2.2]. To this effect the actual rolling records at works are to be reviewed by the manufacturer and occasionally by the Surveyor.

In case of any deviations from the programmed rolling schedules or normalizing or quenching and tempering procedures, the manufacturer shall take the remedial measures required in Ch 1, Sec 1, [1.1.2.2] to the Surveyor's satisfaction.

2.4.4 **Quenching and Tempering – QT**

Quenching is a heat treatment process in which steel is heated to an appropriate temperature above the Ac3 and then cooled using an appropriate coolant for hardening the microstructure.

After quenching, tempering process is carried out in which the steel is reheated to a temperature not higher than the Ac1 to restore toughness properties by improving the microstructure.

2.5 Tensile Properties

2.5.1 **Required Tensile Properties**

Except as specified in 2.5.3, the materials are required to conform to the requirements of Table 1.2.3 as for the tensile properties.

2.5.2 **Tension Test Specimens**

From each heat of steel, two different plates, shapes or bars are chosen and one tension test is to be carried out on each of them. However, if the finished material from a heat is less than 50 tons, one tension test will be sufficient. Also, if the material from one heat differs 9.5 mm (0.375 in.) or more in thickness or diameter, one tension test is to be conducted from both the thickest and the thinnest material rolled, irrespective of the weight represented. One tension test is to be conducted on each plate as quenched and tempered.

For plates made from coils, tension tests are to be carried out from not less than two coils from each heat, except where a single coil is to be certified wherein tension test specimens from that coil only required to be tested. Two tension tests are to be carried out from each coil tested. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen from the approximate center lap. When the coiled material from one heat differs by 1.6 mm (1/16 in.) or more in thickness, test specimens are to be taken from both the thinnest and the thickest material rolled.

2.5.3 **Exceptions**

Shapes less than 645 mm^2 (1 in^2) in cross section and bars, other than flats, less than 12.5 mm (1/2 in.) in thickness or diameter need not be subjected to tension test. However, chemistry consistent with the required tensile properties is to be applied.

2.5.4 **Omission of Elongation Requirements**

The elongation requirements are waived for raised-pattern floor plates not exceeding 12.5 mm (0.50 in.) in thickness.

2.5.5 Retests

Two retests may be carried out on specimens taken from the same sample where the results of the tension tests do not comply with the requirements. For elongation retest, Sec 1, [1.5.3] is to be complied with. The retest specimens are to be taken adjacent to the original specimen, for plates made from coils.

The tested material or that representing the material is accepted if the results of both additional tests meet the requirements. When the results do not meet the requirements, the sample is to be rejected, unless the manufacturer opts to resubmit it after heat treatment or reheat treatment, or as another grade. The remaining material represented by the test may be treated under [2.5.6].,below

2.5.6 Unsatisfactory Tests

Where the tests under [2.5.2] and [2.5.6] fail, the remaining material from the same heat may be accepted only if satisfactory results are obtained on both of the two additional plates, shapes or bars selected as given in [2.5.2].

When results of one or both samples fail to meet the requirements, all materials represented by the tests are to be rejected unless the manufacturer chooses to resubmit each piece individually, or resubmit the lot after heat treatment/reheat treatment or as another grade.

2.6 Impact Properties

2.6.1 Impact Tests

Charpy V-notch impact tests are to be carried out in accordance with Table 1.2.5. Unless otherwise agreed, these same requirements apply for rounds, flats and shapes when specifically ordered in these grades. For rolled sections, impact tests specimens are to be taken from the flanges of channels, beams and tees, and from the legs of angles and bulb angles. One set of three impact specimen is to be cut from the thickest material rolled, except when the maximum thickness or diameter of the material represented by the test differs by 9.5 mm (0.375 in.) or more, in which case, one set of impacts is to be made from both the thickest and the thinnest material represented, regardless of their weight. Ref Sec 1, [1.6.6].

Impact test coupons are to be obtained adjacent to both tension test coupons for plates made from coils, and a third impact test coupon is to be taken immediately after the last plate produced to the qualifying grade or specification; in no case, however, is the frequency of impact testing to be less than that given above for plates, and where additional testing is required, three sets of specimens are to be obtained from each coil tested.

2.6.2 Impact Test Frequency

The frequency of impact testing shall be in accordance with Table 1.2.6.

2.6.3 Initial Test Requirements

The average value of three (3) specimens is to equal or exceed the required average value in the Rule Tables. It is allowed that just one individual value may be below the required average and it is not to be less than 70% of the required average. Where sub-size specimens in Figure1.1.4 are to be used, the modified energy values will apply, as given in Table 1.2.1.

Table 1.2.1: sub size Specimen Impact Requirements

Specimen Size	10 × 7.5 mm (0.394 × 0.295 in.)	10 × 5.0 mm (0.394 × 0.197 in.)	10 × 2.5 mm (0.394 × 0.098 in.)
Required Energy	5E/6	2E/3	E/2
E = energy required for 10 × 10 mm (0.394 × 0.394 in.) specimen			

2.6.4 Retests

When the results fail to meet the above requirements but conditions ii) and iii) below are fulfilled, three additional specimens may be obtained from the location closest to the initial specimens and their test results added to those earlier obtained to form a new average. The material represented may be accepted, if for the six specimens, all the conditions given below are met:

i) The average is not less than the required average.

ii) Not more than one individual value is below 70% of the required average.

iii) Not more than two individual values are below the required average.

The tested material is to be rejected unless the manufacturer elects to resubmit it after heat treatment or reheat treatment, or as another grade, if the test results do not meet the above requirements.

2.6.5 Unsatisfactory Tests

The rest of the material from the heat may be accepted, provided that the satisfactory impact results are to be attained on both of the two plates of the same thickness as the rejected plate in the heat. On the other hand, after impact testing each plate, the manufacturer may qualify material of the same thickness. Also, the plates of lesser thickness in the same heat may be accepted, provided satisfactory results are achieved on impact specimens taken from the next lower thickness than the rejected plate.

2.6.6 Thin Plates

Normally, impact tests are not required for thin plates which are less than 6 mm (0.24 in.) in thickness.

2.7 Marking

2.7.1 Stamped or Stenciled Material

On each finished plate, shape and bar, the **INTLREG** markings and the applicable grades listed in Table 1.2.2 indicating satisfactory compliance with the Rules are to be clearly steel-die-stamped or stenciled by the manufacturer to signify that the material has satisfactorily complied with the prescribed tests and that certificates for the material will be made available to the Surveyor in accordance with Sec-1, [1.4]. **INTLREG** mark without the grade designation shall be given to the coiled steel which is certified for chemical analysis only.

2.7.2 Coils, Lifts and Bundles

Upon application, in special cases, the coils proposed for light plate, secured lifts or bundles of light plates, bars or shapes of comparatively small size may be steel-die stamped, stenciled, or labeled on only the top piece or at another approved location, or the markings may be depicted on a tag attached to each coil, lift or bundle.

2.7.3 Flanging-quality Identification

All material intended for cold flanging, is to be additionally marked F to signify that it is of such quality, when specially approved as per **Pt 3**, Ch 2, Sec 2. Cold flanging is to be carried out as per ASTM A6.

2.7.4 Special Marking and Stamping

In order to facilitate ready identification and signify that material has been produced and satisfactorily tested as specified other than those grades listed in Table 1.2.2, is to be marked with both the initials **INTLREG** and with either the applicable specification number, or such other markings. When a material does not require normalizing but the material is so ordered and produced, then the plates are also to be marked with the initial **N** to indicate that the material has been normalized. The shipyard or fabricator who carries out normalizing heat treatment as specified in [2.4] is to also mark such material with the initial **N**.

2.7.5 Special Impact Testing

When impact testing of steels is carried out at temperatures other than those specified in Table 1.2.5, the grade marking is to be followed by the test temperature in degrees Celsius. A prefix “0” added to the test temperature indicates temperature colder than zero degrees Celsius.

2.7.6 Steel with Improved Through Thickness Properties

Steel plates in compliance with the requirements of Sec 1, [1.11] are to have the letter **Z** marked after the grade designation.

2.7.7 Steel with Ultrasonic Examination

Steels in compliance with the requirements of Sec 1, [1.13] are to have the letter U marked after the grade designation as a final letter.

2.7.8 Shipping Procedure

Any material not bearing these markings is to be forwarded from the steel plants until the prescribed tests have been satisfactorily carried out as per the Rule requirements.

2.7.9 Steel at Secondary Sources

The secondary sources for INTLREG grade steel that requires INTLREG certification shall ensure proper traceability. For proper identification, steel may be marked with the information specified by the manufacturer’s markings to the satisfaction of the Surveyor.

2.8 Surface Finish

2.8.1 Surface Examination

The surface examination of material is is to be carried out by the Surveyor when specially requested by the purchaser. It is to be free from defects and have a workmanlike finish subject to the conditions given below.

2.8.2 Treatment of Surface Defects – Plates

Manufacturer may condition the plates for the removal of surface defects on either surface by grinding, provided each ground area is well faired and the grinding does not reduce the plate thickness

i) More than 7% under the nominal thickness and in no case more than 3.2 mm (0.125 in.) when ordered to weight or;

ii) Below the minimum thickness permissible under Sec 1, [1.9.2] when ordered to thickness.

There may be surface defects on the plates which may be removed by grinding or gouging and chipping and then depositing weld metal, subject to the limiting conditions given below.

2.8.2.1 Extent of Weld Repaired Area

The extent of total weld repaired area of each surface of a plate is not to exceed 2% of the total area.

2.8.2.2 Minimum Thickness Before Weld Repairs

After removing defects prior to welding, the thickness of the plate is not to be reduced by more than 20% of the nominal thickness.

2.8.2.3 Inspection Before Weld Repairs

An experienced mill inspector examines the work to ensure that all the defects have been removed completely and that the foregoing limitations have not been exceeded. The Surveyor is to be given full opportunity to carry out the same inspection. To assure removal of defects, magnetic particle or liquid penetrant examination may be required.

2.8.2.4 Repair-welding Quality

Qualified operators are to carry out all welding operations using an approved welding procedure and low hydrogen filler metal/practice. The welding is to be sound, thoroughly fused, and without undercutting or overlap. Weld metal is to have at least 1.6 mm (0.063 in.) reinforcement, which is to be removed by grinding or chipping and grinding flush with the rolled surface, and present a workmanlike finish.

2.8.3 **Treatment of Surface Defects – Shapes**

Subject to the limitations below, the manufacturer may condition the shapes for the removal of surface defects by chipping or by grinding to sound metal and depositing weld metal.

2.8.3.1 Grinding and Chipping Material Under 9.5 mm (0.375 in.) in Thickness

For material which are less than 9.5 mm (0.375 in.) in thickness, have defects are not more than 0.8 mm (0.031 in.) in depth, the defects may be removed by grinding or chipping and grinding with the edges well faired.

2.8.3.2 Grinding and Chipping Material 9.5 mm (0.375 in.) and Over in Thickness

Materials which are 9.5 mm (0.375 in.) and over in thickness, with defects not more than 1.6 mm (0.063 in.) in depth, the defects may be removed by grinding or chipping and grinding with the edges well faired.

2.8.3.3 Welding Repairs

Subject to the limitations below, for surface defects greater in depth than the limits shown above, grinding or chipping and then depositing weld metal may be used for removing them:

a) The total area of the chipped or ground surface of any piece is not to exceed 2% of the total surface area.

b) After defect preparatory to welding is removed, neither the thickness of the shape is to be reduced by more than 30% of the nominal thickness, nor is the depth of depression before welding is to exceed 12.5 mm (0.50 in.) under any circumstances.

c) The toes of angles, beams, channels and zees and the stems and toes of tees may be conditioned by grinding or chipping and welding. Before welding, the depth of depression, measured from the toe inward, is to be restricted to the thickness of the material at the base of the depression, with a maximum depth limit of 12.5 mm (0.50 in.).

d) An experienced mill inspector is to examine and witness the welding as per the requirements given in [2.8.2.3] and [2.8.2.4].

2.8.4 **Bar-stock Repairs**

Manufacturer may condition the bars for the removal of surface defects by grinding, chipping or some other means, provided that the conditioned area is well faired and the depth of depression does not extend below the nominal thickness or diameter by more than 1.5%.

2.8.5 **Rivets**

The material test requirements for steel/aluminum rivets are to be in compliance with National or International Standards.

Table 1.2.2: Chemical Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Under

Grade	**A**	**B**	**D**	**E**
Deoxidation	Killed or semi-killed (1) (t ≤ 50 mm (2.0 in.)) Killed (t > 50 mm (2.0 in.))		Killed (t ≤ 25 mm (1.0 in.)) Killed and fine grain (t > 25 mm (1.0 in.)) (2)	Killed and fine grain (2)
Chemical Composition (Ladle Analysis), % max. Unless specified otherwise. (8)				
C	0.21 (3)	0.21	0.21	0.18
$Mn_{min.}$	2.5 × C	0.80(4)	0.60	0.70
Si	0.50	0.35	0.10–0.35(5)	0.10–0.35(5)
P	0.035	0.035	0.035	0.035
S(9)	0.035	0.035	0.035	0.035
Ni	Ref Note 6	Ref Note 6	Ref Note 6	Ref Note 6
Cr	Ref Note 6	Ref Note 6	Ref Note 6	Ref Note 6
Mo	Ref Note 6	Ref Note 6	Ref Note 6	Ref Note 6
Cu	Ref Note 6	Ref Note 6	Ref Note 6	Ref Note 6
C + Mn/6	0.40	0.40	0.40	0.40
Marking	**IR/A**	**IR/B**	**IR/D(7)**	**IR/E**

Notes:

1. For Grade A, rimmed steel sections may be accepted up to and including 12.5 mm (0.5 in).
2. Grade D steel over 25 mm and Grade E steel are to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirements. Refer[2.3.4].
3. A maximum carbon content of 0.23% is acceptable for Grade A sections.
4. For Grade B steel of cold flanging quality or where fully killed, the lower limit of manganese may be reduced to 0.60%.
5. Where the content of soluble aluminum is not less than 0.015%, the minimum required silicon content does not apply.
6. The contents of nickel, chromium, molybdenum and copper are to be determined and reported. When the amount does not exceed 0.02%, these elements may be reported as ≤0.02%.
7. Grade D hull steel which is normalized, thermo-mechanical control processed or control rolled is to be marked IR/DN. Intentionally added elements are to be determined and reported.
8. Intentionally added elements are to be determined and reported.
9. For steels of cold flanging quality, the maximum sulfur content is 0.020%

Table 1.2.3: Tensile Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Below

Grade	**Tensile Strength** N/mm^2 (kgf/mm^2, ksi)	**Yield Point** min. N/mm^2 (kgf/mm^2, ksi)	**Elongation**(1,3,4) min. %
A, B, D, E	400-520 (2) (41-53, 58-75)	235 (24, 34)	22

Notes:

1. Based on alternative A flat test specimen or alternative C round specimen in Figure 1.1.2.
2. For Grade A sections, the upper limit of tensile strength may be 550 N/mm^2 (56 kgf/mm^2, 80 ksi).
3. Minimum elongation for alternative B flat specimen in Figure 1.1.2 is to be in accordance with Table 1.2.4.
4. Minimum elongation for ASTM E8M/E8 or A370 specimen is Table 1.2.4 for 200 mm (8 in.) specimen and 22% for 50 mm (2 in.) specimen.
5. Steel ordered to cold flanging quality may have tensile strength range of 380-450N/mm^2 (39-46 kgf/mm^2, 55-65 ksi) and a yield point of 205 N/mm^2 (21 kgf/mm^2, 30 ksi) minimum. Refer also [2.7.3] and Pt 3, Ch 2.

Table 1.2.4: Elongation Requirements for Alternative B Specimen

Thickness (t) in mm (in.)	**Elongation** min. (%)
t ≤ 5 (0.2)	14
5 < t ≤ 10 (0.2 < t ≤ 0.4)	16
10 < t ≤ 15 (0.4 < t ≤ 0.6)	17
15 < t ≤ 20 (0.6 < t ≤ 0.8)	18
20 < t ≤ 25 (0.8 < t ≤ 1.0)	19
25 < t ≤ 30 (1.0 < t ≤ 1.2)	20
30 < t ≤ 40 (1.2 < t ≤ 1.6)	21
40 < t ≤ 50 (1.6 < t ≤ 2.0)	22

Table 1.2.5: Impact Properties of Ordinary-Strength Hull Structural Steel 100 mm (4.0 in.) and Under

Average Absorbed Energy (Refer Note 1) J (kgf-m, ft-lbf)							
		t ≤ 50 mm (2.0 in.)		50 mm < t ≤ 70 mm (2.0 in. < t ≤ 2.8 in.)		70 mm < t ≤ 100 mm (2.8 in. < t ≤ 4.0 in)	
Grade	**Temperature °C (°F)**	Longl.(2)	Transv(2)	Longl.(2)	Transv(2)	Longl(2)	Transv(2)
A	20 (68)	—	—	34 (3.5, 25)(3)	24 (2.4, 17)(3)	41 (4.2, 30)(3)	27 (2.8, 20)(3)
B (4)	0 (32)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)
D	-20 (-4)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)
E	-40 (-40)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)

Notes:

1. The energy shown is minimum for full size specimen. Ref [2.6.3] for sub size specimen requirements.
2. Either direction is acceptable.
3. Impact tests for Grade A are not required when the material is produced using a fine grain practice and normalized.
4. CVN test requirements for Grade B apply where such test is required by Table 1.2.6.

Table 1.2.6: Condition of Supply and Frequency of Impact Tests Ordinary Strength Hull Structural Steel

<table>
<tr><th rowspan="3">Grade</th><th rowspan="3">Deoxidation</th><th rowspan="3">Products</th><th colspan="5">Condition of Supply (Impact Test Lot Size in Tons)</th></tr>
<tr><th colspan="5">Thickness in mm (in.)</th></tr>
<tr><th>t ≤ 12.5
(0.5)</th><th>12.5 < t ≤ 25
(0.5 < t ≤ 1.0)</th><th>25 < t ≤ 35
(1.0< t ≤ 1.375)</th><th>35 < t ≤ 50
(1.375 < t ≤ 2.0)</th><th>50 < t ≤ 100
(2.0 < t ≤ 4.0)</th></tr>
<tr><td rowspan="4">A</td><td>Rimmed</td><td>All</td><td>A (-)</td><td colspan="4"></td></tr>
<tr><td>Semi-Killed</td><td>All</td><td colspan="4" rowspan="3">A (-)</td><td></td></tr>
<tr><td rowspan="2">Killed</td><td>P</td><td>N (-)[4] TM (-) CR (50) AR (50)</td></tr>
<tr><td>S</td><td></td></tr>
<tr><td rowspan="3">B</td><td>Semi-Killed</td><td>All</td><td colspan="2" rowspan="3">A (-)</td><td colspan="2" rowspan="3">A (50)</td><td></td></tr>
<tr><td rowspan="2">Killed</td><td>P</td><td>N (50) TM (50) CR (25) AR (25)</td></tr>
<tr><td>S</td><td></td></tr>
<tr><td rowspan="2">D</td><td rowspan="2">Killed &
Fine Grain</td><td>P</td><td colspan="3" rowspan="2">A (50) N (50)</td><td rowspan="2">N (50)
TM (50) CR (50)</td><td>N (50) TM (50) CR (25)</td></tr>
<tr><td>S</td><td></td></tr>
<tr><td rowspan="2">E</td><td rowspan="2">Killed &
Fine Grain</td><td>P</td><td colspan="4">N (P) TM (P)</td><td>N (P) TM (P)</td></tr>
<tr><td>S</td><td colspan="4">N (25) TM (25) CR (15)</td><td></td></tr>
</table>

Notes:

1. Products: P = plate; S = sections
2. Conditions of Supply: A = Any Condition; N = normalized; AR = As Rolled; TM = thermo-mechanical controlled processing; CR= Control Rolled
3. Frequency of Impact Test (Impact Test Lot Size in Tons):
   (-) = no impact test required
   (P) = each piece
4. Impact tests for Grade A are not required when material is produced using a fine grain practice and normalized.

SECTION 3 HIGHER STRENGTH HULL STRUCTURAL STEEL

Contents

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3.2. Fine Grain Practice 41
3.3. Additional Requirements of TMCP Steel 42

3.1. General

3.1.1 The requirements in this section are intended for products with the following thicknesses:

<table>
<tr><th colspan="2">Type</th><th>Thickness</th></tr>
<tr><td rowspan="2">Plates and Wide Flats</td><td>AH32, DH32, EH32, AH36, DH36 and EH36 steels</td><td>Up to and including 100 mm (4 in.)</td></tr>
<tr><td>AH40, DH40, EH40, FH32, FH36 and FH40 steels</td><td>Up to and including 100 mm (4 in.)</td></tr>
<tr><td colspan="2">Sections and Bars</td><td>Up to and including 50 mm (2 in.)</td></tr>
</table>

3.1.2 The requirements in Sec-2, [2.2] through Sec-2, [2.8] are also applicable to higher-strength hull structural steels with the following paragraphs and Tables replaced by the higher-strength requirements as indicated.

Tables in Section 2	Table Replaced by
Section 2, Table 1.2.2	Section 3, Table 1.3.1
Section 2, Table 1.2.3	Section 3, Table 1.3.2
Section 2, Table 1.2.4	Section 3, Table 1.3.3
Section 2, Table 1.2.5	Section 3, Table 1.3.4
Section 2, Table 1.2.6	Section 3, Table 1.3.5
Section 2,[2.3.4]	Section 3, [3.2]

3.2. Fine Grain Practice

Where fine grain practice is used in making steel, the requirement may be met by one of the conditions given below:

i) A McQuaid-Ehn austenite grain size of 5 or finer in accordance with ASTM E112 for each ladle of each heat, or

ii) Minimum Acid-soluble Aluminum content of 0.015% or minimum total Aluminum content of 0.020% for each ladle of each heat, or

iii) Minimum Columbium (Niobium) content of 0.020% or minimum Vanadium content of 0.050% for each ladle of each heat, or

iv) When Vanadium and Aluminum are used in combination, minimum Vanadium content of 0.030% and minimum acid-soluble Aluminum content of 0.010% or minimum total Aluminum content of 0.015%.

v) When Columbium (Niobium) and Aluminum are used in combination, minimum Columbium (Niobium) content of 0.010% and minimum acid-soluble Aluminum content of 0.010% or minimum total Aluminum content of 0.015%.

3.3. Additional Requirements of TMCP Steel

3.3.1 Carbon Equivalent

As per the following equation the carbon equivalent C_{eq} as determined from the ladle analysis is to meet the requirements in Table 1.3.6:

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

3.3.2 Cold Cracking Susceptibility

The cold cracking susceptibility, P_{cm}, may be calculated with the equation given below, unless otherwise specified by the purchaser:

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

When steel is ordered, selection of the maximum value for P_{cm} is a matter to be agreed between the fabricator and the steel mill.

Table 1.3.1: Chemical Properties of Higher-strength Hull Structural Steel 100 mm (4.0 in.) and bellow

Grades	AH 32, DH 32, EH 32 AH 36, DH 36, EH 36 AH 40, DH 40, EH 40	FH 32, FH 36, FH 40
Deoxidation	Killed, Fine Grain Practice(1)	
Chemical Composition(2)	(Ladle Analysis), % max. unless specified in range	
C	0.18	0.16
Mn	0.90–1.60 (3)	0.90–1.60
Si	0.10–0.50 (4)	0.10–0.50 (4)
P	0.035	0.025
S	0.035	0.025
Al (acid Soluble) min (5,6)	0.015	0.015
Nb(6,7)	0.02–0.05	0.02–0.05
V(6,7)	0.05–0.10	0.05–0.10
Ti(7)	0.02	0.02
Cu (8)	0.35	0.35
Cr (8)	0.20	0.20
Ni (8)	0.40	0.80
Mo (8)	0.08	0.08
Ca (7)	0.005	0.005
N	—	0.009 (0.012 if Al present)
Marking (9) IR/XHYY (X = A, D, E or F; YY = 32, 36 or 40)(9)		

Notes:

1. The steel is to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirement Ref [3.2].
2. The contents of any other element intentionally added is to be determined and reported.
3. AH steel 12.5 mm (0.50 in.) and under in thickness may have a minimum manganese content of 0.70%.
4. Where the content of soluble aluminum is not less than 0.015%, the minimum required silicon content does not apply.
5. The total aluminum content may be used in lieu of acid soluble content, in accordance with [3.2].
6. The indicated amount of aluminum, niobium and vanadium applies when any such element is used singly. When used in combination, the minimum content in [3.2] will apply.
7. These elements need not be reported on the mill sheet unless intentionally added.
8. These elements may be reported as ≤ 0.02% where the amount present does not exceed 0.02%.
9. The marking AB/DHYYN is to be used to denote Grade DHYY plates which have either been normalized, thermo-mechanically control rolled or control rolled in accordance with an approved procedure.
10. Ref [3.3] for carbon equivalent and cold cracking susceptibility requirements for thermo-mechanically controlled steel.
11. For other steels, the carbon equivalent (C_{eq}) may be calculated from the ladle analysis in accordance with the equation in [3.3.1]. Selection of the maximum value of carbon equivalent for these steels is to be agreed between the fabricator and steel mill when the steel is ordered.

Table 1.3.2: Tensile Properties of Higher-strength Hull Structural Steel 100 mm (4.0 in.) and Below

Steel	**Tensile Strength** N/mm^2 (kgf/mm^2, ksi)	**Yield Point (**min.) N/mm^2 (kgf/mm^2, ksi)	**Elongation** (min.) %$^{(1,2,3)}$
AH 32 DH 32 EH 32 FH 32	440-590 (45-60, 64-85)	315 (32, 46)	22
AH 36 DH 36 EH 36 FH 36	490-620 (50-63, 71-90)	355 (36, 51)	21
AH 40 DH 40 EH 40 FH 40	510-650 (52-66, 74-94)	390 (40, 57)	20

Notes:

1. Based on alternative A flat test specimen or alternative C round specimen in Sec-1, Figure 1.1.2.
2. Minimum elongation for alternative B flat specimen in Sec-1, Figure 1.1.2 is to be in accordance with Table 1.3.3.
3. Minimum elongation for ASTM E8M/E8 or A370 specimen is Table 1.3.3 for 200 mm (8 in.) specimen and 20% for 50 mm (2 in.) specimen.

Table 1.3.3: Elongation Requirements for Alternative B Specimen

Thickness (t) in mm (in.)	**Steel Grade**		
	AH32, DH 32, EH 32, FH 32	**AH 36, DH 36, EH 36, FH 36**	**AH 40, DH 40, EH 40, FH 40**
	Elongation (%)		
t ≤ 5 (0.2)	14	13	12
5 < t ≤ 10 (0.2 < t ≤ 0.4)	16	15	14
10 < t ≤ 15 (0.4 < t ≤ 0.6)	17	16	15
15 < t ≤ 20 (0.6 < t ≤ 0.8)	18	17	16
20 < t ≤ 25 (0.8 < t ≤ 1.0)	19	18	17
25 < t ≤ 30 (1.0 < t ≤ 1.2)	20	19	18
30 < t ≤ 40 (1.2 < t ≤ 1.6)	21	20	19
40 < t ≤ 50 (1.6 < t ≤ 2.0)	22	21	20

Table 1.3.4: Impact Properties of Higher-strength Steel 100 mm (4.0 in.) and Below

Average Absorbed Energy(1) J (kgf-m, ft-lbf)							
Grade	Temp. °C (°F)	t ≤ 50 mm (2.0 in.)		50 mm < t ≤ 70 mm (2.0 in. < t ≤ 2.8 in.)		70 mm < t ≤ 100 mm (2.8 in. < t ≤ 4.0 in)	
		Longl (2)	Transv(2)	Longl(2)	Transv(2)	Longl(2)	Transv(2)
AH 32	0 (32)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
AH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
AH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)
DH 32	-20 (-4)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
DH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
DH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)
EH 32	-40 (-40)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
EH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
EH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)
FH 32	-60 (-76)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
FH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
FH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)

Notes:

1. The energy shown is minimum for full size specimen. Refer Sec 2, [2.6.3] for sub size specimen requirement.
2. Either direction is acceptable.

Table 1.3.5: Condition of Supply and Frequency of Impact Tests – Higher-strength Hull Structural Steel

Grade	Deoxidation	Grain Refining Element	Products	Condition of Supply (Impact Test Lot Size in Tons) – Thickness in mm (in.): t ≤ 12.5 (0.5)	12.5 < t ≤ 20 (0.5 < t ≤ 0.8)	20 < t ≤ 25 (0.8 < t ≤ 1.0)	25 < t ≤ 35 (1.0 < t ≤ 1.375)	35 < t ≤ 50 (1.375 < t ≤ 2.0)	50 < t ≤ 100 (2.0 < t ≤ 4.0)
AH 32 AH 36	Killed, Fine Grain Practice	Nb V	P	A (50)	N (50*) TM (50) CR (50)				N (50) TM (50) CR (25)
			S	A (50)	N (50*) TM (50) CR (50) AR (25)				N/A
		Al Al + Ti	P	A (50)		AR (25) N (50*) TM (50) CR (50)		N (50*) TM (50) CR (50)	N (50) TM (50) CR (25)
			S	A (50)		N (50*) TM (50) CR (50) AR (25)			N/A
DH 32 DH 36		Nb V	P	A (50)	N (50) TM (50) CR (50)				N (50) TM (50) CR (25)
			S	A (50)	N (50) TM (50) CR (50)				N/A
		Al Al + Ti	P	A (50)		AR (25) N (50) TM (50) CR (50)	N (50) TM (50) CR (50)		N (50) TM (50) CR (25)
			S	A (50)		AR (25) N (50) TM (50) CR (50)	N (50) TM (50) CR (50)		N/A
EH 32 EH 36		Any	P	N (P) TM (P)					N (P) TM (P)
			S	N (25) TM (25) CR (15)					N/A
FH 32 FH 36		Any	P	N (P) TM (P) QT (P)					N (P) TM (P)
			S	N (25) TM (25) QT (25)					N/A
AH 40		Any	P	A (50)	N (50) TM (50) CR (50)				N (50) TM (50) QT (P)
			S	A (50)	N (50) TM (50) CR (50)				N/A
DH 40		Any	P	N (50) TM (50) CR (50)					N (50) TM (50) QT (P)
			S	N (50) TM (50) CR (50)					N/A
EH 40		Any	P	N (P) TM (P) CR (P)					N (P) TM (P) QT (P)
			S	N (25) TM (25) CR (25)					N/A
FH 40		Any	P	N (P) TM (P) QT (P)					N (P) TM (P) QT (P)
			S	N (25) TM (25) CR (25)					N/A

Notes

1 Products: P = Plate S = Sections

2 Conditions of Supply: A = Any Condition N = Normalized AR = As Rolled CR = Control Rolled QT = Quenched and Tempered TM = thermo-mechanically controlled processing

3 Frequency of Impact Test (Impact Test Lot Size in Tons):

(-) = no impact test required (P) = each piece

(*) = upon application and approval, the impact frequency may be reduced

Table 1.3.6: Carbon Equivalent for Higher-strength Hull Structural Steel 100 mm (4.0 in.) and below, Produced by TMCP

Grade	**Carbon Equivalent**, Max. (%) (Refer note)	
	t ≤ 50 mm (2.0 in.)	50 mm < t ≤ 100 mm (2.0 in. < t ≤ 4.0 in.)
AH 32, DH 32, EH 32, FH 32	0.36	0.38
AH 36, DH 36, EH 36, FH 36	0.38	0.40
AH 40, DH 40, EH 40, FH 40	0.40	0.42

Note:

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

SECTION 4 HIGH STRENGTH QUENCHED AND TEMPERED STEEL

Contents

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4.2. Chemical Composition 48
4.3. Mechanical Properties 49
4.4. Heat Treatment 49

4.1. General

4.1.1. Specific requirements defined in this Section, together with the general requirements in Sec 1, Sec 2 and Sec 3 of this chapter, are applicable to INTLREG high strength quenched and tempered steel plates. Steel product shapes other than plates, such as sections and tubulars, are subject to special considerations.

4.1.2. For material selection, steels are grouped in six categories of 43, 47, 51, 56, 63 and 70 [kgf/mm^2] based on the level of yield strength (Refer Table 1.4.1). Each category combined with four different alphabetic indicators of AQ, DQ, EQ and FQ according to the Charpy V-notch impact test temperature (Refer Table 1.4.2) to designate the steel grades. For example, Grade AQ43 specifies the steel of yield strength of 420 N/mm^2 (43 kgf/mm^2, 61 ksi) given the test temperature of 0°C (32°F).

4.1.3. Table 1.4.3 shows material selection guidelines for each structural element category for INTLREG Grades of Quenched and Tempered Steels.

Table 1.4.1: Steel Category Based on Level of Yield Strength

Category	**43**	**47**	**51**	**56**	**63**	**70**
Yield Strength N/mm^2 (kgf/mm^2, ksi)	420 (43, 61)	460 (47, 67)	500 (51, 73)	550 (56, 80)	620 (63, 90)	690 (70, 100)

Table 1.4.2: Steel Grade Suffix Based on Test Temperature

Grade Suffix	**AQ**	**DQ**	**EQ**	**FQ**
Test Temperature °C (°F)	0 (32)	−20 (−4)	−40 (−40)	−60 (−76)

4.2. Chemical Composition

4.2.1. Ladle Analysis – The steel manufacturer determine the chemical composition by taking samples from each heat and is to conform to the applicable requirements of the grade of steel listed in Table 1.4.3. The steel is to be fully killed, and produced to fine grain practice.

4.2.2. The carbon equivalent (C_{eq}) or the cold cracking susceptibility (P_{cm}) for evaluating the weldability, unless otherwise specified by the purchaser, may be calculated from the ladle analysis according to the following equation:

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

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

Selection of C_{eq} or P_{cm} along with its maximum value is to be agreed between the fabricator and the steel mill when the steel is ordered.

Table 1.4.3: Chemical Composition of High Strength Quenched and Tempered Steels

Grade	Maximum Content of Elements % (Ref note)					
	C	Si	Mn	P	S	N
AQ43 to AQ70	0.21	0.55	1.70	0.035	0.035	0.02
DQ43 to DQ70	0.20	0.55	1.70	0.030	0.030	0.02
EQ43 to EQ70	0.20	0.55	1.70	0.030	0.030	0.02
FQ43 to FQ70	0.18	0.55	1.60	0.025	0.025	0.02

Note:

Elements used for alloying and fine grain treatment are to be as detailed in the approved specification. The following elements are to be reported for each cast or ladle: Ni, Cr, Mo, Nb, V, Zr, Cu and B.

4.3. Mechanical Properties

The tensile and Charpy V-notch impact properties are to be accordingly with Table 1.4.4. One tension test and one set of impact test specimens are to be taken from each heat-treated piece of material. Charpy V-notch impact test specimens may be taken with their longitudinal axis either longitudinal or transverse to the final direction of rolling at the option of the steel manufacturer unless a specific orientation is stated.

4.4. Heat Treatment

These steels are to be supplied in the quenched and tempered condition. Otherwise, the following processes may be reflected as substitutes for the quenching and tempering.

a) Thermo-mechanical controlled process.

b) Direct quenching and tempering.

Table 1.4.4: Mechanical Properties Requirements for High Strength Quenched and Tempered Steels

Grade of Steel	**Mechanical Properties** (Refer Note 1)			**Impact Test** (Refer Note 3)	
	Yield Strength N/mm² (kgf/mm², ksi)	**Tensile Strength N/mm²** (kgf/mm², ksi)	**Elongation % in 5.65√So** [(4)] **minimum**	**Test Temperature** °C (°F)	**Energy Average** J (kgf-m, ft-lb)
AQ43	420 (43, 61)	530/680 (54/69, 77/98)	18	0 (32)	41 (4.2, 30)[(2)] L or 27 (2.8, 20)[(1)] T
DQ43				−20 (−4)	
EQ43				−40 (−40)	
FQ43				−60 (−76)	
AQ47	460 (47, 67)	570/720 (58/73, 83/104)	17	0 (32)	46 (4.7, 34) L or 31 (3.2, 23) T
DQ47				−20 (−4)	
EQ47				−40 (−40)	
FQ47				−60 (−76)	
AQ51	500 (51, 73)	610/770 (62/78, 88/112)	16	0 (32)	50 (5.1, 37) L or 33 (3.4, 24) T
DQ51				−20 (−4)	
EQ51				−40 (−40)	
FQ51				−60 (−76)	
AQ56	550 (56, 80)	670/835 (68/85, 97/120)	16	0 (32)	55 (5.6, 41) L or 37 (3.8, 27) T
DQ56				−20 (−4)	
EQ56				−40 (−40)	
FQ56				−60 (−76)	
AQ63	620 (63, 90)	720/890 (73/91, 104/129)	15	0 (32)	62 (6.3, 46) L or 41 (4.2, 30) T
DQ63				−20 (−4)	
EQ63				−40 (−40)	
FQ63				−60 (−76)	
AQ70	690 (70, 100)	770/940 (78/96, 112/136)	14	0 (32)	69 (7.0, 51) L or 46 (4.7, 34) T
DQ70				−20 (−4)	
EQ70				−40 (−40)	
FQ70				−60 (−76)	

Notes:

1. T = Transverse
2. L = Longitudinal
3. Charpy V-notch impact tests are not required in production for AQ Grades, provided supporting data indicate compliance with this table is obtained in qualification testing.
4. So equals cross-sectional area of test specimen.
5. The elongation for alternative B specimen in Figure 1.1.1 is to be in accordance with Table 1.4.5.
6. The indicated elongations are for specimens taken transverse to the direction of roll. Where longitudinal specimens are specially approved, the minimum elongation values are to be 2% above those shown in Table 1.4.4 and Table 1.4.5.

Table 1.4.5: Elongation Requirements for Alternative B Specimen

Grade of Steel	Thickness, mm						
	≤ 10	>10 ≤ 15	>15 ≤ 20	>20 ≤ 25	>25 ≤ 40	>40 ≤ 50	>50 ≤ 70
AQ43 to FQ43	11	13	14	15	16	17	18
AQ47 to FQ47	11	12	13	14	15	16	17
AQ51 to FQ51	10	11	12	13	14	15	16
AQ56 to FQ56	10	11	12	13	14	15	16
AQ63 to FQ63	9	11	12	12	13	14	15
AQ70 to FQ70	9	10	11	11	12	13	14

Table 1.4.6: Material Selection for Quenched and Tempered Steel Grades

Service Temperature °C (°F)	Secondary (Refer Note)	Primary	Special
0 (32)	AQ43 to AQ70	DQ43 to DQ70	EQ43 to EQ70
−10 (14)	EQ43 to EQ70	EQ43 to EQ70	EQ43 to EQ70
−20 (−4)	EQ43 to EQ70	EQ43 to EQ70	EQ43 to EQ70
−30 (−22)	EQ43 to EQ70	EQ43 to EQ70	EQ43 to EQ70
−40 (−40)	FQ43 to FQ70	FQ43 to FQ70	FQ43 to FQ70
−50 (−58)	FQ43 to FQ70	FQ43 to FQ70	—

Note:
For Secondary members, toughness criteria may be relaxed.

SECTION 5 LOW TEMPERATURE MATERIALS

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5.1. General

The materials for Liquefied Gas Carriers are also to fulfill the requirements given in Ch 1, [1.1.1].

5.2. Marking

Apart from the INTLREG marking requirements detailed in Part 2, the name or brand of the manufacturer, grade designation indicated by a letter, the identification numbers of manufacturer and for pressure vessel quality material, the letters **PV** are to be distinctively marked at each end of the finished plate.

Manufacturer’s name or trade mark is to be provided at each end of the aluminum sheet and plate. The applicable alloy and temper designation, and in addition for plate, the specification number and the lot number is also to be indicated.

5.3. Toughness Tests

5.3.1. Charpy V-notch

The specimen is to be transverse to the final direction of rolling for plates and longitudinal to the final direction of rolling for profiles, shapes and bars. Subject to special approval, acceptance may be based on a minimum lateral expansion opposite the notch of 0.38 mm (0.015 in.) for transverse specimens and 0.50 mm (0.020 in.) for longitudinal specimens. Refer Sec 1, [1.6.6].

5.3.2. Drop-weight Test

Where drop-weight tests are required, they are to be conducted for no-break performance of two specimens as per ASTM E208, “Conducting Drop-weight Tests to Determine Nil-ductility Transition Temperature of Ferritic Steels”. Drop-weight tests are not to be carried out on material of less than 12.5 mm (0.5 in.) thickness. For thickness between 12.5 mm (0.5 in.) and 16 mm (0.63 in.), the E208 specimen P-3 machined to 12.5 mm (0.5 in.) thickness is to be used with a stop distance of 2.29 mm (0.09 in.).

5.4. Service Temperature 0°C (32°F) or Above

Refer to Chapter 1, [1.1.1].

5.5. Service Temperature at or above -55°C (-67°F) up to 0°C (32°F)

In this temperature range, steels are normally carbon manganese steels furnished fully killed fine grain normalized. Refer to Ch 1, [1.1.1].

These steels meet the requirements in Ch 1, [1.1.1] and may be marked **INTLREG/V 0XX** or **INTLREG/VH** 0XX, indicated by **XX** the test temperature in Celsius below zero as per Sec 2,[2.7.5].

5.6. Service Temperature at or above -196°C (-320°F) up to -55°C (-67°F)

In this temperature range, steels are normally of the ferritic nickel-alloy type made with fine-grain practice, but austenitic stainless steels or aluminum alloys may be used as well. Generally, the following ASTM grades of material or their equivalent may be utilized for the temperature listed below. The chemical composition, heat treatment, tensile and impact properties are to be in accordance with the requirements of the applicable approved specification. Refer Ch 1, [1.1.1]

.Table 1.5.1 ASTM Grades Equivalents and Temperature

Material	Temperature	Grade
A203, 2 ¼ % Ni	-62°C (-80°F)	for Grade A
	-59°C (-75°F)	for Grade B
A203, 3 ½ % Ni	-90°C (-130°F)	for Grade D
	-79°C (-110°F)	for Grade E
A645, 5% Ni	-105°C (-155°F) (1)	-
A353, 9% Ni	-196°C (-320°F)	-
A553, 9% Ni	-196°C (-320°F)	-
Austenitic stainless steels	-196°C (-320°F)	-
A658, 36% Ni	-196°C (-320°F)(2)	-
B209, Type 5083, Alum. Alloy	-196°C (-320°F)	-

Note:
1. 5% Nickel steel may be used down to -165°C (-265°F) upon special consideration provided that impact tests are conducted at -196°C (-320°F).
2. Chemistry will be specially considered for lowering the coefficient of expansion.

5.7. Service Temperatures below -196°C (-320°F)

For temperatures below -196°C, austenitic low carbon (less than 0.10%) stainless steels and aluminum alloys are to be used. The chemical composition, heat treatment, and tensile properties are to be in compliance with the requirements of the approved specification. Stainless steels types 304, 304L, and 347 and type 5083 aluminum alloy do not require toughness testing for service temperatures above -254°C (-425°F). Special consideration will be given to toughness tests for -254°C (-425°F) service temperature and below.

SECTION 6 HULL STEEL CASTINGS

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6.1. Process of Manufacture

6.1.1. **General**

The requirements given herein cover carbon-steel castings which are intended to be used in hull construction and equipment such as stern frames and rudder frames and are appropriate to steel castings only where the design and acceptance tests are related to mechanical properties at ambient temperature.

For other applications, especially when the castings are intended for service at low or elevated temperatures, additional requirements may have to be fulfilled. Castings which are in compliance with national or proprietary specifications may be accepted, provided such specifications provide reasonable equivalence to these requirements. This does not exclude the use of alloy steels as per the permissibility expressed in Sec-1.

INTLREG approved processes used in the manufacture of steel and Castings are to be adopted by a manufacturer. Casting are to be manufactured by a manufacturer approved by INTLREG. This approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is to be allowed to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection. Thermal cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken as per recognized good practice and is to be carried out prior to the final heat treatment. When required based on the chemical composition and/or thickness of the castings preheating is to be employed. If required, the affected areas are to be either ground smooth or machined.

When a composite component is joined by welding two or more castings, the welding procedure is to be approved and welding is to be carried out to the satisfaction of the attending Surveyor.

6.1.2. **Chemical Composition**

Killed steel is to be used for the manufacture of castings and the chemical composition is to be appropriate for the type of steel and the mechanical properties for the castings. The sample taken during the pouring of the heat shall be used by the manufacturer to determine the chemical composition of each heat. The ladle analysis is applicable when multiple heats are tapped into a common ladle.

For welded construction and where welded repair is likely, the chemical composition of ordinary grade carbon and carbon-manganese steel castings is to comply with the following limits or, where applicable, the requirements of the approved specification.

Refer to Sect 6,[6.4.2] for special grade castings.

Table 1.6.1: Chemical Composition for Ordinary Grade Casting

Elements	Percentage (%)
Carbon	0.23% max
Silicon	0.60% max
Manganese	0.70 - 1.60 %
Sulphur	0.040% max
Phosphorous	0.040% max
Residual elements	0.80% max

Notes:

1. Grain refining elements such as aluminum may be used at the discretion of the manufacturer. The content of such elements is to be reported.
2. Residual elements individual % maximums (Cu = 0.30, Cr = 0.30, Ni = 0.40, Mo = 0.15)
3. For non-welded castings, the maximum carbon content is to be 0.40%.

6.2. Marking and Retests

6.2.1. Marking

An effective identification system has to be devised by the manufacturer which will enable all finished castings to be traced to the original cast and Surveyor is to be given full facilities for tracing the same, when required.

All the castings shall have the manufacturer’s name or identification mark/pattern number cast/stamped on them, except very small sized one’s such marking impracticable The INTLREG markings, indicating satisfactory compliance with rule requirements, is to be stamped on all castings at such a location that is apparent even after machining and installation. Additionally, all castings individually weighing 227 kg (500 lb.) or more shall have identification numbers of the heats used for pouring the castings, stamped on them.

6.2.2. Retests

The manufacturer may reheat-treat the castings or a lot of castings if the results of the physical tests carried out on them do not conform to the requirements specified. Post reheat-treatment, the manufacturer may select two additional test samples representative of the casting or casting batch. When both the additional retests yield satisfactory results, the casting or batch of castings is acceptable. If one or both retests fail the casting or batch of castings is to be rejected.

6.3. Heat Treatment

The foundry approval to include heat treatment facilities, including subcontracted facilities used in producing INTLREG certified castings. Approved subcontracted facilities are to be included in the scope of foundry approval.

Heat treatment details are to be included in the approval documentation. Foundry qualification is to include all of the heat treatment facilities that the foundry uses.

If additional facilities are selected to carry out heat treatment an INTLREG qualification is to be obtained to include any new facility.

The INTLREG Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification. The extend of monitoring during production is to be agreed with the surveyor.

Unless specifically approved otherwise, all castings are to be either fully annealed, normalized or normalized and tempered in a furnace of ample proportions to bring the whole casting to a uniform temperature above the transformation range on the annealing or normalizing cycle. There has to be adequate provisions in the furnaces for controlling and recording temperature. It is required to "soak" the castings at the proper temperature for a length of time equivalent to 1 hour per 25.5 mm (1 in.) of thickness of the heaviest member for the first 127.5 mm (5.00 in.) plus an additional 15 minutes for each additional 25.5 mm (1.00 in.) over 127.5 mm (5.00 in.) of thickness. The annealed casting shall not be removed from the furnace until and unless the temperature of the entire furnace charge has fallen to or below a temperature of 455°C (850°F). Adequate number of 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 can be verified at regular intervals. Tempering is to be carried out at a temperature of not less than 550°C (1022°F). Bending and straightening or local heating or cooling of annealed castings are not permitted, unless sanctioned by the Surveyor.

The foundry is to maintain records of heat treatment including identification of the of the furnace used, its charge, date and temperature and time together with the number and location of thermocouples. These records are to be made available to the Surveyor as and when requested.

6.4. Mechanical Properties

6.4.1. Ordinary Grade Castings

The tensile properties of steel castings are to conform to the requirements as per the Table 1.6.2 given below.

Table 1.6.2: Mechanical Properties

Tensile strength min.	415 N/mm^2 (42 kgf/mm^2, 60000 psi)
Yield point min.	205 N/mm^2 (21 kgf/mm^2, 30000 psi)
Elongation in 50 mm (2 in.) min.	25%
Reduction of area min.	40%

6.4.2. Special Grade Castings

Special grade materials with additional mechanical and chemical requirements (that are given below) are to be used in the manufacturing of rudder horns, cast stern frames and shoe pieces.

6.4.2.1. Charpy tests

A set of 3 Charpy v-notch impact tests are to be taken from extended part of the thickest part of the casting and have dimensions that represent the thickest casting section. Charpy tests are to be carried out as indicated in Sec 1, [1.6.6] and meet 27 J (20 ft-lbs) at 0°C (32°F).

6.4.2.2. Chemical Composition

Table 1.6.3: Chemical Composition for Special Grade Casting

<table>
<tr><th colspan="2">Elements</th><th>Percentage</th></tr>
<tr><td colspan="2">Carbon</td><td>0.23% max</td></tr>
<tr><td colspan="2">Silicon</td><td>0.60% max</td></tr>
<tr><td colspan="2">Manganese</td><td>0.70 - 1.60%</td></tr>
<tr><td colspan="2">Sulfur</td><td>0.035% max</td></tr>
<tr><td colspan="2">Phosphorous</td><td>0.035% max</td></tr>
<tr><td rowspan="2">Aluminum</td><td>acid soluble</td><td>0.015 - 0.080%</td></tr>
<tr><td>total</td><td>0.020 - 0.10%</td></tr>
<tr><td colspan="2">Residual elements</td><td>0.80% max</td></tr>
<tr><td colspan="3"><u>Note</u>:
For special grade steel castings a ladle and a product analysis is to be made.</td></tr>
</table>

6.5. Test Specimens

6.5.1. **Material Coupons**

Heat treatment of castings and test materials are to carried out together in the same furnace, and quenched in the same bath/ tank (for Q&T castings).

Sufficient test material shall be gathered so that the required number of tests and possible retests is available for each casting. The physical properties of these material coupons are to be determined from test specimens prepared from them which, except as specified in [6.5.2] below, are to be cast integral with the casting to be examined. When this is not feasible, the coupons may be cast with and gated to the casting, and are to have a thickness of not below the critical controlling cross section thickness of the casting or 30 mm (1.2 in.) whichever is greater. In either case, before the heat treatment of the casting is complete, these coupons are not to be detached, nor before they have been stamped by the Surveyor for identification. However, if the material identification system of the manufacturer is acceptable to INTLREG and same is verified through initial and periodical verification, it may be considered in lieu of stamping by the Surveyor before detachment.

It is required to take and furnish two test samples where the finished casting mass exceeds 10,000 kg (22,000 lb.) or is of complex design. In the same manner, where one large casting is made from two or more casts from different pour, two or more test samples are to be furnished corresponding to the number of casts involved. The samples are to be integrally cast at widely separated locations, as much as possible.

6.5.2. **Separately Cast Coupons**

For small castings with an assessed weight of less than 908 kg (2000 lb) each, the coupons may be separately cast, provided manufacturer furnishes an affidavit to the Surveyor stating that these were cast from the same heat as the castings represented and which were also heat-treated with the castings.

6.6. Number of Tests

From each heat in each heat-treatment charge, at least one tension test is to be carried out, except where two or more samples are needed, as specified in Sect 6,[6.5.1] above. One tension test from each heat for castings subject to the same heat-treating procedure may be accepted at the discretion of the attending Surveyor, provided the manufacturer's quality-control procedure includes automatic chart recording of temperature and time.

6.7. Inspection and Repair

6.7.1. General

Surveyor has to examine all castings after final heat treatment and thorough cleaning is done to ensure that they are free from defects, as per related acceptance criteria. The internal surfaces are also to be, inspected if applicable Treatments which may obscure defects are not to be carried out on the surfaces including hammering or peening or other such treatments. If a casting proves to be defective as observed during subsequent inspection, machining or testing, it is to be rejected, regardless of a previous certification.

The manufacturer's recorded dimensions are to be verified to ensure that they meet the specified requirements. The Surveyor is required to spot check key dimensions recorded by the manufacturer to confirm the same.

6.7.2. Minor Defects

Minor defects are the ones which arise when the cavity prepared for welding repair has a depth not greater than 20% of the actual wall thickness, but also not greater than 25 mm (1 in.), and with lineal dimension not greater than four times the wall thickness or greater than 150 mm (6 in.). Shallow depressions or grooves that surface, after defects are removed may be accepted, on condition that they cause no significant reduction in the casting's strength. The resulting defects are to be subsequently ground smooth, and their complete elimination is to be verified by magnetic particle testing or liquid penetrant testing. Minor defects where welding is required are to be treated as weld repairs and repaired as per an approved procedure. If minor defects are found in critical locations, they are to be treated as, and repaired in the same manner as, major defects.

6.7.3. Major Defects

Defects other than minor defects and with dimensions greater than those given in Sect 6, [6.7.2] above are major defects. These may be repaired by welding with the Surveyor's prior approval and using an approved procedure. Where there are excessive major defects as observed by the Surveyor, the casting is to be evaluated to assess whether weld repair is appropriate or not.

6.7.4. Welded Repair

After it has been agreed with the Surveyor, that a casting can be repaired by welding, complete details covering the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending Surveyor,

Prior to undertaking the repair welding of castings, the manufacturer is to prove to the satisfaction of the surveyor, that the welders or welding operators are duly qualified for the intended work

Removal of defects and weld repair are to be carried-out as specified in Chapter 1, sect 6 [6.7] Removal of the defects are to be carried out to sound metal, and prior to welding, the excavation is to be probed by suitable approved non-destructive examination methods to ensure that the defect has been removed. For repair of major defects on large castings such as rudder horns, stern frames, shoe pieces and rudder stocks, welding is not allowed on unheat-treated castings. Corrective welding is to be associated with the use of preheat.

6.7.5. **Post Weld Repair Heat Treatment**

An appropriate post weld heat treatment, as indicated in Sect 6 [6.3] of this section, are to be given to all welded repairs of defects or subject to the prior approval of the INTLREG materials department, consideration may be given to the approval of local stress-relieving heat treatment at a temperature of not less than 550°C (1022°F). The heat treatment employed is dependent on the chemical composition of the casting, the position of the repairs and the casting and dimensions of the defects.

After heat treatment, the weld repairs and adjacent material are to be ground smooth and their complete elimination is to be verified by magnetic particle testing or liquid penetrant testing. Other examination like ultrasonic or radiography may also be required, depending on the dimensions and nat480ure of the original defect. From all forms of non-destructive testing used, satisfactory results are to be obtained.

The records with full details of the extent and location of all minor and major repairs made to each casting and of weld procedures and heat treatments applied are to be maintained by the manufacturer and the copies of these are to be also made available to the Surveyor upon request.

6.7.6. **Non Destructive Testing (NDT)**

Hull castings, such as cast-steel rudder horns and stern frames, are to be subjected to surface inspection by dye penetrant, magnetic particle, or other equivalent means. Refer to Ch 5/Sec 5

Cast steel stern frames are to be subjected to NDE over the entire skeg portion of the casting, including the enlarged portion forming the junction to the propeller post, and at other critical locations as may be indicated on the approved plan of the stern frame. These surfaces are to be clean and free of all substances that will affect the sensitivity of the magnetic-particle test and the degree of magnetization is to create a satisfactory magnetic potential on the surfaces being tested. In addition, cast-steel rudder horns are to be inspected by radiographic means or, at the discretion of the attending Surveyor, as per an approved ultrasonic procedure at the area just beneath the connection to the shell, and at other locations indicated in Ch 5/Sec 5 and as per the approved plan.

At chaplet locations and areas of expected defects, additional NDE is to be considered. The radiographic acceptance standard for all categories of defects is to be at least equal to severity level 4 of ASTM E186, E280 or E446.The ultrasonic acceptance standard is to be at least equivalent to quality level 4 of ASTM A609 respectively.

6.8. Certification

The required type of inspection certificate is to be furnished by the manufacturer that provides the particulars given below for each casting or batch of castings which has been accepted:

i) Order number and purchaser's name

ii) Identification number

iii) Description of castings, steel quality and weight

iv) Steel making process, cast number and chemical analysis of ladle samples

v) Results of non-destructive tests, where applicable

i) Results of mechanical tests

ii) Details of heat treatment, including holding times and temperatures

iii) Test pressure, where applicable

iv) Specifications

SECTION 7 HULL STEEL FORGINGS

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7.1. Process of Manufacture

7.1.1. General

The requirements given herein deals with the carbon-steel forgings intended to be used in hull construction and equipment and are applicable to steel forgings only where the design and acceptance tests are related to mechanical properties at ambient temperature. When the forgings are intended for service at low or elevated temperatures, for other applications, additional requirements may have to be fulfilled. This does not prohibit the use of other steels as allowed by Section 1. Alternatively, forgings which are in compliance with national or proprietary specifications may be accepted on condition that such specifications are equivalent to these requirements.

Forgings are to be made by a manufacturer approved by INTLREG. This approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is allowed to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection at any time. The steel used is to be fully killed and is to be manufactured by an INTLREG approved process.

As per recognized good practice, the shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be undertaken and, unless otherwise approved, it is required to be carried out prior to final heat treatment. Preheating is to be employed when required by the composition and/or thickness of the steel. For some components, machining of all thermal cut surfaces may be required.

When a composite component is made by joining two or more forgings, the proposed welding procedure specification is to be submitted for approval.

7.1.2. Degree of Reduction

The plastic deformation is required to ascertain soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. To calculate the reduction ratio, reference to the average cross-sectional area of the cast material is to be considered. Where initially, the cast material is upset, this reference area may be considered as the average cross-sectional area after this operation. Unless otherwise approved, the total reduction ratio is to be at least:

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

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

7.1.3. Discard

Sufficient discard has to be made from each ingot to ensure freedom from piping and undue segregation.

7.1.4. Chemical Composition

Killed steel is to be used for making all forgings and its chemical composition is to be reported. Unless specially approved, carbon content is not to exceed 0.23% or carbon equivalent (C_{eq}) is not to exceed 0.41%. Specially approved grades with more than 0.35% carbon are to be marked with S after the grade number.

Phosphorus and sulfur contents are not to exceed 0.035%.

Rudder stocks and pintles shall be of a weldable quality.

To determine the chemical composition of each heat, the manufacturer takes a sample preferably during the pouring of the heat. Ladle analysis shall apply when multiple heats are tapped into a common ladle.

7.2. Marking and Retests

7.2.1. Marking

An effective identification system has to be devised by the manufacturer which will enable all finished forgings to be traced to the original cast and Surveyor is to be given full facilities for tracing the same, when required.

In addition to appropriate manufacturer's identification mark/pattern number, INTLREG markings, conforming to the Rule requirements, and as furnished by the Surveyor, is to be stamped on all forgings at such a location that is apparent even after machining and installation. Grade 2 forgings are to be stamped **INTLREG/2**.

7.2.2. Retests

Sufficient test material is to be taken from each forging for the required number of tests and retest purposes. There is provision of reheat-treat the forgings or a lot of forgings when the results of the physical tests do not conform to the requirements specified. However, the manufacturer may reheat-treat such forgings for not more than three additional times. For this purpose, manufacturer may select two additional test samples representative of the casting or casting batch. When both the additional retests yield satisfactory results, the casting or batch of castings is acceptable or else, the casting or batch of castings is to be rejected.

7.3. Heat Treatment

7.3.1. General

Heat treatment facilities used in the manufacture of INTLREG certified forgings are to be included in the forge approval; which includes the subcontracted heat treatment facilities. The forge approval also to include the approved sub contracted facilities.

The approval documentation shall include the heat treatment details. Forge qualification shall include the heat treatment facilities that the forge uses.

If additional facilities are selected to carry out heat treatment and INTLREG qualification is to be obtained to include any new facility.

INTLREG Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification. However, the extend of monitoring during production is to be agreed with the surveyor.

Unless, a deviation from the following procedure is specifically approved, all forgings are to be annealed, normalized, normalized and tempered or quenched and tempered in a furnace of ample proportions to bring the forgings to a uniform temperature.

Adequate number of thermocouples is to be connected to the furnace charge to measure and record that its temperature is uniform unless the temperature uniformity can be verified at regular intervals.

Heat treatment is to be carried out in properly built furnaces which are capable of efficiently controlling and recording temperature. The dimensions of furnace are to be such that whole furnace charge is uniformly heated to the required temperature. For very large forgings, alternative heat treatment methods will be specially considered. If for any reason a forging is heated for further hot working, the forging is to be reheat-treated. Also, if a forging is locally reheated or any straightening operation is performed on it after the final heat treatment, a subsequent stress relieving heat treatment is to be considered.

The forge is to maintain records of heat treatment wherein it is important to keep a record of the furnace used, its charge and temperature and time and date together with the number and location of thermocouples. These records are to be available to the Surveyor as and when required.

7.3.2. Cooling Prior to Heat Treatment

After forging and before reheating for heat treatment, the forgings are to be allowed to cool in a manner appropriate to prevent injury and to bring about the required transformation.

7.3.3. Annealing

The forgings are to be reheated to and maintained at austenitizing temperature for a time that is sufficient to bring about desired transformation in them. Subsequently, these are allowed to cool slowly and evenly in the furnace till the temperature of forgings has fallen to about 455°C (850°F) or lower.

7.3.4. Normalizing

The forgings are to be reheated to and maintained at the proper temperature above the transformation range for sufficient time to bring about the desired transformation and then withdrawn from the furnace and allowed to cool in air.

7.3.5. Tempering

The forgings are to be reheated to and maintained at the proper temperature, which will be below the transformation range, and then to be cooled under appropriate conditions. The tempering temperature is not to be less than 550°C (1022°F).

7.4. Tensile Properties

For tensile properties, Grade 2 steel forgings are to conform to the requirements as per the Table 1.7.1 given below.

Table 1.7.1: Mechanical Properties

Size		Tensile Strength, min. N/mm² (kgf/mm², psi)	Yield Point/ Yield Strength min. N/mm² (kgf/mm², psi)	Longitudinal Specimens			Transverse Specimens	
Solid Diameter or Thickness				Elongation in Gauging Length %		Reduction of Area, Min. %	Elongation in 50 mm (2 in.) Min. %	Reduction of Area, Min. %
Over	Not Over			4d	5d			
	305 mm (12 in.)	415 (42, 60000)	205 (21, 30000)	25	23	38	20	29
305 mm (12 in.)		415 (42, 60000)	205 (21, 30000)	24	22	36	20	29

Note:
In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm² (7 kg/mm², 10000 psi).

7.5. Test Specimens

7.5.1. Location and Orientation of Specimens

The test specimens taken from prolongations with sectional area not less than that of the body of the forging are used for determination of the mechanical properties. Specimens may be taken in a direction parallel to the axis of the forgings i.e. direction in which the metal is mostly drawn or may also be taken transversely.

The axis of longitudinal specimens is to be located at any point midway between the center and the surface of solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings.

The axis of transverse specimens may be located close to the surface of the forgings. For carbon steel forgings, test results from other locations may be specially approved, provided appropriate supporting information is presented which indicates that the properties at the specified locations will be in compliance with the specified tensile properties.

7.5.2. Hollow-drilled Specimens

In lieu of prolongations, the test specimens may be derived from forgings submitted for each test lot or at Surveyor’s discretion; these may be taken from forgings with a hollow drill.

7.5.3. Small Forgings

For small forgings weighing less than 114 kg (250 lb.) each, where the foregoing procedures are not practical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens represent the forgings submitted for testing. In such cases, the special forgings are to be subjected to the same amount of working and reduction as the forgings represented and are to be heat-treated with those forgings.

7.5.4. Specimen Identification

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/ tank (for Q & T forgings).

For identification purposes, the test specimens are not to be detached from the forgings before final heat treatment is complete and test specimens have been stamped by the Surveyor. Where manufacturer's identification system is acceptable to INTLREG and the material is maintained in that condition after through initial and periodical verification, it may be considered in lieu of stamping by the Surveyor prior detachment.

7.6. Number of Tests

7.6.1. Tension Test

7.6.1.1. Large Forgings

For large forgings with rough machined weights of 3180 kg (7000 lb.) or over, one tension test is to be done on each end of the forging.

7.6.1.2. Intermediate-sized Forgings

For forgings with rough machined weights less than 3180 kg (7000 lb.), except as given in the [7.6.1.3] below, one tension test is to be carried out on each forging.

7.6.1.3. Small Forgings

For small normalized forgings with rough machined weights less than 1000 kg (2200 lb.), and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb.), one tension test may be carried out on one forging as representative of a lot, provided the forgings in each such lot are of same size, one grade and kind, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace charge is not to exceed 6000 kg (13200 lb.) for normalized forgings and 3000 kg (6600 lb.) for quenched and tempered forgings.

7.6.2. Brinell Hardness Test

Except those with rough machined weights less than 113 kg (250 lb.), each forging is to be Brinell Hardness tested and are to meet the requirements given in Table 1.7.2.

Table 1.7.2

Grade	Brinell Hardness Number Minimum 10 mm ball, 3000 kg load
2	120

7.6.3. Special Situations

When numbers of pieces are cut from a single forging, individual tests need not necessarily be carried out for each piece, instead forgings may be tested as per whichever of the foregoing procedures is applicable to the primary forging involved.

7.6.4. Examination

Surveyor shall examine all forgings after final heat treatment and once they are found to be free from defects. This is to also include the examination of internal surfaces and bores, where applicable. The manufacturer is required to verify that all dimensions meet the specified requirements.

As per relevant construction Rules or the approved procedure for welded composite components, appropriate NDE is also to be carried out before acceptance and the results are reported by the manufacturer. INTLREG has to agree to the extent of testing and acceptance criteria. Ch 5, Sec 6 is regarded as an example of an acceptable standard.

Yet, if any forging is found to be defective during subsequent machining or testing, it is to be rejected, notwithstanding any previous certification.

7.6.5. Rectification of Defective Forgings

Removal of defects shall be carried out by grinding or chipping and grinding, provided that the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately thrice the groove depth and are to be merged into the surrounding surface so as to avoid any sharp contours. Rectification of the defective material is to be verified by liquid penetrant testing or magnetic particle testing.

Prior approval of INTLREG is required to permit repair welding of forgings. Complete details are to be submitted for approval which covers the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures.

The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging repaired. These may be required to be presented to the Surveyor upon request.

7.7. Certification

The required type of inspection certificate is to be furnished by the manufacturer that provides the particulars given below for each forging or batch of forgings which has been accepted:

a) Order number and purchaser’s name

b) Identification number

c) Description of forgings and steel quality

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

e) Results of mechanical tests

f) Results of nondestructive tests, where applicable

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

h) Specifications

SECTION 8 ORDINARY AND HIGHER STRENGTH STEELS WITH ENHANCED CORROSION RESISTANCE PROPERTIES FOR CARGO OIL TANKS

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8.1 Scope

8.1.1 These requirements apply to ordinary and higher strength steels with enhanced corrosion resistance properties when such steel is used as the alternative means of corrosion protection for cargo oil tanks as specified in the performance standard MSC 289 (87) **and Chapter II-1 Part A1,Regulation 3-11, ,** of the SOLAS Convention **(**Corrosion protection of cargo oil tanks of crude oil tankers).

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

(a) For steel plates and wide flats
- All Grades: Up to 50 mm (2 in.) in thickness

(b) For sections and bars
- All Grades: Up to 50 mm (2 in.) in thickness

8.1.3 Ordinary and higher strength steels with enhanced corrosion resistance properties as defined within this section, are steels whose corrosion resistance performance in the bottom or top of the internal cargo oil tank is tested and approved to satisfy the requirements in MSC.289(87) in addition to other relevant requirements for ship material, structural strength and construction. It is not intended that such steels be used for corrosion resistant applications in other areas of a vessel that are outside of those specified in the performance standard MSC 289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention.

8.1.4 Since steels with enhanced corrosion resistance properties are similar to the ship steels as specified in Ch 1, Sec 2. for Ordinary-strength Hull Structural Steel and Ch 1, Sec 3. for Higher-strength Hull Structural Steel, the basic requirements of Ch 1, Sec 2 and Ch 1, Sec 3, apply to these steels except where modified by this section.

8.1.5 The weldability of steels with enhanced corrosion resistance properties is similar to those given in Pt 2, Ch 3, Sec 1, therefore welding requirements specified in Ch 3, Sec 5 [5.2] for Approval of consumables for welding ordinary and higher strength hull structural steels and Welding procedure qualification tests of steels for hull construction and marine structures also apply except as modified by this section.

8.2 Approval

8.2.1 All materials are to be manufactured at works which have been approved by INTLREG for steel in accordance with Pt 2,Ch 5 Sec 3.

8.2.2 Corrosion tests are to be carried out in accordance with Pt 2, Ch 5, Sec 7. Approval can be given for application in one of the following areas of a cargo oil tank:

a. Lower surface of strength deck and surrounding structures;

b. Upper surface of inner bottom plating and surrounding structures;

c. For both strength deck and inner bottom plating

8.2.3 It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications. If the process or production controls are altered in any way, or any product fails to meet specifications, the manufacturer is to issue a report explaining the reasons, and, in the instance of product which fails to meet specifications, the measures to prevent recurrence. The complete report is to be submitted to the Surveyor along with such additional information as the Surveyor may require. Each affected piece is to be tested to the Surveyor's satisfaction. The frequency of testing for subsequent products is at the discretion of INTLREG.

8.3 Method of Manufacture

Method of manufacture,deoxidation practice and rolling practice is to be in accordance with Pt 2,Ch 5 Sec 3.

8.4 Chemical Composition

8.4.1 The manufacturer's declared analysis will be accepted subject to periodic random checks as required by the Surveyor.

8.4.2 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 be in accordance with the requirements of Ch1, Sec 2, [2.3] for Ordinary-strength Hull Structural Steel and Ch 1, Sec 3, [3.1] for Higher-strength Hull Structural Steel.

8.4.3 The manufacturer will establish a relationship of all the chemical elements which affect the corrosion resistance, the chemical elements added or controlled to achieve this are to be specifically verified for acceptance. Verification is to be based on the ladle analysis of the steel.

8.4.4 The carbon equivalent is to be in accordance with Ch 1, Sec 3, [3.3].

8.5 Conditions of Supply

8.5.1 All materials are to be supplied in one of the supply conditions specified in Ch 1, Sec 2, Table 1.2.6, for Ordinary-strength Hull Structural Steel and Ch 1, Sec 3, Table 1.3.5. for Higher-strength Hull Structural steel.

8.6 Mechanical Properties

8.6.1 Tensile testing is to be carried out in accordance with Ch 1, Sec 2, Table 1.2.3 for Ordinary-strength Hull Structural Steel and Ch 1, Sec 3, Table 1.3.2 for Higher-strength Hull Structural steel. Charpy V-notch Impact Testing is to be carried out in accordance with Ch 1, Sec 2, Table 1.2.5 for Ordinary-strength Hull Structural Steel and Ch 1, Sec 3, Table 1.3.4 for Higher-strength Hull Structural steel.

8.7 Freedom from Defects

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

8.7.2 The acceptance criteria for surface finish and procedures for the repair of defects, as detailed in Ch 1, Sec 2, [2.8] are to be observed.

8.8 Tolerances

8.8.1 Unless otherwise agreed or specially required the thickness tolerances in Ch 1, Sec 1, [1.9], "Permissible Variations in Dimensions" are applicable.

8.9 Identification of Materials

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

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

8.10 Testing and Inspection

8.10.1 Inspection Facilities

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.

8.10.2 Testing Procedures

The prescribed tests and inspections are to be carried out at the place of manufacture before dispatch. The test specimens and procedures are to be in accordance with Ch 1, Sec 1, [1.6]. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.

8.10.3 Through Thickness Tensile Tests

If plates and wide flats with thickness of 15 mm (0.60 in.) and over are ordered with through thickness properties, the through thickness tensile test in accordance with Ch 1, Sec 1, [1.11] is to be carried out.

8.10.4 Ultrasonic Inspection

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

8.10.5 Surface Inspection and Dimensions

Surface inspection and verification of dimensions are the responsibility of the manufacturer. The acceptance by the Surveyor shall not absolve the manufacturer from this responsibility.

8.11 Test Material

Definitions and requirements for test samples are to be in accordance with Ch 1, Sec 1, [1.6].

8.12 Test Specimens

8.12.1 Mechanical Test Specimens

The dimensions, orientation and location of the tensile and Charp V-notch test specimens within the test samples are to be in accordance with Ch 1, Sec 1, [1.6].

8.13 Number of Test Specimens

Number of Tensile and Charpy V-notch Impact test specimens are to be in accordance with Ch 1, Sec 1, [1.6]

8.14 Retest Procedures

To be in accordance with Ch 1, Sec 1, [1.5.3]

8.15 Marking

8.15.1 Every finished piece is to be clearly stamped or stenciled by the maker in at least one place with the ABS markings and the following particulars:

a) Unified identification mark for the grade of steel (e.g., [AH 36]).

b) Steel plates that have complied with these requirements will be marked with a designation by adding a corrosion designation to the unified identification mark for the grade of steel. Example of designation: AH36 RCB

c) The steel with enhanced corrosion resistance properties is to be designated according to its area of application as follows:

1. Lower surface of strength deck and surrounding structures: RCU
2. Upper surface of inner bottom plating and surrounding structures: RCB
3. For both strength deck and inner bottom plating: RCW

d) When required by INTLREG, material supplied in the thermo mechanically controlled process condition is to have the letters “TM” added after the identification mark but before the corrosion designation. (e.g., [EH36 TM RCU Z35).

e) Name or initials to identify the steelworks.

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

g) Cast or other number to identify the piece.

8.15.2 The above particulars, but excluding the manufacturer's name or trade marks where this is embossed on finished products are to be encircled with paint or otherwise marked so as to be clearly legible.

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

8.15.4 In the event that any material bearing the INTLREG brand fails to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

8.16 Documentation

8.16.1 The Surveyor is to verify certificates before the material is accepted by INTLREG.

8.16.2 The number of copies required are to be specified by INTLREG.

8.16.3 INTLREG may require separate documents for each grade of steel.

8.16.4 The certificate is to be supplied in either electronic or paper format as required by INTLREG.

8.16.5 The certificate is 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 [and the manufacturer's brand name].

e. Ladle analysis (for elements specified in Ch 1, Sec.2, Table 1.2.2 for Ordinary-strength Hull structural steel and Ch 1, Sec.3, Table 1.3.1 for Higher-strength Hull structural steel).

f. If the steel is approved in accordance with~~,~~ Ch 1 sect 8[8.2] the weight percentage of each element added or intentionally controlled for improving corrosion resistance.

g. Condition of supply when other than as rolled (i.e., normalized, controlled rolled or thermo mechanically rolled).

h. Test Results

8.16.6 Before the test certificates 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 required tests in the presence of the Surveyor or his authorized deputy. The INTLREG name 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 initialed 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 International Register of Shipping."*

8.16.7 In the case of electronic certification, INTLREG is to agree upon a procedure with the steel mill to confirm release is authorized by the Surveyor.

CHAPTER 2 MATERIALS FOR MACHINERY, EQUIPMENT, BOILERS, PRESSURE VESSELS AND PIPING

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SECTION 1 GENERAL REQUIREMENTS

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1.1. Testing and Inspection

1.1.1. General

All materials that are intended for use in boilers, pressure vessels, piping and machinery of vessels classed or proposed for classification; are subject to test and inspection and require verification by the Surveyor as per the following requirements or their equivalent. Materials, test specimens, and testing procedures with different characteristics from those mentioned in this section; require special approval before application of such materials. The physical tests may be modified to suit conditions as approved in connection with the design.

1.1.2. Test and Test Data

1.1.2.1.Witnessed Tests

Designation (W) indicates that the Surveyor is to observe the testing unless the plant and product is approved under INTLREG's Quality Assurance Program.

1.1.2.2.Manufacturer's Data

Designation (M) indicates that test data is to be provided by the manufacturer without a Surveyor's verification of the procedures used or the results attained.

1.1.2.3.Other Tests

Designation (A) indicates that those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with the Rule requirements.

Refer,Ch 5, Sec 1 of this part for the complete list of indicated designations for the various tests of Ch 2.

1.1.3. Rejection of Previously Accepted Material

If any material proves unsatisfactory in the process of being worked, it is to be rejected, despite holding any previous certificate of satisfactory testing.

1.1.4. Calibrated Testing Machines

The surveyor is to be satisfied that the testing machines are maintained in a proper and accurate condition and that a record of the dates and by whom the machines were rechecked or calibrated is also to be maintained. All tests are to be carried out by competent personnel and as per recognized national or international Standard.

1.1.5. ASTM References

For identification of ASTM references, Refer Ch 1, Sec 1, [1.1.8].

1.2. Defects

All the materials are to be free from any defects including cracks, injurious surface flaws, injurious laminations and other similar defects. Except if allowed for certain specific materials, no welding or dressing for remedying the defects is to be carried out unless sanctioned by the Surveyor. In such cases, where sanction is required, the Surveyor may recommend further probing and necessary heat treatment. Upon Surveyor's satisfaction, the treated part is to be stamped with the Surveyor's identification mark and surrounded by a ring of paint.

1.3. Identification of Materials

1.3.1. A system of marking ingots, slabs, shapes, finished plates, castings and forgings is to be adopted by the manufacturer that will enable them to trace the material to its original heat; and the Surveyor to be given every facility for so tracing material.

1.4. Manufacturer's Certificates

1.4.1. Form of Certificate

Four copies of the certified mill test reports and shipping information (as separate or combined documents) of all the accepted material indicating grade of steel, heat identification numbers, test results and weight shipped are to be furnished to the Surveyor, unless requested otherwise. One copy of the mill test report is to be endorsed by the Surveyor and forwarded to the Purchaser, and three are to be retained for the use of INTLREG. Before these are dispatched to the local INTLREG office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been manufactured by an approved process and that it has withstood the prescribed tests satisfactorily. The following form of certificate will be accepted if printed on each certified mill test report with the name of the firm and initialed by the authorized representative of the manufacturer:

"We hereby certify that the material described herein has been made to the applicable specification by the _________ process (state process) and tested in accordance with the requirements of _____________ (the International Register of shipping Rules or state other specification) with satisfactory results."

Consideration may be given to modifications in the form of the certificate at the request of the manufacturer, on condition that it correspondingly indicates compliance with the Rule requirements to no less degree than indicated in the foregoing statement.

1.4.2. Other Certificates

The steel that is not produced in the steel plant where it is rolled or forged, a certificate is to be provided to the Surveyor that states:

- Its manufacturing process;
- The manufacturer's name (who supplied it); and
- The number of the heat from which it was made

Each plate or bar is to be marked with the number of the heat for identification purpose.

1.5. Marking and Retests

1.5.1. Identification of Test Specimens

Where the Surveyor selects the test specimens, they are not to be detached until stamped with his identification mark; except as otherwise specified. But, in no case, they are to be detached after material receiving its final treatment. INTLREG-tested material conforming to the requirements is to be stamped IR, or as specified for a particular material, for observing compliance with the Rule requirements.

1.5.2. Defects in Specimens

If any test specimen develops defects or shows signs of defective machining, it may be discarded and can be substituted by another specimen. An exception to this is forgings, for which, a retest is not permitted if a defect develops during testing that arises due to cracks, rupture, or flakes in the steel.

1.5.3. Retests

In principle, the elongation value is valid only if the distance between the fracture and nearest gauge mark is not less than 1/3rd of the original gauge length. However, the validity of the result is independent of the location of the fracture, provided the percentage elongation after fracture is equal to or greater than the required value.

Generally, elongation, A_5, is found on a proportional gauge length,

$$5.65\sqrt{S_0} = 5d$$

But may also be given for other specified gauge lengths.

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

$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0.40}$$

1.5.4. Rejected Material

If any set of test specimens fails to meet the Rule requirements, the material from which they have been taken, are to be rejected and the markings withheld or removed.

1.6. Standard Test Specimens

1.6.1. General

Test specimens are to be taken longitudinally covering full thickness or section of material as rolled, unless otherwise specified.

1.6.2. Test Specimens

Test specimens are to be provided only prescribed preparation and they are to simultaneously receive all the treatment, given to the material from which they are cut, if not specified otherwise. Specimens which get distorted by shearing are are to be straightened while the piece is cold. The tensile test machines are to have and accuracy within ±1% of the load.

1.6.3. Tension Test Specimens for Plates and Shapes

Tension test specimens for rolled plates, shapes and flats are to be taken out from the finished material and machined to the form and dimensions as illustrated in Figure 2.1.1. They may be prepared keeping both edges parallel all through their length. The alternatives to the foregoing are given under specific materials.

1.6.4. Tension Test Specimens for Castings (Other than Gray Cast Iron) and Forgings

Tension test specimens for castings (except gray cast iron) and forgings are to be machined to the form and dimensions shown for the round specimen alternative C in Figure 2.1.1 or as in Figure 2.1.2.

1.6.5. Tension Test Specimens (for Gray Cast Iron)

Tension test specimens for gray cast iron are to be machined to the form and dimensions as illustrated in Figure 2.1.3, unless otherwise approved, and from test bars cast separately from the casting represented. These bars are to be poured from ladles of iron that are used to pour the castings under the same sand conditions, and are to get the same thermal treatment as the castings they represent.

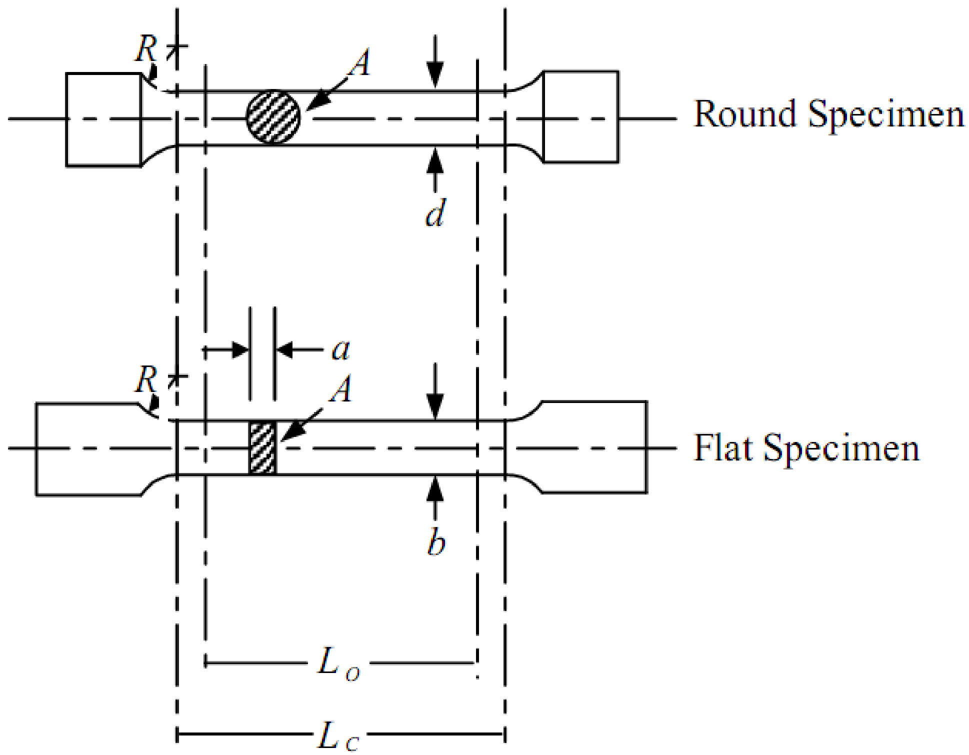
1.6.6. Transverse or Flexure Test Specimens for Gray Cast Iron

Transverse or flexure test specimens for gray cast iron are to be a test bar as cast with a 50 mm (2 in.) diameter and 700 mm (27 in.) length, unless otherwise approved. In accordance with [1.6.5.] above such test bars are to be cast under the same conditions.

1.6.7. Bend Test Specimens for Steel Castings and Forgings

Bend test specimens for steel castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. Its length is not significant, provided that it is sufficient to carry out the bending operation.

The edges on the tensile side of the bend test specimens may have their corners rounded to 1–2 mm (0.040–0.080 in.) radius.



d = diameter (mm)
a = thickness (mm)
b = width (mm)
A = original cross sectional area (mm^2)

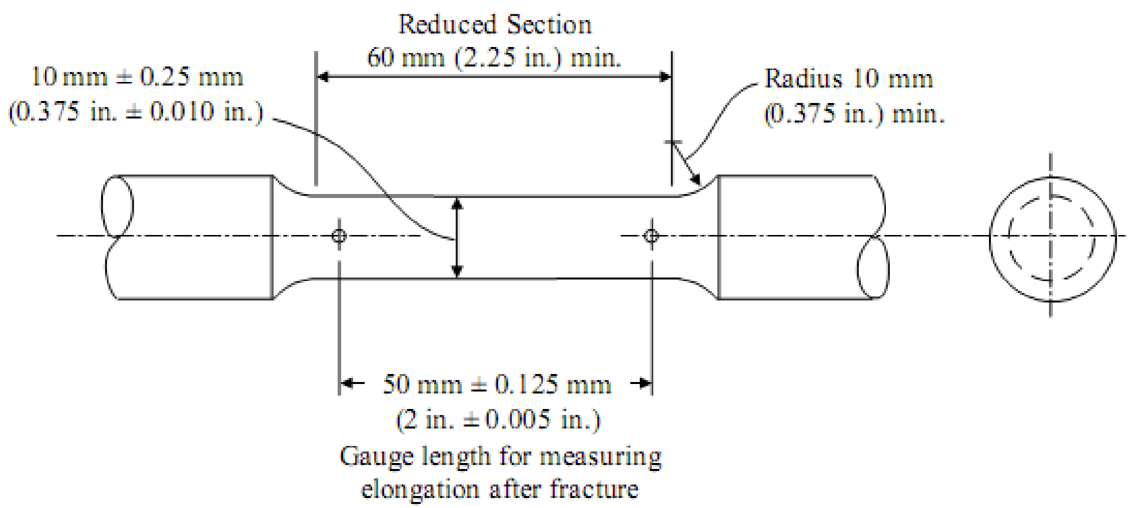
L_0 = original gauge length (mm)
L_c = parallel length (mm)
R = transition radius (mm)

	d	a	b	L_0	L_c	R
Flat specimen Alternative A	–	t(2)	25	5.65 $\sqrt{A}$	$L_o + 2\sqrt{A}$	25
Flat specimen Alternative B	–	t(2)	25	200	225	25
Round specimen Alternative C	14	–	–	70	85	10

Note:

1. Standard specimen as per ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in Ch 1, Table 1.2.3 or Table 1.3.2.
2. t is the full thickness of the material, as produced. If the capacity of the testing machine does not allow full thickness specimens to be broken, the thickness may be reduced by machining one surface only.
3. L_o, the proportional gauge length, is to be greater than 20 mm.

Figure 2.1.1: Standard Tension Test Specimen



Note:

The gauge length and fillets are to be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a manner that the load is to be axial. The reduced section may have a gradual taper from the ends towards the center, with the ends not more than 0.13 mm (0.005 in.) larger in diameter than the center.

Figure 2.1.2: Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length

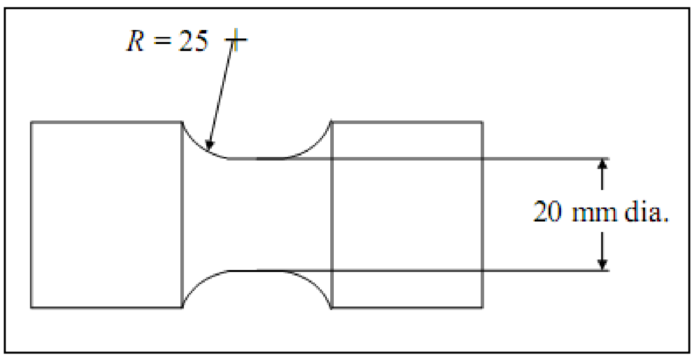


Figure 2.1.3: Tension Test Specimen Machined from Transverse or Flexure Test Bars for Gray Cast Iron

1.7. Definition and Determination of Yield Point and Yield Strength

1.7.1. Yield Point

The yield point is the point at which strain increases without any increase in stress. It is the first stress in a material and is less than the maximum obtainable stress. The stress value is measured the commencement of plastic deformation at yield, or the value of stress measured at the first peak achieved during yielding, even when that peak is equal to or less than any subsequent peaks observed during plastic deformation, at yield. With the halt of the pointer or autographic diagram, yield point may be determined. The 0.5% total extension under load method will also be considered acceptable.

The test is to be done with an elastic stress within the limits as shown in the Table below:

Table 2.1.1: Elastic Stress Limit

Modulus of Elasticity of the Material (E), N/mm^2	Stressing Rate, N/mm^2-s^{-1}	
	Min.	Max.
< 150,000	**2**	**20**
≥ 150,000	**6**	**60**

1.7.2. Yield Strength

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. When no well-defined yield phenomenon exists, yield strength is to be determined by the 0.2% (R_p 0.2) offset method. Alternatively, for material whose stress-strain characteristics are well known from previous tests, in which stress-strain diagrams were plotted, the 0.5% extension under load method may be used. When agreed between the supplier and purchaser for austenitic and duplex stainless steel products, the 1% proof stress (R_p 1) may be determined in addition to R_p 0.2.

The rate of loading / stressing is to be as stated in the above limits.

1.7.3. Tensile Strength

For ductile material, after the yield or proof load is attained, the machine speed during the tensile test is not exceed that corresponding to a strain rate of 0.008 s^{-1}. For brittle materials, like the gray cast iron, the elastic stress rate is not to exceed10 N/mm^2 per second.

1.8. Permissible Variations in Dimensions

1.8.1. Scope

The under tolerance represents the minimum material certification requirements and is to be considered as the lower limit of typical variation range (plus/minus) from the specified dimension.

The manufacturer is responsible for compliance with the specified tolerances and also maintains a procedure acceptable to the Surveyor.

1.8.2. Plates

For plates and wide flats for construction of machinery, excluding boilers, pressure vessels and independent tanks for liquefied gases and chemicals .Ref Sec 2, [2.1.8] of this chapter), the maximum permissible under thickness tolerance is to be in accordance with the following:

These requirements apply to the tolerance on thickness of steel plates and wide flats (referred to as products) with width of 600mm (24 in.) or greater with thicknesses of 5 mm (0.20 in.) and over. The thickness tolerances for products below 5 mm (0.20 in.) may be specially agreed.

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

Class C of ISO 7452 may be applied in lieu of [1.8.2.2], in which case the requirements in [1.8.2.3] and [1.8.2.4] need not be applied.

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

1.8.2.1. Responsibility

Manufacturer is responsible for verification and maintenance of production within the required tolerances. The Surveyor may need to witness some measurements. Shipyard is responsible for the storage and maintenance of the delivered plates in an acceptable level of surface conditions, before these products are used in fabrication.

1.8.2.2. Definitions

a) Thickness tolerances of a given product are defined below:

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

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

Note: Purchaser defines the nominal thickness at the time of enquiry and order.

b) The minus tolerances are to be as in the following Table 2.1.2.

Table 2.1.2:

Nominal Thickness, t, mm (in.)		**Tolerance**, mm (in.)
$5 \le t < 8$	$(0.20 \le t < 0.32)$	–0.4 (–0.016)
$8 \le t < 15$	$(0.32 \le t < 0.59)$	–0.5 (–0.020)
$15 \le t < 25$	$(0.59 \le t < 0.98)$	–0.6 (–0.024)
$25 \le t < 40$	$(0.98 \le t < 1.57)$	–0.8 (–0.032)
$t \ge 40$	$(t \ge 1.57)$	–1.0 (–0.040)

c) Thickness tolerances are not applicable to areas repaired by grinding, in accordance with Ch 1, Sec 2, [2.8.2].

d) Plus tolerances on nominal thickness are to be as per a recognized national or international standard such as ASTM A20

1.8.2.3. Average Thickness

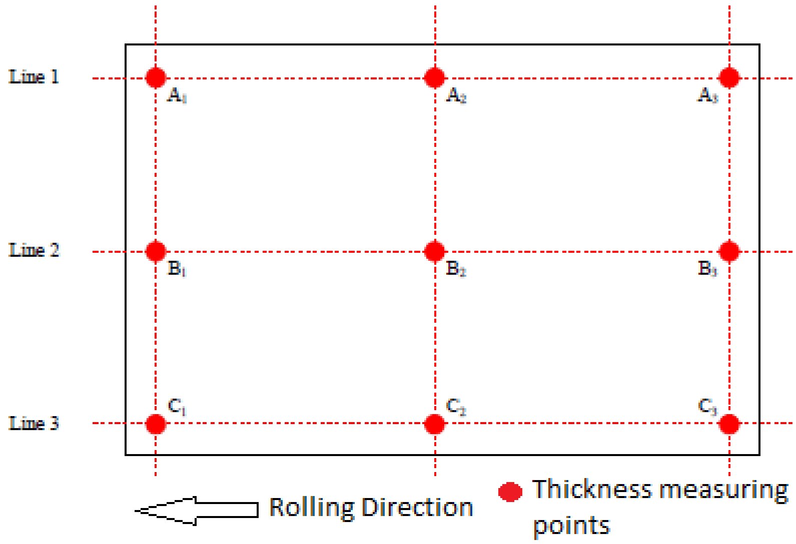
a) The product's average thickness is defined as the arithmetic mean of the measurements made to meet the requirements of [1.8.2.4] below.

b) The average thickness is not to be less than the nominal thickness.

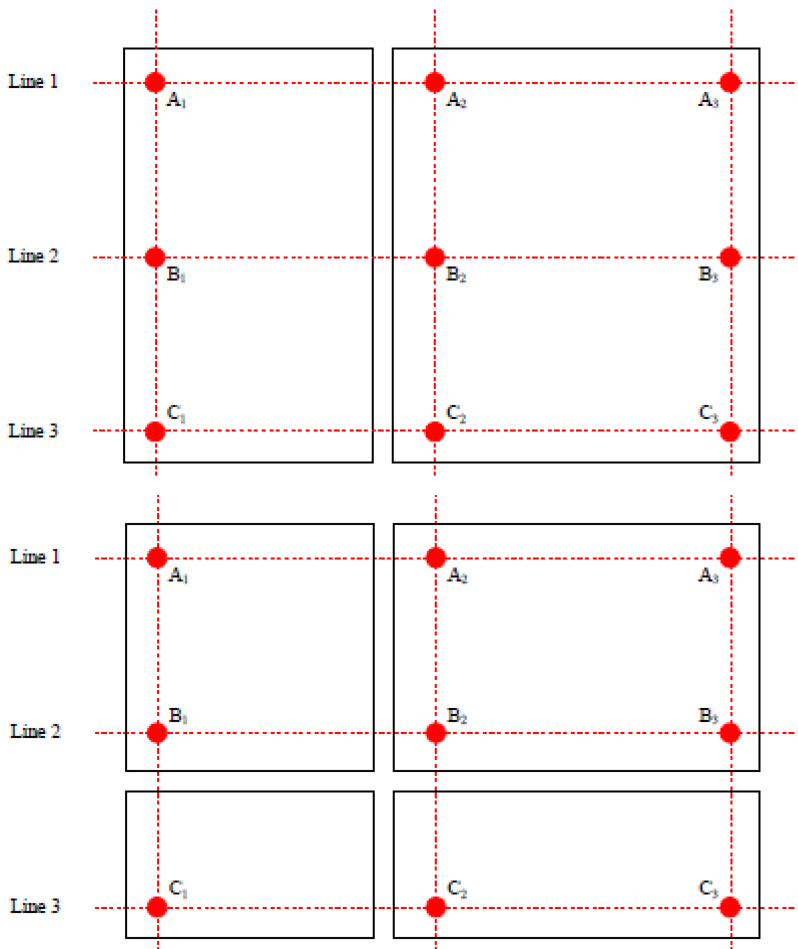
1.8.2.4. Thickness Measurements

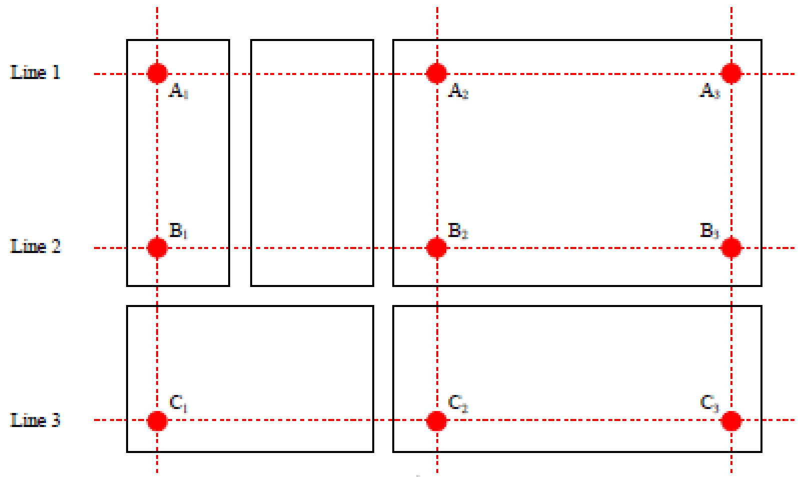
a) Thickness is to be measured at locations defined in Figure 2.1.4. Automated or manual measurement methods may be used.

b) The measurement procedure and its records are to be made available to the Surveyor and copies provided on request.



(a) Thickness Measuring Point locations for Original Steel Plates





(b) Thickness Measuring Point locations for Cut Steel Products

Figure 2.1.4: Locations for Checking Thickness Tolerance and Average Thickness

(Rolling direction same as in (a) above)

Notes:

1. *At least two lineas are to be selected from Lines 1,2 or 3, as shown, and at least three points on each selected line. If more than three points are taken on each line, the number of points on each line is to be the same.*

   The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Example of the original measurments relative to later cut products are shown in Figure 2.1.4 (b). It is to be noted that the examples shown are not representative of all possible cutting scenarios.

2. *Peripheral points are to be located 10- 300 mm (0.375-12.0 in) from the edge, for automated measurements.*

   .

3. *Peripheral points are to be located 10-100 mm (0.375- 4.0 in) from the edge, for manual measurements.*

SECTION 2 STEEL PLATES FOR MACHINERY, BOILERS AND PRESSURE VESSELS

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2.1. General Requirements

2.1.1. General

2.1.1.1. Examination at Mills

The grades of steel covered in[2.2], [2.3] and [2.4] of this section are rolled plates intended for use in machinery, boilers and other pressure vessels. All tests are to be carried out in the presence of a Surveyor at the place of manufacturing or the plant prior to shipping, unless the plant is approved under INTLREG's Quality Assurance Program for Rolled Products. The Surveyor shall examine the material surfaces upon special request from the purchaser. Plates are to to be free from defects with a workmanlike finish, subject to the conditions stated in [2.1.9] below.

2.1.1.2. Alloy Steels or Special Carbon Steels

When alloy steels or carbon steels that are different from those indicated herein are proposed for any purpose, the purchaser's specification is to be submitted for approval in connection with the approval of the design for which the material is proposed. Specifications such as ASTM A387 (Grade C or Grade D) or other steels appropriate for the intended service will be considered.

2.1.2. Marking

2.1.2.1. Plates and Test Specimens

Each finished plate has to be legibly stamped (except as specified in[[2.1.2.4] at two places, not less than 300 mm (12 in.) from the edges, with the manufacturer's name or brand, the manufacturer's identification numbers, the letter indicating the steel grade, and the letters **PV** to indicate pressure-vessel quality.

Plates whose maximum length and crosswise dimensions do not exceed 1800 mm (72 in.), are to have the marking stamped in one place approximately midway between center and an edge.

Each test specimen must have the legible stamp of manufacturer's test identification number. Before being detached, all test specimens are to be ring-stamped, match-marked or otherwise suitably identified to the satisfaction of the attending Surveyor.

2.1.2.2. Heat-treatment Marking

When the heat treatment is to be carried out by the fabricator as specified in [2.3.3] and [2.4.3] of this section, the steel producer has to stamp each plate with letter G to indicate that the material is in the unheat-treated (green) condition. Post heat treatment at the fabricator's plant, the letter **T** is to be stamped following letter **G**.

2.1.2.3. INTLREG Markings

The INTLREG markings **IR**, that indicates satisfactory compliance with the Rule requirements and other markings as provided by the Surveyor, are to be stamped on all plates near the marking as as specified in [2.1.2.1] to indicate that material has satisfactorily complied with the test prescribed, and that certificates for the material will be furnished to the Surveyor in accordance with Sec-1, [1.4]. The marking **IR** without grade designation is to be marked on the outer wrap of each coil shipped, for those certified for chemical analysis only.

2.1.2.4. Thin Plates

Plates under 6.4 mm (0.25 in.) in thickness are to be legibly stenciled with the markings specified in [2.1.2.1] and [2.1.2.2] instead of stamped.

2.1.2.5. Special Impact Testing

The grade marking is to be followed by the test temperature in degrees Celsius when steel is impact tested as per 2.5 of this section. A prefix “0” to the test temperature indicates a temperature colder than zero degrees Celsius.

2.1.3. **Process of Manufacture**

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric furnace. The steel may be cast in ingots or may be strand (continuous) cast. The ratio of reduction of thickness from strand (continuous) cast slab to finished plate is to be a minimum of 3 to 1, unless specially approved.

2.1.3.1. Plates Produced from Coils

The manufacturer or processor is to submit supporting data for review and approval for coiled plate to indicate that the manufacturing, processing and testing will ensure material which is in compliance with the Rules.

2.1.4. **Chemical Composition**

2.1.4.1. Ladle Analysis

The manufacturer shall prepare an analysis of each heat of steel in order to determine the percentage of the elements specified. This analysis is to be carried out from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements as specified for each grade in [2.2.3], [2.3.4] or [2.4.4] of this section.

2.1.4.2. Check Analysis

The chemical composition determined by check analysis is to conform to the requirements as specified for each Grade in [2.2.3], [2.3.4] or [2.4.4] of this section.

2.1.5. **Test Specimens**

2.1.5.1. Selection of Specimens

One tension test specimen is to be taken from each plate as rolled in such manner that the longitudinal axis of the specimen is transverse to the final direction of rolling of the plate. The tension test specimen is to be taken from a corner of the plate. If the final rolling direction of the plate is parallel to the original longitudinal ingot axis, the tension test specimen is to be taken from the “bottom” end of the plate. If the final direction of rolling of the plate is transverse to the original longitudinal ingot axis, or if the relationship of final rolling direction and original ingot axis is unknown, the tension test specimen may be taken from either end. For plates produced from coils, two tension test specimens are to be made from each coil. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen obtained from the approximate center lap.

When required, impact tests are to be obtained adjacent to both tension test coupons and a third coupon is to be obtained immediately after the last plate produced to the qualifying grade or specification.

2.1.5.2. Specimens from Plates 19 mm (0.75 in.) and Under in Thickness

Tension test specimens for plates 19mm (0.75 in.) and below in thickness are to be the full thickness of the material and are to be machined to the form and dimensions shown in Figure 2.1.1 or with both edges parallel.

2.1.5.3. Specimens from Plates Over 19 mm (0.75 in.) Thickness

Tension test specimens may be machined to the form and dimensions shown in Figure 2.1.2 for plates over 19 mm (0.75 in.) in thickness, and the axis of each such specimen is to be placed as nearly as possible midway between the center and the surface of the plate, or for plates up to 101.6 mm (4 in.) inclusive in thickness, they may be the full thickness of the material and of the form shown in Figure 2.1.1 when sufficient testing-machine capacity is available.

2.1.5.4. Stress Relieving

When required, the test specimens are to be stress-relieved by gradually and uniformly heating them to 590–650°C (1100–1200°F), holding at temperature for at least 1 hour per 25 mm (1 in.) thickness and cooling in still atmosphere to a temperature not exceeding 315°C (600°F). In the case of plates which are to be heat-treated and subsequently stress-relieved, the test specimens for such plates are to, before testing, be stress-relieved following the heat treatment.

2.1.6. **Tensile Properties**

2.1.6.1. Tensile Requirements

The material is to conform to the tensile requirements as specified for each grade in [2.2.5], [2.3.6] or [2.4.6] of this section.

2.1.6.2. Elongation Deduction for Material Under 7.9 mm (0.313 in.) Thick

A deduction from the specified percentage of elongation in 200 mm (8 in.) of 1.25% is to be made for each decrease of 0.8 mm (0.031 in.) of the specified thickness below 7.9 mm (0.313 in.) for material under 7.9 mm (0.313 in.) in thickness.

2.1.6.3. Elongation Deduction for Material Over 88.9 mm (3.50 in.) Thick

For material over 88.9 mm (3.50 in.) in thickness, a deduction from the specified percentage of elongation in 50 mm (2 in.) of 0.50% is to be made for each increase of 12.7 mm (0.50 in.) of the specified thickness above 88.9 mm (3.50 in.). This deduction is not to exceed 3%.

2.1.7. **Retests**

2.1.7.1. For All Thicknesses.

If the result of any of the physical tests specified for any of the material does not conform to the requirements, then at the request of the manufacturer, two additional specimens may be taken from the same plate and tested in the manner specified. However, in that case, both of the specimens must conform to the requirements .Refer Sec 1, [1.5.3].

2.1.7.2. For Heat-treated Material

When any heat-treated material fails to conform to the mechanical requirements, the material may be reheat treated, and all physical tests are to be repeated. The Surveyor is to re-examine the plate surfaces following any additional heat treatment, where plates are specially ordered requiring surface inspection.

2.1.8. **Thickness Variation**

No plate is to vary more than 0.25 mm (0.01 in.) or 6% under the thickness specified, whichever is the lesser.

2.1.9. **Finish**

Plates may be conditioned by the manufacturer for the removal of surface defects on either surface by grinding, except when ordered for riveted construction. The ground area should be well faired and grinding does not reduce the thickness of the plate below the permissible minimum thickness.

2.1.10. **Weldability**

In [2.2], [2.3] or [2.4] of this section, all of the grades which are covered are intended for fusion welding, but fundamental importance must be given to the welding technique and the welding procedure is to be in accordance with approved methods. Refer Pt 2, Ch 3.

2.2. Steel Plates for Intermediate-temperature Service

2.2.1. **Scope**

MA, MB, MC are the three grades of low and intermediate-tensile-strength carbon-steel plates covered herein.

2.2.2. **General**

The various grades are in accordance with ASTM designations as follows.

ASTM – A285 Grades A, B, C

INTLREG – Grades MA, MB, MC

The maximum thickness of these grades is to be 50.8 mm (2.0 “).

2.2.3. **Chemical composition**

The steel is to conform to the following requirements of Table 2.2.1 as to chemical composition.

Table 2.2.1: Chemical Composition

	Grade MA	Grade MB	Grade MC
Carbon, max. %	0.17	0.22	0.28
Manganese, max. %	0.90	0.90	0.90
Phosphorus, max. %	0.035	0.035	0.035
Sulfur, max. %	0.045	0.045	0.045

Copper(2), when Copper Steel is specified			
Ladle Analysis	0.20/0.35	0.20/0.35	0.20/0.35
Check Analysis	0.18/0.37	0.18/0.37	0.18/0.37
Note: 1. Refer 2.1.4. 2. When specified, the maximum incidental copper content is to be 0.25%.			

2.2.4. **Specimen preparation**

Test specimens are to be prepared for testing from material in its rolled condition.

2.2.5. **Tensile properties**

The material is to conform to the Table 2.2.2 as to tensile properties.

Table 2.2.2: Tensile Properties

	Grade MA	Grade MB	Grade MC
Tensile Strength N/mm^2 (kgf/mm^2) (psi)	310–450 (31.5–46) (45000–65000)	345–485 (35–49) (50000–70000)	380–515 (39–53) (55000–75000)
Yield Strength, min, N/mm^2 (kgf/mm^2, psi)	165 (17, 24000)	185 (19, 27000)	205 (21, 30000)
Elongation in 200 mm (8 in) min, %*	27	25	23
Elongation in 50 mm (2 in) min, %	30	28	27
Note : Refer 2.1.6.2 and 2.1.6.3			

2.3. Steel Plates for Intermediate- and Higher-temperature Service

2.3.1. **Scope**

Seven grades of steel plates designated MD, ME, MF, MG, H, I and J are covered. Grades MD, ME, MF and MG cover intermediate and higher-tensile-strength ranges in carbon-silicon steel plates; Grades H, I and J cover three high-tensile-strength ranges in carbon-molybdenum steel plates.

2.3.2. **General**

The various grades are in substantial agreement with ASTM designations as follows:

ASTM – A515 Grades 55, 60, 65, 70 INTLREG – Grades MD, ME, MF, MG

ASTM – A204 Grades A, B, C INTLREG – Grades H, I, J

Plates are limited in thickness as follows:

Grade MD to 304.8 mm (12.0 ");

Grades ME, MF and MG to 203.2 mm (8.0 ");

Grades H and I to 152.4 mm (6.0 “)

Grade J to 101.6 mm (4 “).

2.3.3. Heat Treatment

2.3.3.1. Treatment

Plates of Grades MD, ME, MF and MG over 50.8 mm (2.0“) and Grades H, I and J over 38.1 mm (1.5“) in thickness are to be treated either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with the hot-forming operation, the temperature to which the plates are heated for hot forming is to be equivalent to and is not to significantly exceed the normalizing temperature. In case, this treatment is not carried out at the rolling mill, the testing is to carried out in accordance with [2.3.3.3].

2.3.3.2. Heat-treatment instructions on orders

Orders to the plate manufacturer or the fabricator by the purchaser must clearly specify when plates are to be heat-treated and any special requirement that the test specimens be stress-relieved, so that suitable provision may be made for the heat treatment of the test specimens. It must also be stated in the purchase orders to the mill whether the rolling mill or the fabricator is to perform the required heat treatment of the plates.

2.3.3.3. Responsibility for heat treatment

When a fabricator is equipped and decides to conduct the required normalizing or fabricates by hot forming as provided in [2.3.3.1], the plates are to be accepted on the basis of tests made at the plate manufacturer’s plant on specimens heat-treated in accordance with the purchaser’s order requirements. In case, the heat-treatment temperatures are not specified on the purchase order, the plate manufacturer is to carry out heat treatment of the specimens under conditions considered appropriate to meet the test requirements. The plate manufacturer is to inform the fabricator of the procedure followed in treating the specimens at the mill for guidance in treating the plates. When the plates are to be normalized at the plate manufacturer’s plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

2.3.4. Chemical composition

The steel is to conform to the requirements of Table 2.2.3 as to chemical composition.

2.3.5. Test specimens

2.3.5.1. Plates not requiring heat treatment

Where plates do not require heat treatment, the test specimens are to be prepared for testing from the material in its rolled condition. Plates of Grade H, I and J are to be used in a boiler or pressure vessel which is to be stress-relieved, the test specimens for Grades H, I and J are to be stress-relieved. Refer [2.1.5] of this section

2.3.5.2. Plates requiring heat treatment

For plates requiring heat treatment .Refer [2.3.3.1] the test specimen are to be prepared from the material in its heat-treated condition, or from full-thickness samples similarly and simultaneously treated. When Grades H, I and J plates are to be used in a boiler or pressure vessel which is to be stress-relieved, the test specimens for Grades H,I and J are to be stress-relieved after the heat treatment. Refer [2.1.5] and [2.3.3] of this section

2.3.6. **Tensile properties**

The material is to conform to the requirements of Table 2.2.4 as to tensile properties

2.4. Steel Plates for Intermediate- and Lower-temperature Service

2.4.1. Scope

The four grades of carbon-manganese-silicon steel plates made to fine-grain practice in four tensile-strength ranges designated K, L, M, N are covered.

2.4.2. General

The various grades are in substantial agreement with ASTM designation, as follows.

ASTM – A516 Grades 55, 60, 65, 70

INTLREG – Grades K, L, M, N

Plates are limited in thickness, as follows:

Grade K to 304.8 mm (12.0 in.);

Grades L, M and N to 203.2 mm (8.0 in.).

Materials for Liquefied Gas Carriers are to comply with Ch 1, [1.1.1].

2.4.3. Heat Treatment

2.4.3.1. Grain Refinement

Plates over 38.1 mm (1.5 in.) are to be heat-treated to produce grain refinement either by normalizing or heating uniformly for hot forming. If the required treatment is to be obtained in conjunction with hot forming, the temperature to which the plates are heated for hot forming is to be equivalent to and is not to exceed significantly the normalizing temperature. If this treatment is not done at the rolling mill, the testing is to be carried out in accordance with [2.4.3.3]. For improved notch toughness for plates 38 mm (1.5 in.) and under in thickness, heat treatment is to be specified as above.

2.4.3.2. Heat-treatment Instructions on Orders

Orders given out to the plate manufacturer or the fabricator by the purchaser to specify when plates are to be heat-treated for grain refinement, and any special requirements that the test specimens be stress-relieved, so that adequate provision may be made for the heat treatment of the test specimens. It must also be stated in the purchase orders to the mill whether the rolling mill or the fabricator is to perform the required heat treatment of the plates.

2.4.3.3. Responsibility for Heat Treatment

When a fabricator is equipped and decides to perform the required normalizing or fabricates by hot forming as provided in [2.4.3.1], the plates are to be accepted on the basis of tests made at the plate manufacturer's plant on specimens heat-treated in accordance with the purchaser's order requirements. In case, the heat-treatment temperatures are not specified on the purchase order, the plate manufacturer is to carry out heat treatment of the specimens under conditions considered suitable for grain refinement, and also to meet the test requirements. The plate manufacturer is to inform the fabricator of the procedure followed in treating the specimens at the mill for guidance in treating the plates. When the plates are to be normalized at the plate manufacturer's plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

2.4.4. Chemical Composition

The chemical composition of the material shall be in accordance with the requirements detailed in Table 2.2.5.

2.4.5. Test Specimens

2.4.5.1. Plates 38.1 mm (1.5 in.) and Under in Thickness

For plates with thickness 38.1 mm (1.5 in.) and under, not requiring heat treatment, the test specimens are to be prepared for testing from the material in its rolled condition.

2.4.5.2. Plates Requiring Heat Treatment

For plates 38.1 mm (1.5 in.) and under in thickness, requiring heat treatment (Refer [2.4.3.1]), or for plates over 38.1 mm (1.5 in.) in thickness, the test specimens are to be prepared from the material in its heat-treated condition, or from full-thickness samples similarly and simultaneously treated.

2.4.6. Tensile Properties

The tensile properties of the material is to comply with the requirements of Table 2.2.6.

2.5. Materials for Low Temperature Service [Below -18°C (0°F)]

In accordance with those requirements listed in Ch 1, Sec 5, [5.5], materials intended for service temperatures of below -18°C (0°F) may be provided. When the Charpy V-notch impact tests are conducted at 5°C (10°F) below minimum design temperature in accordance with Ch 1, Sec 5, [5.3.1] other special low temperature materials, meet the applicable requirements of Ch-1, Sec 5, [5.6]. For austenitic stainless steels or aluminum alloys such as type 5083, such tests are not required.

Table 2.2.3: Chemical Composition for Plate Grades MD, ME, MF, MG, H, I, J

	MD	**ME**	**MF**	**MG**	**H**	**I**	**J**
Carbon, max. %:							
For plates 25.4 mm (1.0 in.) and under in thickness	0.20	0.24	0.28	0.31	0.18	0.20	0.23
For plates over 25.4 mm (1.0 in.) to 50.8 mm (2.0 in.) incl., in thickness	0.22	0.27	0.31	0.33	0.21	0.23	0.26
For plates over 50.8 mm (2.0 in.) to 101.6 mm (4.0 in.) incl., in thickness	0.24	0.29	0.33	0.35	0.23	0.25	0.28

For plates over 101.6 mm (4.0 in.) to 203.2 mm (8.0 in.) incl., in thickness	0.26	0.31	0.33	0.35	0.25	0.27	
For plates over 203.2 mm (8.0 in.) to 304.8 mm (12.0 in.) incl., in thickness	0.28						
Manganese, max, %	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Phosphorous max, %	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulphur, max, %	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Silicon, %:							
Ladle analysis	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30
Check analysis	0.13-0.33	0.13-0.33	0.13-0.33	0.13-0.33	0.13-0.32	0.13-0.32	0.13-0.32
Molybdenum, %:							
Ladle analysis					0.45-0.60	0.45-0.60	0.45-0.60
Check analysis					0.41-0.64	0.41-0.64	0.41-0.64
Note: Refer also [2.1.4] of this section.							

Table 2.2.4: Tensile Properties for Plate Grades MD, ME, MF, MG, H, I, J (1)

	MD	**ME**	**MF**	**MG**	**H**	**I**	**J**
Tensile Strength,							
in N/mm^2	380-515	415-550	450-585	485-620	450-585	485-620	515-655
in kgf/mm^2	39-53	42-56	46-60	49-63	46-60	49-63	53-67
in psi	55000-75000	60000-80000	65000-85000	70000-90000	65000-85000	70000-90000	75000-95000
Yield Strength, min.,							
in N/mm^2	205	220	240	260	255	275	295
in kgf/mm^2	21	22.5	24.5	27	26	28	30.5
in psi	30000	32000	35000	38000	37000	40000	43000
Elongation in 200 mm, (8 in.), min., %	23 (2)	21 (2)	19 (2)	17 (2)	19 (2) (5)	17 (2)(5)	16 (2)(5)
Elongation in 50 mm, (2 in.) min., % (Refer Note 4)	27 (3)	25 (3)	23 (3)	21 (3)	23 (3)	21 (3)	20 (3)

Note:

1. A characteristic of certain types of alloy steels is a local, disproportionate increase in the degree of necking down or contraction of the specimens under tension tests, resulting in a decrease in the percentage of elongation as the gauge length is increased. The effect is not so pronounced in the thicker plates.
2. Refer [2.1.6.2] of this section.
3. Refer [2.1.6.3] of this section.
4. When specimen shown in Figure 2.1.2 is used.
5. For plates over 6.4 mm (0.25 in.) to 19.1 mm (0.75 in.) inclusive, in thickness, if the percentage of elongation of a 200 mm (8 in.) gauge-length test specimen falls not more than 3% below the amount specified, the elongation is to be considered satisfactory, provided the percentage of elongation in 50 mm (2 in.) across the break is not less than 25%

Table 2.2.5: Chemical Composition for Plate Grades K, L, M, N

	K	L	M	N
Carbon, max, %:				
For plates 12.7 mm (0.50 in.) and under in thickness	0.18	0.21	0.24	0.27
For plates over 12.7 mm (0.50 in.) to 50.8 mm (2.0 in.) incl.	0.20	0.23	0.26	0.28
For plates over 50.8 mm (2.0 in.) to 101.6 mm (4.0 in.) incl.	0.22	0.25	0.28	0.30
For plates over 101.6 mm (4.0 in.) to 203.2 mm (8.0 in.) incl.	0.24	0.27	0.29	0.31
For plates over 203.2 mm (8.0 in.) to 304.8 mm (12.0 in.) incl.	0.26			
Manganese, %:				
For plates 12.7 mm (0.50 in.) and under in thickness				
Ladle	0.60/0.90	0.60/0.90	0.85/1.20	0.85/1.20
Check	0.56/0.94	0.56/0.94	0.80/1.25	0.80/1.25
For plates over 12.7 mm (0.50 in.) to 304.8 mm (12.0 in.) incl				
Ladle	0.60/1.20	0.85/1.20	0.85/1.20	0.85/1.20
Check	0.56/1.25	0.80/1.25	0.80/1.25	0.80/1.25
Phosphorus, max., %	0.035	0.035	0.035	0.035
Sulphur, max., %	0.04	0.04	0.04	0.04
Silicon, %:				
Ladle	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.30
Check	0.13/0.33	0.13/0.33	0.13/0.33	0.13/0.33

Note: Refer also [2.1.4] of this section.

Table 2.2.6: Tensile Properties for Plate Grades K, L, M, N

	K	L	M	N
Tensile Strength,				
in N/mm^2	380-515	415-550	450-585	485-620
in kgf/mm^2	39 to 53	42 to 56	46 to 60	49 to 63
in psi	55000-75000	60000-80000	65000-85000	70000-90000
Yield Strength, min.,				
in N/mm^2	205	220	240	260
in kgf/mm^2	21	22.5	24.5	27
in psi	30000	32000	35000	38000
Elongation in 200 mm, (8 in.), min., %	23 (1)	21 (1)	19 (1)	17 (1)
Elongation in 50 mm, (2 in.), min., % (Refer Note 3)	27 (2)	25 (2)	23 (2)	21 (2)

Notes:

1. Refer [2.1.6.2] of this section
2. Refer [2.1.6.3] of this section
3. When specimen shown in Figure 2.1.2 is considered.

SECTION 3 HOT-ROLLED STEEL BARS FOR MACHINERY

Contents

3.1 General....................101
3.2 Manufacture....................101
3.3 Tests....................101
3.4 Certification....................101

3.1 General

3.1.1. This Section gives the general requirements for hot rolled bars and sections intended for use in machinery.

3.1.2. Hot-rolled steel bars are to be made by a manufacturer approved by INTLREG.

3.1.3. INTLREG approval is valid for 5 years subject to annual verification and /or endorsement by the attending Surveyor.

3.1.4. *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.

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

3.2 Manufacture

3.2.1. Hot-rolled steel bars up to and including 305 mm (12 in.) diameter, presented for inspection after special approval for each specific application, are to be made by one or more of the following processes: open-hearth, basic-oxygen, electric-furnace or such other process as may be approved.

3.2.2. In accordance with Sec-6, [6.1.5], hot-rolled bars used in lieu of carbon-steel forgings (Refer Sec 6) are to be fully killed, heat treated and the cross-sectional area of the un-machined finished bar is not to exceed one-sixth of the cross-sectional area of the ingot.

Additionally, hot-rolled bars used in lieu of forgings for tail shafts are to meet the nondestructive examination requirements of Sec 6,[6.1.9.1]

3.2.3. The tensile properties are to meet the requirements of Sec-6, Table 2.6.2 for the proposed application.

3.3 Tests

3.3.1 Four (4) tension tests are to be taken from each lot of material exceeding 907 kg (2000 lb) in weight. When the weight of a lot is 907 kg (2000lb) or less, two tension tests may be taken. In any case, only one tension test will be required from any one bar.

3.3.2 A lot is to consist of bars from the same heat; if the bars are heat-treated, then a lot is to consist of bars from the same heat which have been heat-treated in the same furnace charge.

3.3.3 If the bars in a lot differ 9.5 mm (0.375 in.) or more in diameter, the test specimens taken are to be representative of the greatest and least diameter bar.

3.4 Certification

3.4.1. The Manufacturer is to provide a certificate to the Surveyor which states that the material has been manufactured following an approved procedure and that it has satisfactorily withstood the prescribed tests as per Sec 1, [1.4] of this chapter.

SECTION 4 ROLLED STEEL BARS FOR CHAIN, CAST AND FORGED MATERIALS FOR ACCESSORIES AND MATERIALS FOR STUDS

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4.1. General

4.1.1. Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) or Grades 1, 2 or 3 chains, cast and forged materials for accessories and materials for studs are to be in accordance with this section.

For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

Separate approvals are required if bar is to be supplied to more than one cable manufacturer.

These Rules are not intended to replace or modify any part of a chain manufacturer's specification approved by INTLREG.

4.1.2. Process and Qualification of Manufacture

The manufacturers of materials for anchor chain and accessories are to be approved by the INTLREG. For Grade 1 bars, no approval is required. The bar manufacturers are to submit the manufacturing specifications and details of the manufacturing procedure. The approval tests are to be carried out in accordance with Ch 2 Sect 12 of this part, the scope of which is to be agreed with INTLREG.

The steel is to be made by the open-hearth, basic oxygen, vacuum-arc remelt, electro-slag remit electric furnace or such process as may be specially approved.

The steel bars are to be supplied in rolled condition, unless otherwise specified.

4.1.3. Deoxidation Practice

Bars are to be fully killed and, additionally, Grade U2 or U3 bars are to be produced to a fine grain practice.

4.1.4. Chemical Composition and Heat Treatment

The chemical composition and heat treatment are to be as per the manufacturer's specification which is to be approved by INTLREG. In general, they are to conform to Table 2.4.1.

4.1.5. Mechanical Properties

Mechanical tests are to be carried out in accordance with [4.2] of this section and the results are to meet the requirements given in Sec-12, Table 2.12.5.

4.1.6. Dimensional properties

The tolerances on diameter and roundness (d_{max} – d_{min}) are to be within the limits given in Table 2.4.2, unless otherwise approved. Where d_{max} and d_{min} indicate the maximum and minimum diameter measured at the section under consideration.

4.2. Material Testing

4.2.1. Heat Treatment of Test Specimens

Test specimens are to be taken from material heat-treated in the same manner as intended for the finished chain.

4.2.2. Number of Tests

From two different bars of steel from each heat, one tensile and three impact test specimens are to be taken, except when the material from a heat is less than 50 metric tons (49.21 long tons), in which case, tests from one bar will be adequate.

However, where the material from one heat differs 9.5 mm (0.375 in.) or more in diameter, one set of tests is to be taken from the thinnest and thickest material rolled.

4.2.3. Tension Test Specimens

As shown in Sec-12, Figure 2.12.3, tension test specimens for bar material are to be taken at $^2/_3$ r or as close thereto as possible and machined to Ch-1, Figure 1.1.2 or an appropriate national standard specimen.

The required minimum percentage of elongation values in Sec-12, Table 2.12.5 are based on specimens having gauge lengths equal to five (5) times the diameter. The equivalent elongation value for specimens having other gauge lengths is to be calculated by the following equation:

$$n = 2E\left(\sqrt{A}/L\right)^{0.4}$$

Where,

n = Equivalent minimum elongation;

A = Actual cross-sectional area of the specimen;

L = Actual gauge length;

E = Specified minimum percentage elongation for specimens having a gauge length of five (5) times the diameter.

The above equation is not applicable to quenched and tempered steel, for which the specimen is to have a gauge length of five (5) times the specimen diameter.

4.2.4. Bend Test Specimens

Bend test specimens may be either the full section of the bar or may be machined at the option of the manufacturer to a 25 mm (1 in.) diameter or to a rectangular cross section of 25 mm × 12.5 mm (1 in. × 0.5 in.), but not less than 12.5 mm × 12.5 mm (0.5 in. × 0.5 in.). Each specimen is to withstand, without fracture, cold bending around a mandrel diameter and through the angle as specified in Sec 12, Table 2.12.5.

4.2.5. Impact Test Specimens

Impact test specimens are to be in accordance with Ch 1, Sec 1, [1.6.6]. as shown in Sec 12, Figure 2.12.3, they are to be cut and notched. The average value of three (3) specimens to be in compliance with the requirements of Sec 12, Table 2.12.2.

4.2.6. Additional Tests before Rejection

When a specimen fails to meet the requirements of Sec 12, Table 2.12.2, retests in accordance with [Ch 1, Sec 2,[2.5.5], [2.5.6],[2.6.4] and [2.6.5] may be permitted, as applicable.

4.2.7. Manufacturer’s Option

At the discretion of the chain manufacturer, the above material tests (normally conducted prior to chain fabrication) may be waived, provided the required test specimens representative of each heat are taken from finished links after final heat treatment, if any, and in the same proportion of number of tests to tonnage as outlined in Sec 12, [12.1.7.2].

4.2.8. Freedom from Defects

The materials are to be free from internal and surface defects that might adversely affect proper workability and use. Repairing of the surface defects may be carried out to the satisfaction of the Surveyor by grinding, provided the admissible tolerance is not exceeded.

4.2.9. Identification of Material

An identification system shall be effectively followed by the Manufacturers in order to ensuring traceability of the material to the original cast.

4.2.10. Marking

The minimum markings which are required for the steel bars shall comprise of the manufacturer’s brand mark, the steel grade and an abbreviated symbol of the heat. Steel bars with diameters up to and including 40 mm (1.6 in.) and combined into bundles may be marked on permanently affixed labels.

4.2.11. Material Certification

The Bar material for Grade 2 or Grade 3 is to be certified by INTLREG.. Manufacturers shall forward to the Surveyor a certificate for each consignment including the following data as a minimum:

- Manufacturer’s name and/or purchaser’s order No.;
- Number and dimensions of bars and weight of consignment;
- Steel specification and chain grade;
- Heat number;
- Manufacturing procedure;
- Chemical composition;
- Details of heat treatment of the test sample (where applicable);
- Number of test specimens (where applicable);
- Results of mechanical tests (where applicable)

4.2.12. Forged Steels for Chain Cables and Accessories

Forged steel used in the manufacture of chain cables and accessories are to be in accordance with Chapter-1, Section-7, “Hull Steel Forgings”, except when specified in the following paragraphs.

The chemical composition is to comply with the specification approved by INTLREG. The chemical composition of every heat of material must be determined and certified by the steel manufacturer.

The stock material may be supplied in the as-rolled condition. Finished forgings are to be properly heat treated, i.e., normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant grade of chain.

4.2.13. Cast Steels for Chain Cables and Accessories

Cast steel used in the manufacture of chain cables and accessories are to be in accordance with Chapter-1, Section-6, “Hull Steel Castings”, except when specified in the following paragraphs.

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

All castings must be properly heat treated (i.e., normalized, normalized and tempered or quenched and tempered), whichever is specified for the relevant grade of chain.

4.2.14. Materials for Studs

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

Table 2.4.1: Rolled Bars for Chain – Chemical Composition and Intended Chain Condition

Bar Stock Grade	**U1**	**U2**	**U3**
Intended Chain Grade	Grade 1	Grade 2	Grade 3
Deoxidation	fully killed	fully killed, fine grain	fully killed, fine grain
Intended Chain Condition	as rolled	as rolled or normalized(4)	normalized, normalized and tempered or quenched and tempered
Chemical Composition (1) , (Ladle Analysis) - % max unless specified otherwise			
C	0.20	0.24	0.36
Si	0.15 - 0.35	0.15 - 0.55	0.15 - 0.55
Mn	0.40 min.	1.00 - 1.60	1.00 - 1.90
P	0.040	0.035	0.035
S	0.040	0.035	0.035
Al (2) (total) min	-	0.020	0.020
Bar Stock Marking	IR/U1	IR/U2 (3),(4)	IR/U3

Notes:

1. Other intentionally added elements are to be reported on the mill sheet.
2. Specified aluminum contents may be partly replaced by other grain refining elements. Refer Ch 1, Sec 3, [3.2].
3. Bars impact tested in accordance with Note 1 to Sec-12, Table 2.12.5 to be marked IR/U2AW.
4. Normalized bars for Grade 2 chains are to be marked IR/U2N.

Table 2.4.2: Rolled Bar for Chain – Dimensional Tolerances

Specified Bar Diameter, mm (in.)		Tolerance on Diameter, mm (in.)	Tolerance on (d_{max} – d_{min}) mm (in.)
over	up to		
less than 25 (1.0)		- 0, + 1.0 (0.04)	0.6 (0.02)
25 (1.0) or above	35 (1.37)	- 0, + 1.2 (0.05)	0.8 (0.03)
35 (1.37)	50 (2.0)	- 0, + 1.6 (0.06)	1.1 (0.04)
50 (2.0)	80 (3.12)	- 0, + 2.0 (0.08)	1.50 (0.06)
80 (3.12)	100 (4.0)	- 0, + 2.6 (0.10)	1.95 (0.08)
100 (4.0)	120 (4.75)	- 0, + 3.0 (0.12)	2.25 (0.09)
120 (4.75)	160 (6.25)	- 0, + 4.0 (0.16)	3.00 (0.12)

SECTION 5 SEAMLESS FORGED-STEEL DRUMS

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5.1. Tests and Inspections

1.1.1. If any seamless forged-steel drums are presented for survey after special approval for each application, they are to be tested and surveyed as per the applicable procedures given for steel forgings. One tension test is to be carried out from each end of the forging midway between the inner and outer surfaces of the wall in a tangential direction and two specimens to be taken from opposite sides of the drum.

1.1.2. Grade A and Grade B material is to have the minimum properties as specified in Table 2.5.1.

Table 2.5.1

	Grade A	**Grade B**
Tensile strength	415 N/mm^2 (42 kgf/mm^2;60,000 psi)	515 N/mm^2 (53 kgf/mm^2; 75,000 psi)
Yield strength	205 N/mm^2 (21 kgf/mm^2; 30,000 psi)	260 N/mm^2 (26.5 kgf/mm^2; 37,500 psi)
Elongation in a 50 mm (2 in.) gauge length	23%	19%

5.2. Heat Treatment

1.2.1. After final treatment of the forgings, except as specified herein, tests for acceptance are to be carried out. The drums may be treated and tested prior to re-forging when the ends of drums are closed in by re-forging after machining. After re-forging, the whole of the forging is to be simultaneously re-treated. If the original treatment was annealing, the re-anneal is to be above the transformation range, but not above the temperature of the first anneal. The re-treatment is to be identical with the original, if the original treatment was normalizing and tempering.

SECTION 6 STEEL MACHINERY FORGINGS

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6.1. Carbon Steel Machinery Forgings

6.1.1. Process of Manufacture

The following requirements deal with carbon-steel forgings intended to be used for the purpose of machinery construction. Optionally, forgings which are in compliance with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by INTLREG.

INTLREG approval is valid for a period of 5 years subject to annual verification and/or endorsement by the attending Surveyor. At any time, the Surveyor is permitted to monitor important aspects of forging production, which include but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

The steel is to be manufactured by an INTLREG approved procedure and is to be fully killed. Crankshafts may require special approval for the proposed method of manufacture, where grain flow is required in the most favorable direction with regard to the mode of stressing in service. In such cases, tests may be required to demonstrate that satisfactory microstructure and grain flow are obtained. The shaping of forgings or rolled slabs and billets by thermal cutting, scarfing or arc-air gouging is to be carried out, in accordance with recognized good practice and unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be carried out when required by the composition and/or thickness of the steel. Subsequent machining of all thermal cut surfaces may be required for certain components.

The proposed welding procedure specification is to be submitted for approval when two or more forgings are joined by welding to form a composite component. The plastic deformation must ensure soundness, uniformity of structure and acceptable mechanical properties after heat treatment. On the basis of the average cross-sectional area of the cast material the reduction ratio is to be assessed. If the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

The total reduction ratio is to be at least as below, unless otherwise approved:

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

'L' and 'D' are the length and diameter, respectively, of the part of the forging under consideration. In order to secure freedom from piping and undue segregation a sufficient discard is to be made from each ingot.

6.1.2. ASTM designations

The grades are in accordance with ASTM as follows:

INTLREG grade	ASTM designation
2	A668, Class B
3	A668, Class D
4	A668, Class E
4C	A668, Class E

6.1.3. Chemical composition

All forgings are to be made of killed steel. An analysis of each heat is to be done in order to determine the percentages of the elements specified. The chemical composition thus determined shall be reported to the Surveyor and is to conform to the requirements of Table 2.6.1. The carbon content of Grades 2, 3 and 4 is not to exceed 0.23% or carbon equivalent (C_{eq}) of Grades 2, 3 and 4 is not to exceed 0.41%, unless specially approved, Refer Table 2.6.1. The carbon content of Grade 4C is not to exceed 0.55%. Welding of Grade 4C is not permitted unless specially approved. Specially approved grades having more than the maximum specified carbon are to have S marked after the grade designation.

Forgings for rudder stocks and pintles are to be of weldable quality.

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.

Table 2.6.1: Chemical composition requirements for Carbon Steel Machinery Forgings, in %

Element	Grade 2	Grade 3	Grade 4	Grade 4C
Carbon	0.23(2)	0.23(2)	0.23(2)	0.36 to 0.55
Manganese	0.30–1.50	0.30–1.50	0.30–1.50	0.30–1.50
Silicon(3)	0.10–0.45	0.10–0.45	0.10–0.45	0.10–0.45
Sulfur	0.035	0.035	0.035	0.035
Phosphorus	0.035	0.035	0.035	0.035

Note:

1. Single values are maximum, unless noted.
2. The carbon content may be increased above this level, provided that the carbon equivalent (C_{eq}) is not more than 0.41 %, calculated using the following formula:
   $$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} (\%)$$
3. Silicon minimum is applicable if the steel is silicon killed.

6.1.4. Marking, retests and rejection

6.1.4.1. Marking

The manufacturer is to have an efficient system of identification that can trace all finished forgings to the original cast and the Surveyor is to be provided with proper facilities for tracing the forgings when required.

Additionally, to appropriate identification markings of the manufacturer, INTLREG markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be discernable after machining and installation. Moreover, Grade 2, Grade 3, Grade 4, and Grade 4C forgings are to be stamped IR/2, IR/3, IR/4 and IR/4C, respectively.

6.1.4.2. Retests

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with Sec 1, [1.5]. Where satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. The forging or batch of forgings is to be rejected where one or both retests fail. The manufacturer may reheat treat forgings that have failed to meet test requirements, in accordance with [6.1.5.6]. After that, the forgings are to be submitted for all mechanical testing.

6.1.4.3. Rejection

Any forging with injurious discontinuities which are found prior to or subsequent to acceptance at the manufacturer’s plant is to be subject to rejection.

6.1.5. Heat treatment

6.1.5.1. General

Heat treatment facilities used in producing INTLREG certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities involved in the forging.

If additional facilities are selected to carry out heat treatment an INTLREG qualification is to be obtained to include any new facility.

The INTLREG Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification. During production the, extend of monitoring is to be agreed with the Surveyor.

Unless a departure for the following procedures is specifically approved, Grade 2 and 3 forgings are to be annealed, normalized or normalized and tempered. Grade 4 and 4C forgings are to be normalized and tempered or double-normalized and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

A sufficient number of 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 can be verified at regular intervals.

Heat treatment is to be carried out in well-constructed furnaces, which are properly maintained with adequate means to control and record temperature. The furnace must be of such dimensions which can ensure that the entire furnace charge is heated uniformly to the requisite temperature. In cases of very large forgings, special consideration will be given to alternative methods of heat treatment. If for any reason a forging is subsequently heated for further hot working, then the forging is to undergo reheat treatment. Where a forging is reheated locally or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment is to be considered. The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, along with the number and location of thermocouples. These records are to be made available at the request of the Surveyor.

Required Heat Treatment and Minimum Tempering Temperature		
Grade	Heat Treatment	Temperature °C (°F)
A1	Quench + temper	620 (1150)
A2	Quench + temper	580 (1075)
A3	Quench + temper	580 (1075)
A4	Quench + temper	565 (1050)
A5	Quench + temper	565 (1050)
A6	Quench + temper	565 (1050)

Alternative heat treatment procedures may be specially approved with due consideration given to the section thickness and the intended function of the forged component. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

6.1.5.2. Cooling prior to heat treatment

After forging and before reheating for heat treatment, the forgings are allowed to cool in a manner to prevent injury and to accomplish transformation.

6.1.5.3. Annealing

The forgings are to be reheated to and held at the required austenitizing temperature for sufficient time which can lead to the desired transformation and then be allowed to cool gradually and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

6.1.5.4. Normalizing

The forgings are to be reheated to and held at the required temperature above the transformation range for sufficient time which can lead to the desired transformation and then withdrawn from the furnace and allowed to cool in air. Use of water sprays and air blasts may be specially approved in order to achieve more rapid cooling. The faster cooling rates are to be agreed upon by the purchaser.

6.1.5.5. Tempering

The forgings are to be reheated to and held at the proper temperature, which is to be below the transformation range but above the minimum temperature in Ch 2,Sec 6 [6.2.3] and table 2.6.4, and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until a temperature below 315°C (600°F) is reached.

6.1.5.6. Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

6.1.5.7. Surface Hardening

Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer 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.

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.

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.

6.1.6. Mechanical properties

Tensile properties of the forging are to conform to the requirements of Table 2.6.2. Each forging, except those with rough machined weight of less than 113 kg (250 lbs), is to be hardness tested to meet the following requirements.

ABS Grade	Hardness, BHN (10mm dia ball 3000 kg load)
A1	201 to 241
A2	223 to 262
A3	248 to 293
A4	285 to 331
A5	302 to 352

A6	341 to 415

Table 2.6.2: Tensile Property requirements for Carbon-Steel Machinery Forgings

Grade	Size, in mm (in)	Tensile Strength(2) in N/mm^2 (kgf/mm^2, ksi)	Yield Strength(3) in N/mm^2 (kgf/mm^2, ksi)	Longitudinal (4)			Tangential(4)		
				Elongation(5), in %		RA, in %	Elongation(5), %		RA(6), %
				Gauge Length			Gauge Length		
				4d	5d		4d	5d	
2	≤ 300 (12)	415 (42, 60)	205 (21, 30)	25	23	38	20	18	29
	> 300 (12)	415 (42, 60)	205 (21, 30)	24	22	36			
3	≤ 200 (8)	515 (53, 75)	260 (26.5, 37.5)	24	22	40	18	16	28
	> 200 (8) ≤ 300 (12)	515 (53, 75)	260 (26.5, 37.5)	22	20	35			
	> 300 (12) ≤ 500 (20)	515 (53, 75)	260 (26.5, 37.5)	20	18	32			
	> 500 (20)	515 (53, 75)	260 (26.5, 37.5)	19	17	30			
4, 4C(6)	≤ 500 (20)	570 (58.5, 83)	295 (30.5, 43)	20	18	35	17	16	27

Notes:

1. All tensile property requirements are minimum, unless indicated.
2. In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm^2 (7 kgf/mm^2, 10000 psi).
3. Yield strength is determined by the 0.2% offset method.
4. When tangential specimens are taken from wheels, rings, rims, discs, etc. in which the major final hot working is in the tangential direction, the tension test results are to meet the requirements for longitudinal specimens.
5. Elongation gauge length is 50 mm (2 in.); Refer Sec-1, Figure 2.1.2.
6. Size over 500 mm (2 in.) will be specially considered
   RA = Reduction of area

6.1.7. Test specimens

6.1.7.1. Location and orientation of specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations with a sectional area not less than the body of the forging. The length of the prolongation is to be such that the distance from the test specimen mid-gauge to the end of the prolongation is to be 89 mm (3.5 in.) or one-half the forging section thickness or diameter, whichever is less. Specimens can be taken in a direction parallel to the axis of the forging in the direction in which the metal is mostly drawn out or tangential to that direction, as indicated by the ductility requirements in Table 2.6.5. The locations of the axes of longitudinal specimens must be at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings.

The locations of the axes of transverse specimens must be close to the surface of the forgings. In the case of reduction gear ring forgings, reduction gear pinions and gear forgings, and reduction gear shaft forgings, the test specimen location and orientation are specified in [6.1.8.1 (d), (e) & (f)], respectively. Test results from other locations may be specially approved, provided adequate supporting information is furnished, which indicates that the specified location will be in compliance with the specified tensile properties.

6.1.7.2. Hollow-drilled specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

6.1.7.3. Very small forgings

For very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impracticable, a special forging may be made in order to obtain test specimens provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings should be subject to the same amount of working and reduction as the forgings represented and should undergo heat treatment with those forgings.

6.1.7.4. Identification of specimens

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/ tank (for Q&T forgings).

The test specimens are not to be separated from the forgings before the final heat treatment of the forgings is complete and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found appropriate to INTLREG and is maintained in that condition through initial and periodical verification by INTLREG, it may be considered in lieu of stamping by the Surveyor prior to detachment.

6.1.8. Number and Location of Tests

6.1.8.1 Tension test

a) *Large forgings*: For large forgings with rough machined weights of 3180 kg (7000 lb.) or more, one tension test specimen is to be taken from each end of the forging. For ring and hollow cylindrical forgings, the two tensile test specimens may be taken 180 degrees apart from the same end of the forging.

b) *Intermediate-sized forgings*: At least one tension test specimen is to be taken from each forging for forgings with rough machined weights less than 3180 kg. (7000 lb.), except as noted in the following paragraph.

c) *Small forgings*: For small normalized forgings with rough machined weights less than 1000 kg (2200 lb.), and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb), one tension test specimen may be taken from one forging as representative of a lot, where the forgings in the lot are of one grade and kind, are of a similar size, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge must not to go beyond 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings.

d) *Reduction Gear Ring Forgings*: Where ring forgings for reduction gears are involved, two tension tests are to be taken 180 degrees apart from a full-size prolongation left on one end of each individual forging or both ends of each multiple forging. Test specimens are to be in a tangential orientation at mid-wall of the ring as close as practical to the end of the rough machined surface of the forging.

e) *Reduction gear pinion and gear forgings*: For pinion and gear forgings for reduction gears, the tension test is to be taken in the longitudinal or tangential orientation from a location which is as close as possible to the mid-radius location of the main body (toothed portion) of solid forgings or the mid-wall of bored forgings. Extending the axial length of the main body (toothed portion) of the forging for a sufficient distance would be an appropriate location for tension specimen removal.

f) *Reduction gear shaft forgings*: In the case of shaft forgings for reduction gears, the tension test is to be taken in the longitudinal direction at the mid-radius location of a full size prolongation.

g) *Carburized forgings*: 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 [6.1.7] above except that, irrespective of the dimensions or mass of the forging, the tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction. The test material is to be machined to a diameter of D/4 or 60 mm, 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 forge master or gear manufacturer, 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 INTLREG.

6.1.8.2 Hardness tests

a) **Large, intermediate and small sized forgings**: Each forging, except those with rough machined weights of less than 113 kg (250 lbs.), is to be hardness tested to meet the following requirements. The variation in hardness of any forging is not to exceed 30 Brinell Hardness numbers.

INTLREG Grade	Hardness, BHN, Minimum
2	120
3	150
4, 4C	170

b) **Reduction Gear forgings:** For ring forgings for reduction gears, the Brinnel hardness tests are to be taken at approximately ¼ of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

Outside diameter, cm.(in)	**Number of hardness tests**
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart
203 to 305 (80 to 120)	3 on each end, 120 degrees apart
Over 305 (120)	4 on each end, 90 degrees apart

c) **Reduction Gear Pinion and Gear Forgings:** In case of pinion and gear forgings with diameters 203 mm (8 in.) and over, four Brinnel hardness tests are to be made on the outside surface of that portion of the forging on which teeth will be cut, two tests being made on each helix 180 degrees apart and the tests on the two Helices are to be 90 degrees apart. On each forging under 203 mm (8 in.) in diameter two Brinnel hardness tests are to be made on each helix 180 degrees apart. Hardness tests are to be taken at the quarter-face width of the toothed portion diameter.

d) **Disk, Ring and Hollow Forging:** In Each forging, except those with rough machined weights of less than 113 kg (250 lbs), is to be hardness tested to meet the requirements of [6.1.8.2] (a). Forgings are to be tested at the approximate mid-radius and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

e) **Very Small Forgings:** In cases involving very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot; Refer [6.1.7.3].

6.1.9. Examination

After final heat treatment, all forgings are to be examined in accordance with [6.1.9] by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications. Where applicable, this is to include the examination of internal surfaces and bores.

The manufacturer is to verify that all dimensions meet the specified requirements.

When required by the relevant construction Rules, or by the approved procedure for welded composite components, appropriate nondestructive 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 INTLREG . Ch 5,sect 5,[5.2.6] is regarded as an example of an acceptable standard.

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

6.1.9.1. Surface Inspection of Tail Shaft Forgings

All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor.

6.1.9.2. Ultrasonic Examination of Tail Shaft Forgings

Forgings for tail shafts 455 mm (18 in.) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor.

6.1.10. Rectification of defective forgings

Defects may be rectified by grinding or chipping and grinding, provided that the component dimensions remain 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.

Repair welding of forgings may be permitted subject to prior approval by INTLREG. In such cases, relevant information related to the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

Prior to the repair welding of forgings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending surveyor.

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

6.1.11. Certification

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

a) Purchaser’s name and order number;

b) Identification number;

c) Description of forgings and steel quality;

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

e) Results of mechanical tests;

f) Results of nondestructive tests, where applicable;

g) Details of heat treatment, including temperature and holding times;

h) Specification.

6.2. Alloy Steel Gear Assembly Forgings

6.2.1. Process of manufacture

6.1.9.1 General

The following requirements cover gear and pinion alloy steel forgings intended to be used principally for propulsion units and auxiliary turbines. Typical components include forging rims and blanks for steel gears and pinions, used in shipboard gear assemblies. The steel is to be fully killed and is to be manufactured by a process approved by INTLREG. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by INTLREG.

The validity of the INTLREG approval is for 5 years subject to annual verification and/or endorsement by the attending Surveyor. At any time, the Surveyor is to be permitted to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

The shaping of forgings or rolled slabs and billets by thermal 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 thermal cut surfaces may be required.

When two or more forgings are joined to form a composite component by welding, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation must ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. Calculation of the reduction ratio must be with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

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

- For forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \leq D$.
- For forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$.

- For forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting.

- For rolled bars used in lieu of forgings, 6:1.

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

A sufficient discard is to be made from each ingot in order to secure freedom from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging effectively.

6.1.9.2 ASTM designations

The grades are in accordance with ASTM, as follows:

INTLREG Grade	ASTM designation
A1	A291 Grade2
A2	A291 Grade3
A3	A291 Grade4
A4	A291 Grade5
A5	A291 Grade6
A6	A291 Grade7

6.1.9.3 Chemical composition

All forgings are to be made from killed steel. An analysis of each heat is to be made in order to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of Table 2.6.3. The analysis is to be carried out with a coupon cast during the pouring of the heat.

Table 2.6.3: Chemical Composition Requirements for Alloy Steel Gear Assembly Forgings, %

Element	Grade A1	Grade A2	Grades A3, A4, A5 and A6
Carbon	0.50	0.45	0.35 to 0.50
Manganese	0.40 to 0.90	0.40 to 0.90	0.40 to 0.90
Silicon (2)	0.35	0.35	0.35
Sulfur	0.040	0.040	0.040
Phosphorus	0.040	0.040	0.040
Nickel	Note 3	0.50	1.65 min.
Chromium	Note 3	1.25	0.60 min.
Molybdenum	Note 3	0.15 min.	0.20 to 0.60
Copper	0.35	0.35	0.35
Vanadium	0.10	0.50	0.10

Notes:
1. Single values are maxima, unless noted.
2. If the steel is vacuum-carbon deoxidized, the silicon content is to be 0.10 maximum.
3. The nickel, chromium and molybdenum contents are to be specially approved.

6.2.2. Marking, retests and rejection

6.2.2.1. Marking

The manufacturer is to adopt one such system of identification that can trace all finished forgings to the original cast. The Surveyor is to be provided with adequate facilities for tracing the forgings, when required.

Apart from appropriate identification markings of the manufacturer, INTLREG markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations where it is easily discernible after machining and installation. In addition, Grade A1 through Grade A6 forgings are to be stamped IR/A1, IR/A2, IR/A3, IR/A4, IR/A5, and IR/A6, respectively.

6.2.2.2. Retests

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with Sec-1, [1.5] or Ch 1, Sec 2, [2.6.4]. Where satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. The forging or batch of forgings is to be rejected where one or both retests fail. The manufacturer may opt for reheat treatment for those forgings which have failed to meet test requirements, in accordance with [6.2.3.7] below. After reheat-treating, the forgings are to be submitted for all mechanical testing.

6.2.2.3. Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

6.2.3. Heat treatment

6.2.3.1. General

Heat treatment facilities used in producing INTLREG certified forgings are to be included in the forge approval; including subcontracted hear treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Forge qualification is to include all of the heat treatment facilities that the forge will used. Heat treatment details are to be included in the approval documentation.

If additional facilities are selected to carry out heat treatment an INTLREG qualification is to be obtained to include any new facility.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of 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 can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces, which have efficiently maintained adequate means to control and record temperature. The furnace dimensions must be such ensure that the entire furnace charge is heated uniformly to the requisite temperature. In the case of very large forgings, special consideration is given to alternative methods of heat treatment. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated. Where a forging is reheated locally or any straightening operation is carried out after the final heat treatment, a subsequent stress relieving heat treatment is to be considered.

The forge must keep records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, along with the number and location of thermocouples. The records are to be made available to the Surveyor on request.

The required heat treatment for each forging grade is given in Table 2.6.4.

Table 2.6.4: Required heat treatment and minimum tempering temperature

Grade	Heat treatment	Temperature, in °C (°F)
A1	Quench + Temper	620 (1150)
A2	Quench + Temper	580 (1075)
A3	Quench + Temper	580 (1075)
A4	Quench + Temper	565 (1050)
A5	Quench + Temper	565 (1050)
A6	Quench + Temper	565 (1050)

Alternative heat treatment procedures may be specially approved with due consideration given to the section thickness and the intended function of the forged component. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

6.2.3.2. Cooling prior to heat treatment

After forging and before reheating for heat treatment, the forgings are allowed to cool down in a manner to prevent injury and to carry out transformation.

6.2.3.3. Annealing

The forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time that can cause the desired transformation and then be allowed to cool down gradually and evenly in the furnace until the temperature has reduced to about 455°C (850°F) or lower.

6.2.3.4. Normalizing

The forgings are to be reheated to and kept at proper temperature above the transformation range for a sufficient time in order to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air.

6.2.3.5. Tempering

The forgings are to be reheated to and held at proper temperature, which is to be below the transformation range but above the minimum temperature in [6.2.3.1], and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until a temperature below 315°C (600°F) is reached.

6.2.3.6. Stress relieving

Where heat treatment for mechanical properties is carried out before final machining, the forgings are to be stress relieved after machining at a temperature 28°C (50°F) to 55°C (100°F) below the previous tempering temperature, but in no case less than 540°C (1000°F). The cooling rate is not to exceed 55°C (100°F) per hour until temperature below 315°C (600°F) is reached.

6.2.3.7. Retreatment

The manufacturer may opt for re-heat treatment of the forging, but not be more than three additional times.

6.2.4. Mechanical properties

6.2.4.1. Tensile properties

The tensile properties of the forging are to be in compliance with the requirements of Table 2.6.5.

Table 2.6.5: Tensile property requirements for Alloy Steel Gear Assembly Forgings

Grade	Diameter, in mm (in)	Tensile Strength, in N/mm^2 (kgf/mm^2, ksi)	Yield Strength,(2) in N/mm^2 (kgf/mm^2, ksi)	Longitudinal			Tangential		
				Elongation(3) in %, Gauge Length		RA, in percent	Elongation(3), in %, Gauge Length		RA, in percent
				4d	5d		4d	5d	
A1	≤ 255 (10)	655 (67, 95)	485 (49, 70)	20	18	45	18	16	35
	> 255 (10) ≤ 510 (20)	655 (67, 95)	485 (49, 70)	20	18	45	19	16	34
	> 510 (20)	655 (67, 95)	485 (49, 70)	18	16	38	16	15	30
A2	≤ 255 (10)	725 (74, 105)	550 (56, 80)	19	17	45	17	16	34
	> 255 (10) ≤ 510 (20)	725 (74, 105)	550 (56, 80)	19	17	45	16	15	32
	> 510 (20)	725 (74, 105)	550 (56, 80)	18	16	38	14	13	30
A3	≤ 255 (10)	825 (84, 120)	655 (67, 95)	16	15	40	13	12	32
	> 255 (10) ≤ 510 (20)	825 (84, 120)	655 (67, 95)	14	13	35	12	11	30
	> 510 (20)	795 (81, 115)	620 (63, 90)	13	12	33	10	9	25
A4	≤ 255 (10)	965 (98, 140)	795 (81, 115)	16	15	40	14	13	35
	> 255 (10) ≤ 510 (20)	930 (95, 135)	760 (77, 110)	14	13	35	12	11	30
	> 510 (20)	895 (91, 130)	725 (74, 105)	12	11	30	10	9	25

A5	≤ 255 (10)	1000 (102, 145)	825 (84, 120)	15	14	40	13	12	35
	> 255 (10) ≤ 510 (20)	965 (98, 140)	795 (81, 115)	14	13	35	12	11	30
	> 510 (20)	930 (95, 135)	760 (77, 110)	12	11	30	10	9	25
A6	≤ 255 (10)	1170 (120,70)	965 (98, 140)	14	13	35	12	11	30
	> 255 (10) ≤ 510 (20)	1140 (116, 165)	930 (95, 135)	12	11	30	10	9	25
	> 510 (20)	105 (112, 160)	895 (91, 130)	10	9	25	10	9	25

Notes:
1. All tensile property requirements are minimum, unless indicated.
2. Yield strength is determined by the 0.2% offset method.
3. Elongation gauge length is 50 mm (2 in.) Refer Sec 1, Figure 2.1.2.
4. RA = Reduction of Area

6.2.4.2. Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs.), is to undergo hardness test to meet the following requirements. The variation in hardness of Grade A11 forgings is not to exceed 30 Brinell Hardness numbers.

INTLREG Grade	Hardness, BHN, (10 mm dia. ball, 3000 kg load)
A7	201 to 241
A8	223 to 262
A9	248 to 293
A10	285 to 331

6.2.5. Test specimens

6.2.5.1. Location and orientation of specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or tangential to that direction, as indicated by the ductility requirements in Table 2.6.5. The axes of the longitudinal specimens are to be located at any point 32 mm (1.25 in) below the surface of the forging. The axes of the tangential specimens are to be located as near to the surface of the forging as practicable. In the cases of reduction gear ring forgings, reduction gear pinions and gear forgings, and reduction gear shaft forgings, the test specimen location and orientation are specified in [6.2.5.3] (d), (e) & (f), respectively.

6.2.5.2. Identification of specimens

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/ tank (for Q & T forgings).

The test specimens are not to be removed from the forgings before completion of the final heat treatment of the forgings and stamping of the test specimens by the Surveyor for identification purpose. Where the material identification system of the manufacturer is found acceptable to INTLREG and is maintained in that condition through initial and periodical verification by INTLREG, material identification system of the manufacture may be considered in lieu of stamping by the Surveyor before detachment.

6.2.5.3. Tension tests

a) *Large forgings*: In the case of large forgings with rough machined weights of 3180 kg (7000 lb.) or over, one tension test is to be taken from each end of the forging. For ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

b) *Intermediate-sized forgings*: At least one tension test is to be taken from each forging, in the case of forgings with rough machined weights less than 3180 kg. (7000 lb.), except as noted in the following paragraph.

c) *Small forgings*: In small normalized forgings with rough machined weights less than 1000 kg (2200 lb.) and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb.), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb.) for normalized forgings and 3000 kg (6600 lb.) for quenched and tempered forgings.

d) *Sleeves, Couplings and Nut Forgings*. In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

6.2.5.4. Hardness

a) *Large, intermediate and small sized forgings*: Each forging except those with rough machined weights of less than 113 kg (250 lbs.) is to be hardness tested to meet the requirements of [6.2.4.2]. The forging is to be tested at locations 180 degrees apart on each end.

b) *Sleeves, Couplings and Nut Forgings*: In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, Brinell hardness tests are to be taken at approximately 1/4 of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

Outside diameter, cm.(in)	Number of hardness tests
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart

6.2.6. Examination

After final heat treatment, all forgings are to be examined in accordance with [6.1.9] of this section by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications.

6.2.6.1 Surface Inspection of Tail Shaft Forgings
All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor.

6.2.6.2 Ultrasonic Examination of Tail Shaft Forgings
Forgings for tail shafts 455 mm (18 in) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor.

6.2.7. Rectification of defective forgings

Rectification of defects is to be carried out in accordance with [6.1.10] of this section.

6.2.8. Certification

The manufacturer is to provide the required type of inspection certificate, in accordance with [6.1.11] of this section.

6.3. Alloy Steel Shaft and Stock Forgings

6.3.1. Process of manufacture

6.3.1.1. General

The following requirements cover shaft and stock alloy steel forgings intended to be used mainly for propulsion units and stock type applications. Typical components include tail shafts, intermediate shafts, thrust shafts, other torsional shafts, sleeves, couplings, propeller nuts, rudder stocks and canard stocks, used in shipboard units. The steel is to be fully killed and is to be manufactured by a process approved by INTLREG. Alternatively, forgings which are in compliance with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by any INTLREG-approved manufacturer. INTLREG approval validity is for 5 years subject to annual verification and/or endorsement by the attending Surveyor. At any time, the Surveyor is permitted to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

The shaping of forgings or rolled slabs and billets by thermal 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 where it is necessary based on the composition and/or thickness of the steel. Subsequent machining of all thermal cut surfaces may be required for certain components.

When two or more forgings are welded to form a composite component, the proposed welding procedure specification is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. Calculation of the reduction ratio must be with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

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

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

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

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation.

6.3.1.2. ASTM designations

The grades are in accordance with ASTM, as follows:

INTLREG Grade	**ASTM designation**
A7	A470 Class 2
A8	A470 Class 4
A9	A470 Class 6
A10	A470 Class 7

6.3.1.3. Chemical composition

All forgings are to be made of killed steel. An analysis of each heat is to be carried out to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of Table 2.6.6. The analysis is to be carried out with a coupon cast during the pouring of the heat.

Table 2.6.6: Chemical composition requirements for Alloy Steel Shaft and Stock Forgings, in %

Element	Grade A7	Grade A8	Grades A9 and A10
Carbon	0.25	0.28	0.28
Manganese	0.20 to 0.60	0.20 to 0.60	0.20 to 0.60
Silicon	0.15 to 0.30 (2)	0.15 to 0.30 (2)	0.10 (3)
Sulfur	0.015	0.015	0.015
Phosphorus	0.012	0.012	0.012
Nickel	2.50 min.	2.50 min.	3.25 to 4.00
Chromium	0.75	0.75	1.25 to 2.00
Molybdenum	0.25 min.	0.25 min.	0.25 to 0.60
Vanadium	0.03 min.	0.03 min.	0.05 to 0.15
Antimony	Refer Note 4	Refer Note 4	Refer Note 4

Notes:
1. Single values are maxima, unless noted.
2. If the steel is vacuum-carbon deoxidized, the silicon content is to be 0.10 maximum.
3. If the steel is vacuum arc re melted, the silicon content range may be 0.15% to 0.30%.
4. The antimony content is to be reported for information.

6.3.1.4. Product analysis

The forgings are to be subjected to a product chemical analysis and meet the requirements of Table 2.6.6, as modified by the product variation requirements specified in A778, General Requirements for Steel Forgings.

6.3.2. Marking, retests and rejection

6.3.2.1. Marking

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 provided with adequate facilities for tracing the forgings, when required.

Apart from appropriate identification markings of the manufacturer, INTLREG markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all forgings in such locations where it is easily noticeable after machining and installation. In addition, Grade A7 through Grade A10 forgings are to be stamped IR/A7, IR/A8, IR/A9 and IR/A10, respectively.

6.3.2.2. Retests

Adequate test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging. If the results of the mechanical tests for any forging or any lot of forgings do not conform to the requirements specified, two additional test samples representative of the forging or forging batch may be taken in accordance with Sec-1, [1.5] or Ch 1, Sec 2, [2.6.4]. If satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with [6.3.3.6] below. After reheat-treating, the forgings are to be submitted for all mechanical testi[ng.

6.3.2.3. Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

6.3.3. Heat treatment

6.3.3.1. General

Heat treatment facilities used in producing INTLREG certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

If additional facilities are selected to carry out heat treatment an INTLREG qualification is to be obtained to include any new facility.

The INTLREG Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of 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 can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record 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. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated. 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.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

The required heat treatment for each forging grade is as per Table 2.6.7.

Table 2.6.7: Required heat treatment and minimum tempering temperature

Grade	Heat treatment	Temperature, in °C (°F)
A7	Double Normalize + Temper	580 (1075)
A8	Double Normalize + Temper	580 (1075)
A9	Normalize, Quench + Temper	580 (1075)
A10	Normalize, Quench + Temper	580 (1075)

Unless a departure from the following procedure is specifically approved, Grade A11 forgings are o be normalized and tempered, or normalized, quenched and tempered. Grade A12, A13, A14 and A15 forgings are to be normalized, quenched and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

6.3.3.2. Cooling prior to heat treatment

Forgings are allowed to cool in a manner to prevent injury and to accomplish transformation, after forgings and before reheating for heat treatment.

6.3.3.3. Annealing

Forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to affect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C Normalizing (850°F) or lower.

6.3.3.4. Normalizing

Forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to affect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use with Grade A7 and A8 forgings to achieve more rapid cooling. The faster cooling rates are to be agreed to by the purchaser.

6.3.3.5. Tempering

Forgings are to be reheated to and held at the proper temperature, which is to be below the transformation range but above the minimum temperature in [6.3.3.1] above, and are then to be cooled at a rate not exceeding 100°F (55°C) per hour until a temperature below 315°C (600°F) is reached.

6.3.3.6. Retreatment

The manufacturer may re-heat treat the forging, but not more than three additional times.

6.3.4. Mechanical properties

6.3.4.1. Tensile properties

The tensile properties of the forging are to conform to the requirements of Table 2.6.8 and Table 2.6.10

Table 2.6.8: Tensile property requirements for Alloy Steel Shaft and Stock Forgings

Grade	Tensile Strength, in N/mm^2 (kgf/mm^2, ksi)	Yield Strength,(2) in N/mm^2 (kgf/mm^2, ksi)	Yield Strength, (3) in N/mm^2 (kgf/mm^2, ksi)	Longitudinal			Radial		
				Elongation (4), in %		RA,(5) in %	Elongation (4), in %		RA,(5) in %
				Gauge Length			Gauge Length		
				4d	5d		4d	5d	
A7	550 (56, 80)	415 (42, 60)	380 (39, 55)	22	20	50	20	18	50
A8	725 (74, 105)	620 (63, 90)	585 (60, 85)	17	16	45	16	15	40
A9	725 (74, 105) to 860 (88, 125)	620 (63, 90)	585 (60, 85)	18	16	52	17	16	50
A10	825 (84, 120) to 930 (95, 135)	690 (70, 100)	655 (67, 95)	18	16	52	17	16	50

Notes:
1. All tensile property requirements are minimum, unless indicated.
2. Yield strength is determined by the 0.2% offset method.
3. Yield strength is determined by the 0.02% offset method.
4. Elongation gauge length is 50 mm (2 in.); Refer Sec 1, Figure 2.1.2.
5. RA = Reduction of Area

Table 2.6.10: Tensile property requirements for General Shipboard Alloy Steel Forgings

Grade	Size, in mm (in)	Tensile Strength, in N/mm² (kgf/mm², ksi)	Yield Strength(2), in N/mm² (kgf/mm², ksi)	Longitudinal Elongation, (3) in % Gauge Length 4d	Longitudinal Elongation, (3) in % Gauge Length 5d	Longitudinal RA, in %(4)	Tangential Elongation, (3) in % Gauge Length 4d	Tangential Elongation, (3) in % Gauge Length 5d	Tangential RA, in %
A11	≤ 180 (7)	655 (67, 95)	485 (49, 70)	20	18	50	18	16	40
	> 180 (7) ≤ 255 (10)	620 (63, 90)	450 (46, 65)	20	18	50	18	16	40
	> 255 (10) ≤ 510 (20)	620 (63, 90)	450 (46, 65)	18	16	48	16	15	40
A12	≤ 180 (7)	725 (74, 105)	550 (56, 80)	20	18	50	18	16	40
	> 180 (7) ≤ 255 (10)	690 (70, 100)	515 (53, 75)	19	17	50	17	16	40
	> 255 (10) ≤ 510 (20)	690 (70, 100)	515 (53, 75)	18	16	48	16	15	40
A13	≤ 100 (4)	860 (88, 125)	725 (74, 105)	16	15	50	14	13	40
	> 100 (4) ≤ 180 (7)	795 (81, 115)	655 (67, 95)	16	15	45	14	13	35
	> 180 (7) ≤ 255 (10)	760 (77, 110)	585 (60, 85)	16	15	45	14	13	35
	> 255 (10) ≤ 510 (20)	760 (77, 110)	585 (60, 85)	14	13	40	12	11	30
A14	≤ 100 (4)	1000 (102, 145)	825 (84, 120)	15	14	45	13	12	35
	> 100 (4) ≤ 180 (7)	965 (98, 140)	795 (81, 115)	14	13	40	12	11	30
	> 180 (7) ≤ 255 (10)	930 (95, 135)	760 (77, 110)	13	12	40	12	11	30
	> 255 (10) ≤ 510 (20)	930 (95, 135)	760 (77, 110)	12	11	38	11	10	30
A15	≤ 100 (4)	1170 (120, 170)	965 (98, 140)	13	12	40	11	10	30
	> 100 (4) ≤ 180 (7)	1140 (116, 165)	930 (95, 135)	12	11	35	11	10	30
	> 180 (7) ≤ 255 (10)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28
	> 255 (10) ≤ 510 (20)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28

Notes:
1. All tensile property requirements are minima, unless indicated.
2. Yield strength is determined by the 0.2% offset method.
3. Elongation gauge length is 50 mm (2 in.); Refer Sec 1, Figure 2.1.2.
4. RA = Reduction of Area

6.3.4.2. Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs.), is to be hardness tested to meet the following requirements. The variation in hardness of Grade A11 forgings is not to exceed 40 Brinell Hardness numbers. The variation in hardness of Grades A12 forgings through A15 forgings is not to exceed 50 Brinell Hardness numbers.

INTLREG Grade	Size in mm (in.)	Hardness, BHN (10mm dia. Ball 3000 kg load)
A11	≤ 180(7)	197 to 255
	>180 (7) ≤ 255(10)	187 to 235
	>255 (10) ≤ 510(20)	187 to 255
A12	≤ 180(7)	212 to 269
	>180 (7) ≤ 510(20)	207 to 269
A13	≤ 100(4)	255 to 321
	>100 (4) ≤ 180(7)	235 to 302
	>180 (7) ≤ 510(20)	223 to 293
A14	≤ 100(4)	293 to 352
	>100 (4) ≤ 180(7)	285 to 341
	>180 (7) ≤ 255(10)	269 to 331
	>255 (10) ≤ 510(20)	269 to 341
A15	≤ 180(7)	331 to 401
	>180 (7) ≤ 255(10)	321 to 388
	>255 (10) ≤ 510(20)	321 to 402

6.3.5. Test specimens

6.3.5.1. Location and orientation of specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or may be taken in a radial direction, as indicated by the ductility requirements in Table 2.6.5. The axes of the specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings. In the cases of sleeves, couplings and nut forgings, the test specimen location and orientation are specified in [6.3.5.3] (d).

6.3.5.2. Identification of specimens

Forgings and test material are to be heat treated together in the same furnace, and quenched in the same bath/ tank (for Q&T forgings)

The test specimens are not to be detached from the forgings before completion of the final heat treatment of the forgings and stamping of the test specimens by the Surveyor for identification purpose. Where the material identification system of the manufacturer is found acceptable to INTLREG and is maintained in that condition through initial and periodical verification by INTLREG, it may be considered in lieu of stamping by the Surveyor before detachment.

6.3.5.3. Tension tests

a) *Large forgings*: In the case of large forgings with rough machined weights of 3180 kg (7000 lb.) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

b) *Intermediate-sized forgings*: In the case of forgings with rough machined weights less than 3180 kg. (7000 lb.), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

c) *Small forgings*: In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb.) and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb.), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb.) for normalized forgings and 3000 kg (6600 lb.) for quenched and tempered forgings.

d) *Sleeves, couplings and nut forgings*: In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

6.3.5.4. Hardness

a) *Large, intermediate and small sized forgings*: Each forging, except those with rough machined weights of less than 113 kg (250 lbs.), is to be hardness tested to meet the requirements of [6.3.4.2] above. The forging is to be tested at locations 180 degrees apart on each end.
b) *Sleeves, couplings and nut forgings*: In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, Brinell hardness tests are to be taken at approximately ¼ of the radial thickness from the outside diameter and in accordance with the following frequency and locations:

Outside diameter, cm.(in)	**Number of hardness tests**
To 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart

6.3.6. Examination

All forgings are to be examined after final heat treatment, in accordance with [6.1.9] of this section, by the Surveyor and found free from defects. The finish is to be free of cracks, seams, laps, cold shuts, laminations, shrinkage and burst indications.

6.3.6.1. Surface inspection of tail shaft forgings

All tail shaft forgings are to be subjected to a nondestructive examination such as magnetic particle, dye penetrant or other nondestructive method. Discontinuities are to be removed to the satisfaction of the Surveyor. Refer Pt 5A,Ch 4,Sect 5[5.2] for surface inspection requirements in finished machined condition.).

6.3.6.2. Ultrasonic examination of tail shaft forgings

Forgings for tail shafts 455 mm (18 in) and over in finished diameter are to be ultrasonically examined to the satisfaction of the attending Surveyor.

6.3.7. Rectification of defective forgings

Rectification of defects is to be carried out in accordance with [6.1.10] of this section.

6.3.8. Certification

The manufacturer is to furnish the required type of inspection certificate, in accordance with [6.1.11] of this section.

6.4. General shipboard alloy steel forgings

6.4.1. Process of manufacture

6.4.1.1. General

The following requirements cover alloy steel forgings intended to be used for general shipboard applications. The steel is to be fully killed and is to be manufactured by a process approved by INTLREG. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Forgings are to be made by a manufacturer approved by INTLREG.

INTLREG approval validity is for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection. 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. Subsequent machining of all flame cut surfaces may be required for certain components.

When two or more forgings are welded to form a composite component, details of the proposed welding procedure is to be submitted for approval.

The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio calculation must be with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

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

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

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

A sufficient discard is to be made from each ingot to secure freedom from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging.

6.4.1.2. ASTM designations

The grades are in accordance with ASTM, as follows:

INTLREG Grade	ASTM designation
A11	A668 Class J
A12	A668 Class K

A13	A668 Class L
A14	A668 Class M
A15	A668 Class N

6.4.1.3. Chemical composition

All forgings are to be made of killed steel. An analysis of each heat is to be made to determine the percentages of the elements specified. The chemical composition thus determined is to be reported to the Surveyor and is to conform to the requirements of Table 2.6.9. The analysis has to be carried out with a coupon cast during the pouring of the heat.

Table 2.6.9: Chemical composition requirements for General Shipboard Alloy Steel Forgings, in %

Element	**Grades A11, A12, A13, A14 and A15**
Carbon	Refer Note 2
Manganese	Refer Note 2
Silicon (3)	0.10 min.
Sulfur	0.040
Phosphorus	0.040
Nickel	Refer Note 2
Chromium	Refer Note 2
Molybdenum	Refer Note 2
Copper	Refer Note 2
Vanadium	Refer Note 2

Notes:
1. Single values are maximum, unless noted.
2. The indicate contents are to be reported.
3. Silicon minimum is applicable if the steel is silicon killed.

6.4.2. Marking, Retests and Rejection

6.4.2.1. Marking

The manufacturer is to adopt a system of identification which can trace all finished forgings to the original cast and the Surveyor is to be given full facilities for tracing the forgings, when required.

In addition to appropriate identification markings of the manufacturer, INTLREG markings, indicating satisfactory compliance with the Rule requirements and as furnished by the Surveyor, are to be stamped on all forgings in such locations as to be noticeable after machining and installation. In addition, Grade A11 through Grade A15 forgings are to be stamped IR/A11, IR/A12, IR/A13, IR/A14 and IR/A15, respectively.

6.4.2.2. Retests

Sufficient number of test material must be provided for each forging in order to conduct the required number of tests and possible retests. If the results of the mechanical tests for any forging or any lot of forgings do not comply with the specified requirements, then two additional test samples representative of the forging or forging batch may be taken in accordance with Sec 1, [1.5] or Ch 1, Sec 2, [2.6.4]. The forging or batch of forgings is acceptable when satisfactory results are obtained from both of the additional tests. The forging or batch of forgings is to be rejected when one or both retests fail. The manufacturer may reheat-treat forgings that have failed to meet test requirements, in accordance with [6.4.3.6] below. After reheat-treating, the forgings are to be submitted for all mechanical testing.

6.4.2.3. Rejection

Any forging having injurious discontinuities that are observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

6.4.3. Heat treatment

6.4.3.1. General

Heat treatment facilities used in producing INTLREG certified forgings are to be included in the forge approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

Heat treatment details are to be included in the approval documentation.

If additional facilities are selected to carry out heat treatment an INTLREG qualification is to be obtained to include any new facility.

The INTLREG Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of 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 can be verified at regular intervals.

Heat treatment is to be carried out in well-built furnaces which are efficiently maintained and have suitable means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the required temperature. For very large forgings, alternative methods of heat treatment will be specially considered. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated. Where a forging is reheated locally or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, along with the number and location of thermocouples. The records are to be made available to the Surveyor upon request.

Unless a deviation from the following procedures is specifically approved, Grade A11 forgings are to be normalized and tempered, or normalized, quenched and tempered. Grades A12, A13, A14 and A15 forgings are to be normalized, quenched and tempered. The furnace is to be of ample proportions to bring the forgings to a uniform temperature.

6.4.3.2. Cooling prior to heat treatment

After forging and before reheating for heat treatment, forgings are allowed to cool in a manner to prevent injury and to accomplish transformation.

6.4.3.3. Annealing

Forgings are to be reheated to and held at the proper austenitizing temperature for a sufficient time to affect the desired transformation and then be allowed to cool slowly and evenly in the furnace until the temperature has fallen to about 455°C (850°F) or lower.

6.4.3.4. Normalizing

Forgings are to be reheated to and held at the proper temperature above the transformation range for a sufficient time to effect the desired transformation and then withdrawn from the furnace and allowed to cool in air. Water sprays and air blasts may be specially approved for use to achieve more rapid cooling. The faster cooling rates are to be agreed by the purchaser.

6.4.3.5. Tempering

Forgings are to be reheated to and held at the proper temperature, which will be below the transformation range, and are then to be cooled under suitable conditions to 315°C (600°F) or lower.

6.4.3.6. Retreatment

The manufacturer may re-heat-treat the forging, but not more than three additional times.

6.4.4. Mechanical properties

6.4.4.1. Tensile properties

The tensile properties of the forging are to conform to the requirements of Table 2.6.10.

Table 2.6.10: Tensile property requirements for General Shipboard Alloy Steel Forgings

Grade	**Size, in mm (in)**	**Tensile Strength,** in N/mm² (kgf/mm², ksi)	**Yield Strength(2),** in N/mm² (kgf/mm², ksi)	**Longitudinal**			**Tangential**		
				Elongation, (3) in %		**RA, in %(4)**	**Elongation**, (3) in %		**RA, in %(4)**
				Gauge Length			**Gauge Length**		
				4d	**5d**		**4d**	**5d**	
A11	≤ 180 (7)	655 (67, 95)	485 (49, 70)	20	18	50	18	16	40
	> 180 (7) ≤ 255 (10)	620 (63, 90)	450 (46, 65)	20	18	50	18	16	40
	> 255 (10) ≤ 510 (20)	620 (63, 90)	450 (46, 65)	18	16	48	16	15	40
A12	≤ 180 (7)	725 (74, 105)	550 (56, 80)	20	18	50	18	16	40
	> 180 (7)	690 (70, 100)	515 (53, 75)	19	17	50	17	16	40

	≤ 255 (10)								
	> 255 (10) ≤ 510 (20)	690 (70, 100)	515 (53, 75)	18	16	48	16	15	40
A13	≤ 100 (4)	860 (88, 125)	725 (74, 105)	16	15	50	14	13	40
	> 100 (4) ≤ 180 (7)	795 (81, 115)	655 (67, 95)	16	15	45	14	13	35
	> 180 (7) ≤ 255 (10)	760 (77, 110)	585 (60, 85)	16	15	45	14	13	35
	> 255 (10) ≤ 510 (20)	760 (77, 110)	585 (60, 85)	14	13	40	12	11	30
A14	≤ 100 (4)	1000 (102, 145)	825 (84, 120)	15	14	45	13	12	35
	> 100 (4) ≤ 180 (7)	965 (98, 140)	795 (81, 115)	14	13	40	12	11	30
	> 180 (7) ≤ 255 (10)	930 (95, 135)	760 (77, 110)	13	12	40	12	11	30
	> 255 (10) ≤ 510 (20)	930 (95, 135)	760 (77, 110)	12	11	38	11	10	30
A15	≤ 100 (4)	1170 (120, 170)	965 (98, 140)	13	12	40	11	10	30
	> 100 (4) ≤ 180 (7)	1140 (116, 165)	930 (95, 135)	12	11	35	11	10	30
	> 180 (7) ≤ 255 (10)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28
	> 255 (10) ≤ 510 (20)	1105 (112, 160)	895 (91, 130)	11	10	35	10	9	28

Notes:
1. All tensile property requirements are minima, unless indicated.
2. Yield strength is determined by the 0.2% offset method.
3. Elongation gauge length is 50 mm (2 in.); Refer Sec 1, Figure 2.1.2.
4. RA = Reduction of Area

6.4.4.2. Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lbs.), is to be hardness tested to meet the following requirements. The variation in hardness of Grade A11 forgings is not to exceed 40 Brinell Hardness Numbers. The variation in hardness of Grades A12 forgings through A15 forgings is not to exceed 50 Brinell Hardness Numbers.

Table 2.6.11.

INTLREG Grade	Size, in mm (in.)	Hardness, BHN, (10 mm dia. ball, 3000 kg load)
A11	≤ 180 (7) > 180 (7), ≤ 255 (10) > 255 (10), ≤ 510 (20)	197 to 255 187 to 235 187 to 255
A12	≤ 180 (7) > 180 (7), ≤ 510 (20)	212 to 269 207 to 269
A13	≤ 100 (4) > 100 (4), ≤ 180 (7) > 180 (7), ≤ 510 (20)	255 to 321 235 to 302 223 to 293
A14	≤ 100 (4) > 100 (4), ≤ 180 (7) > 180 (7), ≤ 255 (10) > 255 (10), ≤ 510 (20)	293 to 352 285 to 341 269 to 331 269 to 341
A15	≤ 180 (7) > 180 (7), ≤ 255 (10) > 255 (10), ≤ 510 (20)	331 to 401 321 to 388 321 to 402

6.4.5. Mechanical testing

6.4.5.1. Location and orientation of specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The length of the prolongation is to be such that the distance from the test specimen mid-gauge to the end of the prolongation is to be 89 mm (3.5 in) or one-half the forging section thickness or diameter, whichever is less. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out or tangential to that direction, as indicated by the ductility requirements in Table 2.6.10. The axes of the specimens are to be located at any point midway between the center and the surface of the solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings.

6.4.5.2. Hollow-drilled specimens

In lieu of prolongations, the test specimens may be taken from forgings submitted for each test lot; or if satisfactory to the Surveyor, test specimens may be taken from forgings with a hollow drill.

6.4.5.3. Very small forgings

In the cases of very small forgings weighing less than 113 kg (250 lb.) each, where the foregoing procedures are impractical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings should be subjected to the same amount of working and reduction as the forgings represented and should be heat-treated with those forgings.

6.4.5.4. Identification of specimens

The test specimens are not to be detached from the forgings before the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is acceptable to INTLREG and is maintained in that condition throughout initial and periodical verification by INTLREG, it may be considered in lieu of stamping by the Surveyor before detachment.

6.4.6. Number and location of tests

6.4.6.1. Tension tests

a) *Large forgings*: In the case of large forgings with rough machined weights of 3180 kg (7000 lb.) or over, one tension test is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.

b) *Intermediate-sized forgings*: In the case of forgings with rough machined weights less than 3180 kg. (7000 lb.), except as noted in the following paragraph, at least one tension test is to be taken from each forging.

c) *Small forgings*: In the case of small normalized forgings with rough machined weights less than 1000 kg (2200 lb.) and quenched and tempered forgings with rough machined weights less than 500 kg (1100 lb.), one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The maximum lot size for testing purposes is 25 forgings and the total mass of the furnace charge is not to exceed 6000 kg (13200 lb.) for normalized forgings and 3000 kg (6600 lb.) for quenched and tempered forgings.

d) *Sleeves, couplings and nut forgings*: In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.

6.4.6.2. Hardness tests

a) *Large, intermediate and small sized forgings*: Each forging, except those with rough machined weights of less than 113 kg (250 lbs.), is to be hardness tested to meet the requirements of [6.4.4.2] above. Forgings are to be tested at locations 180 degrees apart on each end.

b) *Discs, rings and hollow forgings*: Each forging except, those with rough machined weights of less than 113 kg (250 lbs.), is to be hardness tested to meet the requirements of [6.4.4.2] above. Forgings are to be tested at the approximate mid-radius and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

c) *Very small forgings*: In cases involving very small forgings weighing less than 113 kg (250 lb.) each, where the foregoing procedures are impractical, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot; Refer [6.4.5.3] above.

6.4.7. Examination

All forgings are to be examined carefully after final heat treatment, in accordance with [6.1.9] of this section, by the Surveyor and found free from any form of defects. The finish is to be free of scale, cracks, seams, laps, fins, cold shuts, laminations, nicks, gouges, pipe, shrinkage, porosity and burst indications.

6.4.8. Rectification of defective forgings

Rectification of defects is to be carried out in accordance with [6.1.10] of this section.

6.4.9. Certification

The manufacturer is to provide the required type of inspection certificate, in accordance with [6.1.11] of this section.

SECTION 7 STEEL CASTINGS FOR MACHINERY, BOILERS AND PRESSURE VESSELS

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7.1. General

7.1.1. Process of manufacture

The following requirements mainly cover carbon-steel castings intended to be used in machinery, boiler and pressure-vessel construction, such as crankshafts, turbine casings and bedplates. Additional requirements may be necessary for other applications, especially when the castings are intended for service at low temperatures. Castings which conform to national or proprietary specifications may also be accepted, on condition that such specifications give reasonable equivalence to these requirements. None of the above excludes the use of alloy steels in compliance with the permissibility expressed in Sec-1, [1.1]. The steel is to be manufactured using an INTLREG approved procedure.

Castings are to be manufactured by any INTLREG approved manufacturer. INTLREG approval is valid for 5 years subject to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection. Thermal cutting, scarfing or arc-air gouging for removal of surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If required, the affected areas are to be either machined or ground smooth.

When two or more castings are welded to form a composite component, the proposed welding procedure is to be submitted for approval and welding is to be carried out to the satisfaction of the attending Surveyor.

Sulfur and phosphorous contents are to be less than 0.040% and silicon less than 0.60%. For welded construction, the maximum carbon content is to be 0.23%.

7.1.2. ASTM designations

The various Grades are in accordance with ASTM, as follows and, in addition, the requirements of this Section apply:

INTLREG Grade	ASTM designation
1	A27, Grade 60–30
2	A27, Grade 70–36
3	A216, Grade WCA
4	A216, Grade WCB

7.2. Marking and retests

7.2.1. Marking

The manufacturer is to adopt a system of identification which will enable trace all finished castings to the original cast and the Surveyor is to be given required facilities for tracing the castings when necessary.

All castings are to be marked with the manufacturer’s name or identification mark and pattern number, except those of small size as this type of marking is impracticable. The INTLREG markings, indicating satisfactory compliance with the

Rule requirements, and as furnished by the Surveyor is to be stamped on all castings accepted in such location as to be discernible after machining and installation. Grade 1, 2, 3 and 4 castings are to be stamped **IR/1**, **IR/2**, **IR/3** and **IR/4**, respectively. Moreover, identification numbers of the heats used for pouring the castings are to be stamped on all castings individually weighing 227 kg (500 lb.) or more.

7.2.2. Retests

For any casting or any lot of castings, if the results of the physical tests do not comply with the specified test requirements, then the manufacturer may reheat-treat the castings or lots of castings. Two additional test samples representative of the casting or casting batch may be taken. If results obtained from both of the additional tests are satisfactory, then the casting or batch of castings is acceptable. Where one or both retests fail, the casting or batch of castings is to be rejected.

7.3. Heat treatment

Heat treatment facilities used in producing INTLREG certified castings are to be included in the foundry approval; this includes subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of foundry approval.

Foundry qualification is to include all of the heat treatment facilities that the foundry will use.

Heat treatment details are to be included in the approval documentation.

If additional facilities are selected to carry out heat treatment an INTLREG qualification is to be obtained to include any new facility.

The INTLREG Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

All castings are to be either fully annealed, normalized or normalized and tempered in a furnace of ample proportions, except in cases specially approved otherwise, in order to bring the whole casting to uniform temperature above the transformation range on the annealing or normalizing cycle. The furnaces are to be well-maintained and have appropriate means to control and record temperature. Castings are to be held soaking at the apt temperature for at least a length of time equivalent to one hour per 25.5 mm (1 in.) of thickness of the heaviest member. Removal of no annealed casting is to be done from the furnace until the temperature of the entire furnace charge has fallen to a temperature of 455°C (850°F) or below. A sufficient number of 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 can be verified at regular intervals. Tempering is to be carried out at a temperature of not less than 550°C (1022°F).

Local heating or cooling and bending and straightening of annealed castings are not permitted, except in some special cases with the express sanction of the Surveyor.

The foundry is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, along with the number and location of thermocouples. The records are to be made available to the Surveyor as and when required.

7.4. Tensile properties

Tensile properties of the steel castings are to comply with the following requirements:

Table 2.7.1: Tensile Properties

INTLREG Grade	**Tensile Strength**, Min., N/mm^2 (kgf/mm^2, psi)	**Yield Point / Yield Strength**, Min., N/mm^2 (kgf/mm^2, psi)	**Elongation** Min., % Gauge Length		**Reduction of Area** Min%
			4d	*5d*	
1	415 (42, 60000)	205 (21.0, 30000)	24	22	35
2	485 (49, 70000)	250 (25.5, 36000)	22	20	30
3	415 (42, 60000)	205 (21.0, 30000)	24	22	35
4	485 (49, 70000)	250 (25.5, 36000)	22	20	35

7.5. Application

7.5.1. General and high-temperature applications

For miscellaneous applications, any of the above grades may be used. Grade 3 or Grade 4 castings are to be used for boiler mountings, valves, fittings and for pressure parts of boilers and other pressure vessels where the temperature does not surpass 427°C (800°F). Refer Pt 5A, Ch 8, Sec 2, [2.2.2.2].

7.5.2. Propeller and forging applications

For propellers and for castings, any of the above grades may be used which have been approved to take the place of forgings.

7.5.3. Alloy steels or special carbon steels

When alloy steels or carbon steels differing from the requirements of [7.4] are proposed for any purpose, the purchaser’s specification shall be submitted for approval in connection with the approval of the design for which the material is proposed. Specifications such as ASTM A356 or A217 Grades WC1, WC6, or WC9, or other steels suitable for the proposed service will be considered.

7.6. Test specimens

7.6.1. Material coupons
Castings and test material are to be heat treated together in the same furnace, and quenched in the same bath/ tank (for Q & T forgings).

Sufficient test material is to be provided for each casting for the required number of tests and possible retests. The physical properties are to be determined from test specimens prepared from coupons which, except as specified in [7.6.2] below, are to be cast integral with the casting to be inspected. When this is impracticable, the coupons may be cast with and gated to the casting and are to have a thickness of not less than the critical controlling cross section thickness of the casting or 30 mm (1.2 in.) whichever is greater. In any case, these coupons are not to be separated until the heat treatment of the castings is complete, nor until the coupons have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to INTLREG and is maintained in that condition through initial and periodical verification by INTLREG, it may be considered in lieu of stamping by the Surveyor before detachment.

Two test samples are to be provided in those cases where the casting finished mass is more than 10,000 kg (22,000 lb) or is of complex design. When large castings are made from two or more casts which are not from the same pour, two or more test samples are to be provided, corresponding to the number of casts involved. The samples are to be integrally cast at locations as widely separated as possible.

Note: Controlling cross section thickness si the diameter of the largest theoretical sphere which can be inscribed with the volume of the casting.

7.6.2. Separately cast coupons

For small castings having an estimated weight of less than 907 kg (2000 lb.), each of the coupons may be cast separately, provided the Surveyor is furnished an affidavit by the manufacturer stating that the separately cast coupons were cast from the same heat as the castings represented and that they were heat treated with the castings.

7.7. Number of tests

7.7.1. Machinery castings

From each heat in each heat-treatment charge, at least one tension test is to be made, except where two or more samples are required as indicated in [7.6.1] above. If the procedure used by the manufacturer for quality-control includes satisfactory automatic chart recording of temperature and time, then one tension test may be allowed from each heat for castings subject to the same heat-treating procedure followed, at the discretion of the attending Surveyor.

7.7.2. Steel propeller castings

From each blade of a built-up propeller, one tension test is to be made, and for solid propellers there is to be one tension test from each of two opposite blades when the propeller is over 2130 mm (7 ft) in diameter and one tension test from one of the blades when the diameter of the propeller is 2130 mm (7 ft) or smaller.

7.8. Inspection and repair

7.8.1. General

All castings are to be carefully examined by the Surveyor after final heat treatment and thorough cleaning to ensure that the castings do not have defects. Where applicable, internal surfaces are to be examined, surfaces are not to be hammered or peened or treated in any way which can obscure defects.

In case, a casting proving to be defective during subsequent machining or testing, it is to be rejected, notwithstanding any previous certification.

The manufacturer to verify and confirm that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer’s recorded dimensions.

When the relevant construction Rules require, castings undergo pressure test prior to final acceptance. These tests are to be carried out in the presence and to the satisfaction of the attending Surveyor.

7.8.2. Minor defects

When the cavity prepared for welding has a depth not greater than 20% of the actual wall thickness, defects are to be considered minor, but in no case greater than 25 mm (1 in.), and has no lineal dimension greater than four times the wall thickness nor greater than 150 mm (6 in.). Shallow grooves or depressions formed due to the removal of defects may be accepted, only if that they do not bring about any major reduction in the overall 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 Magnetic Particle Testing (MT) or Liquid Penetration Testing (PT). Repairs of minor defects where welding is needed are to be treated as weld repairs and repaired using an approved procedure. At critical locations, the minor defects are to be treated as and repaired in the same manner as major defects.

7.8.3. Major defects

Defects other than the minor ones and having dimensions greater than those given in [7.8.2] above may be repaired, with the Surveyor's approval, by following an approved welding procedure.

7.8.4. Welded repair

When it has been agreed that a casting can be repaired by welding, complete details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be furnished for approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending surveyor.

Prior to the repair welding of castings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work assigned to them.

In accordance with a recognized standard, removal of defects and weld repair are to be conducted. Refer Ch 5, Sec 5. The removal of defects is to be carried out to sound metal, and prior to welding, the excavation is to be investigated by suitable approved, nondestructive examination methods to confirm that the defect has been removed. In the case of repair of major defects, welding is not permitted on unheat-treated castings. Corrective welding is to be associated with the use of preheat.

7.8.5. Post weld-repair heat treatment

As indicated in [7.3] of this section, all welded repairs of defects are to be given a suitable post weld heat treatment, or subject to the prior agreement of the INTLREG materials department. Consideration may be given to the acceptance of a local stress relieving heat treatment at a temperature of not less than 550°C (1022°F). The heat treatment employed will be dependent on the chemical composition of the casting, the casting and repair weld dimensions, and the position of the repairs. The extent of weld repair is to be in accordance with Ch 1, Sec 6, [6.7].

After the 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 ultrasonic or radiography may also be required, depending on the dimensions and nature of the original defect. From all forms of nondestructive testing used, satisfactory results are to be achieved.

The manufacturer is to maintain records carrying full description of the extent and location of minor and major repairs made to each casting and details of weld procedures and heat treatments applied. These records are to be made accessible to the Surveyor and copies to be furnished on request.

7.8.6. Crankshaft castings

The foregoing provisions may not be valid in their entirety to repair crankshaft castings. For this purpose, the applicable procedures and extent of repairs will be specially considered. All castings for crankshafts are to be properly preheated before welding.

7.9. Nondestructive testing

When mandatory by the relevant construction Rules or by the approved procedure for welded components, proper nondestructive testing is also to be carried out prior to acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria is to be in accordance with INTLREG. Ch 5, Sec-5 is regarded as an example of an acceptable standard. Additional NDE is to be considered at chaplet locations and areas of expected defects.

7.10. Certification

The required type of inspection certificate shall be provided by the manufacturer providing the following particulars for each casting or batch of castings 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 nondestructive tests, where applicable
g) Details of heat treatment, including temperature and holding times
h) Where applicable, test pressure
i) Specification

SECTION 8 AUSTENITIC STAINLESS STEEL PROPELLER CASTINGS

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8.1. Process of manufacture and foundry approval

8.1.1. Process of manufacture

The following requirements include austenitic stainless steel castings which are intended to be used for propellers and propeller blades. The stainless steel is to be melted by the electric arc or electric induction process, or any other procedure as may be approved.

8.1.2. Foundry approval

Stainless steel propellers and propeller components, including Grade CF-3 and other grades, are to be cast by INTLREG-approved foundries. For this purpose, foundries are to demonstrate that the necessary facilities and skilled personnel are available with them and can ensure proper manufacture of propellers which will satisfy these Rules.

INTLREG approval is valid for 5 years and is subject to annual verification and/or endorsement by the attending Surveyor. At any point of time, the Surveyor is permitted to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

8.1.3. Scope of the approval test

The following aspects of manufacture are to be taken into account:

a) Casting types and sizes;
b) Material specifications;
c) Repair procedures;
d) Ladle capacities;
e) Manufacturing practices and procedures for: Melting and pouring, molding, heat treatment, welding repairs, hot and cold straightening, destructive and nondestructive testing methods and equipment, and chemical and metallographic capabilities.

Cast coupons of the propeller materials involved are to be tested to verify that their composition and mechanical properties comply with these Rules.

8.1.4. Quality control

Additional information like, the company's facilities and organization, particularly, those related to quality control, is required to be presented including certification in accordance with national or international organizations standards, such as ISO standards.

8.2. Inspection and repair

8.2.1. The entire surface of the finished propeller is to be visually examined. A liquid penetrant examination of critical areas is to be carried out. Additionally, all suspect areas should be examined by the liquid penetrant method. Until fitted on the vessel, suitable precautionary measures need to be taken to protect the surfaces of all propellers from the corrosive effects of industrial environments. All inspections and repairs are to be carried out to the satisfaction of the Surveyor.

8.3. Chemical composition

8.3.1. An analysis of each heat is to be carried out by the manufacturer from a test sample which is representative of the heat and is taken during the pouring of the heat. The chemical composition in % thus determined must conform to the requirements specified in Table 2.8.1 below.

Table 2.8.1: Chemical Composition

Composition	Percentage
Carbon max. (Refer Note)	0.03
Manganese max.	1.50
Silicon max.	2.00
Phosphorus max.	0.04
Sulfur max.	0.04
Chromium	17.0–21.0
Nickel	8.0–12.0
Note: A carbon content up to and including 0.0345% is considered to meet the 0.03 maximum requirement	

8.4. Tensile properties

The metal represented by the test specimens is to conform to the following minimum tensile properties.

Table 2.8.2: Tensile Properties

Grade	Tensile strength N/mm^2 (kgf/mm^2, psi)	Yield strength N/mm^2 (kgf/mm^2, psi)	Elongation in 50 mm (2 in.) %
CF-3	485 (49, 70,000)	205 (21, 30,000)	35

8.5. Tests and marking

8.5.1. Test specimens

The test-coupon casting from which the tension test specimen is machined is to be of an approved form. The tension test specimen is to be machined to the dimensions shown in Figure 2.1.2 in Sec 1. The test coupons may be cast either separately or integrally.

8.5.2. Separately cast coupons

Separately cast test coupons are to be poured from the same ladles of metal used to pour the castings, and into molds of the same material as used for the casting. Test coupons are to be heat treated with the castings represented. In cases where more than one ladle of metal is required for a casting, a test coupon is to be provided for each ladle. Satisfactory evidence is to be furnished to the Surveyor to identify the test coupons as representing the material to be tested.

8.5.3. Integral coupons

Integral test coupons are to be furnished as coupons attached to the hub or on the blade. Where possible, test bars attached on blades are to be located in an area between 0.5 to 0.6R, where R is the radius of the propeller. Test bars are not to be detached from the casting before the final heat treatment is over. Removal is to be by non-thermal means.

8.5.4. Number of tests

One tension test is to be made for each casting when integrally cast test coupons are provided. One tension test is to be made from each ladle when separately cast test coupons are provided. The test results are to conform to the requirements prescribed in [8.4] above.

8.5.5. Special compositions

It is recognized that other alloys have been developed and proven by tests and service experience to be satisfactory. When propeller materials not meeting the chemical compositions in [8.3] above are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

8.5.6. Marking

Each propeller or propeller blade is to be marked with the manufacturer's name and other relevant identification markings in one such location where they are easily noticeable after finishing and assembly. Grade CF-3 castings are to be stamped **IR/CF–3** which confirms satisfactory compliance with Rule requirements. Alloys produced to specifications other than those covered herein as per the permissibility expressed in [8.5.5] are to be stamped **IR/S**, and with the applicable specification number.

SECTION 9 GRAY-IRON CASTINGS

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9.1. Scope

9.1.1. Gray iron castings, as defined in the relevant construction rules, are to be manufactured and tested as per the requirements of this Section.

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

9.1.3. For castings which are small in size and are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of INTLREG.

9.2. Process of manufacture

9.2.1. Gray iron castings (for example, castings that are required to be certified per Pt 5A, Ch 2, Table 2.1.1 are to be made at INTLREG-approved foundries where the manufacturer has demonstrated to the satisfaction of INTLREG that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

INTLREG approval validity is for 5 years and is subject to annual verification and/or endorsement by the attending Surveyor. At any time, the Surveyor is permitted to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

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

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

9.3. Quality of castings

9.3.1. It is to be ensured that the castings are free from any surface or internal defects, which can prove to be detrimental to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved design.

9.4. Chemical composition

9.4.1. The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain mechanical properties specified for the castings. The chemical composition of ladle sample is to be reported to INTLREG.

9.5. Heat treatment

9.5.1. Except as required for [9.5.2], castings may be supplied in either the cast or heat-treated condition.

9.5.2. For specific applications such as, high temperature service or when dimensional stability is important, castings may require a suitable tempering or stress relieving heat treatment.

9.6. Mechanical tests

9.6.1. For each casting or batch of castings, sufficient test material is to be provided for the purpose of required tests and possible re-tests.

9.6.2. Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser, and are to be in the form of round bars 30 mm (1.2 in.) in diameter and of a suitable length. They are to be of cast iron from the same ladle as the castings in molds of the same type of material as the molds for the castings and are not to be stripped from the molds until the metal temperature is below 500°C (930°F). When two or more test samples are cast simultaneously in a single mold, the bars are to be at least 50 mm (2.0 in.) apart.

9.6.3. Integrally cast samples may be used when a casting is more than 20 mm (0.8 in.) thick and its mass exceeds 200 kg (440 lb.), subject to agreement between the manufacturer and the purchaser. The type and location of the sample are to be selected to provide approximately the same cooling conditions as for the casting it represents and also subject to agreement.

9.6.4. With the exception of [9.6.7], at least one test sample is to be cast with each batch.

9.6.5. With the exception of [9.6.6], a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed 2,000 kg (4,400 lbs.) of fettled castings and a single casting will constitute a batch if its mass is 2,000 kg (4,400 lbs) or more.

9.6.6. For large mass casting / continuous melting of the same grade, produced by continuous melting, the batch weight may be taken as the weight of casting produced in two hours of pouring. The pouring rate should not be accelerated beyond the capacity of the caster.

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

9.6.8. Suitable marking of all test samples is to be provided to ensure their proper identification with the castings which they represent.

9.6.9. Where castings are supplied in the heat-treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples, the sample shall be removed from the casting only after the heat treatment.

9.6.10. One tensile test specimen is to be prepared from each test sample. 30 mm (1.2 in.) diameter samples are to be machined to the dimensions given in Sec-1, Figure 2.1.3. Where test samples of other dimensions are specially required, the tensile test specimens are to be machined to agreed dimensions.

9.6.11. All tensile tests are to be conducted following test procedures in accordance with Section-1 of this chapter. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

9.7. Mechanical properties

9.7.1. Tensile strength

9.7.1.1. The tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. The value selected for the specified minimum tensile strength is not to be less than 200 N/mm^2 (29.0 ksi) but subject to any additional requirements of the relevant construction Rules. The fractured surfaces of all tensile test specimens are to be granular and gray in appearance.

9.7.1.2. In case the tensile test fails to meet the requirements, two more tests may be made from the same piece. If both of these additional tests are satisfactory, then the item and/or batch (as applicable) would be acceptable. On the other hand, if one or both of these tests fail, then the item and/or batch would be rejected.

9.7.1.3. Higher strength castings

When higher-strength cast iron is proposed for any purpose, the purchaser's specifications are to be submitted specially for approval in connection with the approval of the design for which the material is intended.

9.8. Inspection

9.8.1. All castings are to be cleaned and suitably prepared for examination. The surfaces are not to be hammered, peened or treated in any way which can make the defects obscure.

9.8.2. All castings are to be visually inspected by the Surveyor which include the examination of internal surfaces, where applicable. Unless otherwise agreed, the responsibility for the verification of dimensions lies with the manufacturer.

9.8.3. Supplementary examination of castings by suitable nondestructive testing procedures is generally not required unless otherwise stated on the approved plan or in circumstances where there is reason to suspect the soundness of the casting.

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

9.8.5. In any such case where the casting is proved to be defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

9.9. Rectification of defective casting

9.9.1. Small surface blemishes may be eliminated with the help of local grinding, but at the discretion of the surveyor.

9.9.2. Castings having local porosity may be rectified by means of impregnation with suitable plastic filler subject to approval.

9.9.3. In general, welding repairs are not permitted. Where welding is proposed, details of the proposed repair are to be furnished for review prior to commencement of the repair work.

9.10. Identification of castings

9.10.1. The manufacturer is to adopt a system of identification, which facilitates tracing of all finished castings to the original ladle of metal. The Surveyor is to be provided with proper facilities to trace the castings when required.

9.10.2. Prior to acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

a) Grade of cast iron;
b) Identification number or other marking enabling the full history of the casting to be traced;
c) Manufacturer's name or trademark;
d) Date of final inspection;
e) INTLREG office, initials or symbol;
f) Personal stamp of Surveyor responsible for inspection;
g) Test pressure, if applicable.

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

9.11. Certification

9.11.1. The manufacturer is to provide the Surveyor with a test certificate or shipping statement indicating 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 quality of cast iron;
c) Identification number;
d) Results of mechanical test;
e) Where applicable, general details of the heat treatment;
f) Where specifically required, the chemical analysis of ladle samples;
g) Where applicable, test pressures.

SECTION 10 DUCTILE (NODULAR) IRON CASTINGS

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10.1. Scope

10.1.1. As detailed in the relevant construction Rules, important spheroidal or nodular graphite iron castings are to be manufactured and tested according to the requirements of this Section.

10.1.2. Where the design and acceptance tests are associated to mechanical properties, at ambient temperature, these requirements are appropriate only to castings. Additional requirements may be essential for other applications, especially when the castings are intended for service at low or elevated temperatures.

10.1.3. Those castings which are in compliance with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by INTLREG.

10.1.4. Where large quantities of small castings are produced, the manufacturer may opt for alternative procedures for testing and inspection which is subject to the approval of INTLREG.

10.2. Manufacture

10.2.1. Ductile iron castings (for example, castings that are required to be certified per Pt 5A, Ch 2, Table 2.1.1 are to be made at INTLREG-approved foundries where the manufacturer has demonstrated to the satisfaction of INTLREG that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

INTLREG approval is valid for 5 years which is subject to annual verification and/or endorsement by the attending Surveyor. At any time, the Surveyor is to be permitted to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection.

10.2.2. Appropriate mechanical methods are to be applied for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

10.2.3. Where castings of the equivalent type are regularly manufactured in quantity, the manufacturer is to carry out tests necessary to prove the quality of the prototype castings and is also to carry out periodical examinations for verification of the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

10.3. Quality of casting

10.3.1. It is essential that the Castings are to be free from any form of surface or internal defects which can prove to be detrimental to their proper application in service. The surface finish is to be in compliance with good practice and any specific requirements of the approved design.

10.4. Chemical composition

10.4.1. The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is appropriate to attain the desired mechanical properties specified for the castings. The chemical composition of the ladle samples is to be reported to INTLREG.

10.5. Heat treatment

10.5.1. Castings may be supplied in either as cast or heat-treated condition except as required by [10.5.2].

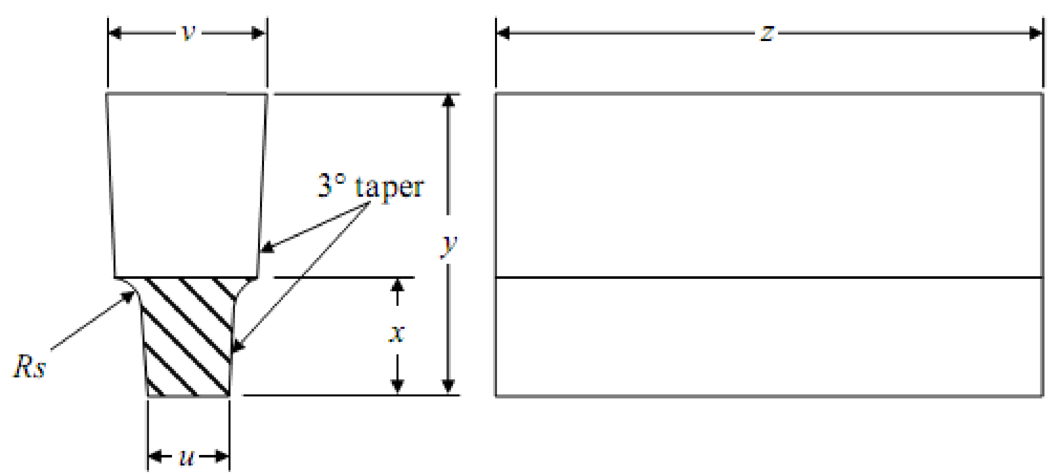
10.5.2. For applications such as high temperature service or where dimensional stability is essential, it may be needed that castings be given a proper tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining. The materials in Table 2.10.2 are to go through a fertilizing heat treatment.

10.5.3. Complete particulars of the proposed procedure and specification to locally harden the surface of a casting are to be submitted for approval.

10.6. Mechanical tests

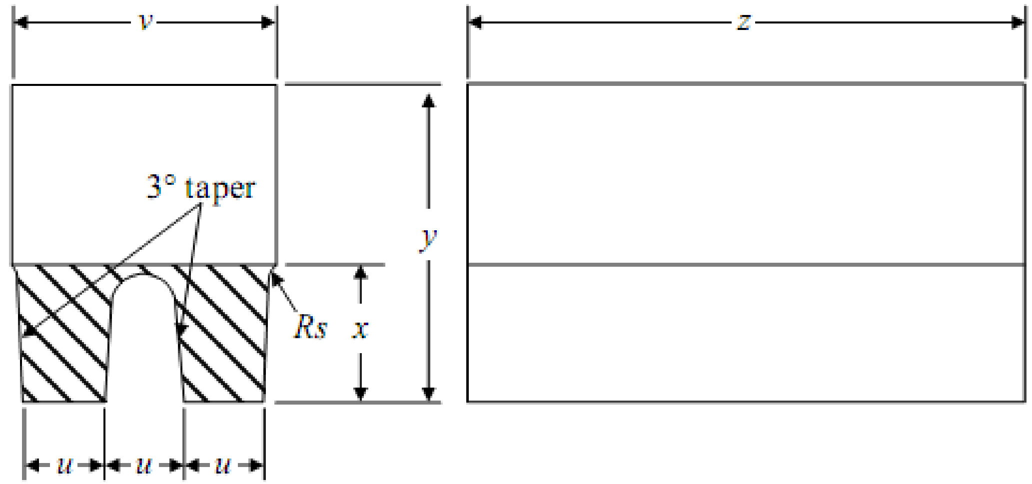
10.6.1. Sufficient test material is to be provided for each casting or batch of castings in order to carry out the required tests and possible re-test.

10.6.2. Generally, the test samples are to be one of the standard types indicated in Figure 2.10.1, Figure 2.10.2 and Figure 2.10.3 with a thickness of 25 mm (1.0 in.). Test samples of other dimensions to Figure 2.10.1, Figure 2.10.2 and Figure 2.10.3 may, though, be specifically required for some components.



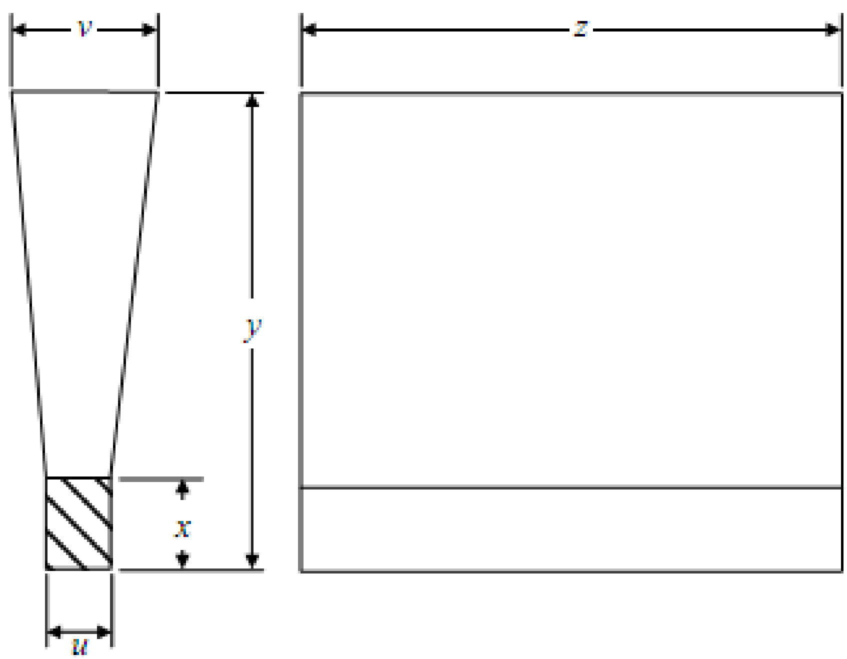
Dimensions mm (in.)	Standard Sample	Alternative Samples when Specially Required		
u	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
v	55 (2.2)	40 (1.6)	90 (3.5)	125 (5.0)
x	40 (1.6)	30 (1.2)	60 (2.4)	65 (2.6)
y	100 (4.0)	80 (3.2)	150 (6.0)	165 (6.5)
z	To suit testing machine			
Rs	Approximately 5 mm (0.20 in.)			

Figure 2.10.1: Type A Test Samples (U-type)



Dimensions – mm (in.)	Standard
u	25 (1.0)
v	90 (3.5)
x	40 (1.6)
y	100 (4.0)
z	To suit testing machine
Rs	Approximately 5 mm (0.20 in.)

Figure 2.10.2: Type B test samples (Double U-type)



Dimensions mm (in.)	**Standard Sample**	**Alternative Samples when Specially Required**		
u	25 (1.0)	12 (0.5)	50 (2.0)	75 (3.0)
v	55 (2.2)	40 (1.6)	100 (4.0)	125 (5.0)
x	40 (1.6)	25 (1.0)	50 (2.4)	65 (2.6)
y	140 (5.5)	135 (5.5)	150 (6.0)	175 (7.0)
z	To suit testing machine			
Min. thickness of mold surrounding test	40 (1.6)	40 (1.6)	80 (3.2)	80 (3.2)

Figure 2.10.3: Type C Test samples (Y-type)

10.6.3. For each casting, at least one test sample is to be provided and, unless otherwise required, may be either gated to the casting or independently cast. Test material of other suitable dimensions may be given integral with the casting as an alternate option.

10.6.4. Additional test samples are to be provided for large castings where more than one ladle of treated metal is used, so as to be representative of each ladle used.

10.6.5. As a substitute to [10.6.2], a batch testing procedure may be adopted for castings with a fettled mass of 1,000 kg (2,200 lb.) or less. In a batch all castings are to be of similar type and dimensions, and cast from the same ladle of treated metal. For each multiple of 2,000 kg (4,400 lb.) of fettled castings in the batch, one separately cast test sample is to be provided.

10.6.6. Where separately cast test samples are used, they are to be cast in molds prepared from the similar type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the molds until the temperature is below 500°C (930°F).

10.6.7. All test samples must have suitable markings to identify them with the castings which they represent.

10.6.8. In those cases, where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

10.6.9. From each test sample, one tensile specimen is to be made and is to be machined to the dimensions given in Sec-1, Figure 2.1.2. Note that for nodular cast iron with an elongation less than 10%, the radius R ≥ 20 mm (0.8 in.).

10.6.10. In accordance with Section-1, of this chapter, all tensile tests are to be conducted using test procedures. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

10.6.11. In addition, impact tests may be required. In such cases, from each sample, a set of three specimens of an approved type is to be prepare. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with Ch 1, Sec 1, Figure 1.1.4.

10.7. Mechanical properties

10.7.1. Table 2.10.1 and Table 2.10.2 below provide the minimum requirement for 0.2% proof stress and elongation conforming to different strength levels. Typical Brinell hardness values are also given in Table 2.10.1 and are provided for information purposes only.

10.7.2. Supply of castings to any specified minimum tensile strength chosen within the general limits detailed in Table 2.10.1, and any additional requirements of the relevant construction Rules.

10.7.3. Unless otherwise agreed, only the tensile strength and elongation need to be decided. The results of all tensile tests are to conform to the appropriate requirements of Table 2.10.1.

10.7.4. Two further tests may be carried out from the same piece, when the tensile test fails to meet the requirements. Where both 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 rejected.

The additional tests mentioned 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.

Table 2.10.1: Mechanical properties for Spheroidal or Nodular Cast iron

Specified minimum tensile strength, N/mm^2 (ksi)	0.2% proof stress, N/mm^2 (ksi)	Elongation on $5.65 \sqrt{S_o}$ (%) min	Typical hardness (Brinell)	Typical structure of matrix
370 (54)	230 (33)	17	120-180	Ferrite
400 (58)	250 (36)	12	140-200	Ferrite
500 (73)	320 (46)	7	170-240	Ferrite/Pearlite
600 (87)	370 (54)	3	190-270	Ferrite/Pearlite
700 (102)	420 (61)	2	230-300	Pearlite
800 (116)	480 (70)	2	250-350	Pearlite or tempered structure

Notes:
1. Intermediate values for mechanical properties may be obtained by interpolation.
2. In the case of integrally cast samples, the elongation may be 2 percentage points less.

Table 2.10.2: Mechanical properties for Spheroidal or Nodular Cast Iron with

Additional Charpy requirements

Specified minimum Tensile strength, N/mm² (ksi)	**0.2% proof stress,** N/mm² (ksi)	**Elongation on 5.65 $\sqrt{S_o}$ (%) min**	**Typical hardness (Brinell)**	**Impact Energy Test min values**(3)		**Typical Structure of Matrix**
				Test temp.	**Ave Joules**	
350 (51)	220 (32)	22 (2)	110-170	+20	17 (14)	Ferrite
400 (58)	250 (36)	18(2)	140-200	+20	14 (11)	Ferrite

Notes:
1. Intermediate values for mechanical properties may be obtained by interpolation.
2. In the case of integrally cast samples, the elongation may be 2 percentage points less.
3. The average value measured on three Charpy V-notch specimens. One result may be below the average value but not less than the minimum shown in parentheses.

10.8. Inspection

10.8.1. For examination, all castings are to be cleaned and suitably prepared. The surfaces are not to be hammered, peened or treated in any way which can obscure defects.

10.8.2. The Surveyor is to visually examine all castings including, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

10.8.3. In general, supplementary examination of castings by appropriate nondestructive test procedures is not generally required, unless otherwise stated on the approved plan or in circumstances where there is reason to suspect the soundness of the casting.

10.8.4. Whenever required by the relevant construction Rules, castings are to be pressure tested prior to final acceptance.

10.8.5. If any casting is proved to be defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

10.8.6. Cast crankshafts are to undergo a magnetic particle inspection. Crack like indications are not allowed.

10.9. Metallographic examination

10.9.1. A metallographic examination is to be carried out on crankshafts.

10.9.2. A representative sample from each ladle of treated metal, whenever required, is to be prepared for metallographic examination. These samples may be taken from the tensile test specimen but alternate arrangements for the provisions of the samples may be opted provided that they are taken from the ladle towards the end of the casting period.

10.9.3. Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are detailed in Table 2.10.1 and are intended for information purposes only.

10.10. Rectification of defective castings

10.10.1. Small surface blemishes may be rectified with the help of local grinding at the discretion of the Surveyor.

10.10.2. Castings containing local porosity may be rectified by impregnation with suitable plastic filler, subject to prior approval from the Surveyor.

10.10.3. In general, welding repairs are not permitted.

10.11. Identification of castings

10.11.1. The manufacturer is to adopt a suitable identification system, which will facilitate all finished castings to be traced to the original ladle of treated metal. The Surveyor is to be provided with adequate facilities for tracing the castings when required.

10.11.2. Before acceptance, all castings, which have been tested and inspected with satisfactory results are to be legibly marked by the manufacturer with the following details:

a) Grade of cast iron;
b) Identification number or other marking enabling the full history of the casting to be traced;
c) Manufacturer's name or trademark;
d) Date of final inspection;
e) INTLREG office, initials or symbol;
f) Personal stamp of Surveyor responsible for inspection;
g) Test pressure, if applicable.

10.11.3. Where manufacturing of small castings is carried out in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

10.12. Certification

10.12.1. The manufacturer is to provide the Surveyor with a test certificate or shipping statement with the following particulars for each casing or batch of castings that has been accepted:

a) Purchaser's name and order number;
b) Description of castings and quality of cast iron;
c) Identification number;
d) Results of mechanical tests;
e) Where applicable, general details of heat treatment;
f) Where specifically required, the chemical analysis of the ladle samples;
g) Where applicable, test pressure.

SECTION 11 ANCHORS

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11.1. General requirements

11.1.1. Scope

These requirements are for the materials, manufacture, testing and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars.

The manufacturing requirements are applicable to ordinary anchors and Superior Holding Power (SHP) anchors.

11.1.2. Types of anchor

11.1.2.1. Ordinary anchors (Also Refer Pt 4,Ch 3,Sec 4)

Ordinary stockless anchors shall be of an approved design. Any changes or alterations from the approved design shall be approved prior to manufacture.

The mass of the heads of stockless anchors as well as pins and fittings are to be less than 60% of the total mass of the anchor.

11.1.2.2. Superior Holding Power (SHP) anchors

SHP anchors of an approved design are to be subjected to special approval by the Society. During manufacture, any changes or alterations to the approved design made shall be done with prior approval.

SHP anchors are to be appropriate for ship use and need not require prior adjustment or special placement on the seabed.

SHP anchors are to have in any case twice the holding power of ordinary stockless anchors of the same weight.

The mass of each bower anchor can be reduced by up to 25% of the mass specified in Table 2.11.6. Inclusion of approved manufacturers of SHP anchors shall be done in a specific directory maintained by INTLREG.

11.1.2.3. Super High Holding Power (SHHP) Anchors for restricted service and to a maximum weight of 1500 kg (3306 lbs.)

The super high holding power anchors with holding powers of at least 4 times the holding power of ordinary anchors are to be given special approval. The mass of each bower anchor can be reduced by up to 50% of the mass specified in Table 2.11.6.

11.2. Materials for anchors

11.2.1. **Ordinary Anchors**

11.2.1.1 All anchors are to be manufactured from materials meeting the requirements in INTLREG Rules for Materials and Welding (Part 2) and produced by a manufacturer approved by INTLREG.

11.2.1.2 Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Ch 2, Sec 11 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with aluminum.

11.2.1.3 Cast steel anchor flukes and shanks are to have integrally cast test coupons. Before the completion of the final heat treatment cycle, the test coupons are not to be detached. The detachment must be carried out in such a way that it does not cause any physical or metallurgical damage to the anchor component. Test coupons are not to be detached until the Surveyor has stamped them for identification. Test coupons are to be traceable to the cast components they represent and test reports are to be traceable to the test coupons.

11.2.1.4 Two Test Programs "A" and "B" are permitted in accordance with [11.4.3] of this section. Charpy V notch (CVN) impact testing of cast material is required. Other grades of steels shall be specially considered for the manufacture of swivels.

11.2.1.5 The requirements of Ch 1,Sec 7 shall be complied with when manufacturing forged steel anchor pins, shanks, swivels and shackles. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

11.2.1.6 In accordance with the requirements of Ch 1, Sec 1, rolled plates and bars for fabricated steel anchors are to be manufactured and tested.

11.2.1.7 According to the requirements of Ch 1, Sec 1 or Ch 2, Sec 3, rolled bars intended for pins, swivels and shackles are to be manufactured and tested.

11.2.2. **Superior Holding Power (SHP) Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs)**

11.2.2.1. In Addition to the requirements given in [11.2.1] above, steel is to be selected in accordance with Pt 3, Ch 2, Table 2.2.2 Class II. The welding consumables are to meet the toughness for the base steel grades.

11.2.2.2. Toughness of the anchor shackles is to meet that for Grade 3 anchor chain. The toughness of steel castings is to be not less than a Charpy V-notch energy average of 27 J at 0°C (2.8 kgf-m at 0°C, 20 ft-lbs at 32°F).

11.3 Manufacture of anchors

11.3.1. Tolerance

The below mentioned assembly and fitting tolerances are to be applied unless otherwise specified in standards or on drawings demonstrated to be appropriate.

The clearance either side of the shank within the shackle jaws is to be no more than 3 mm (0.12 inch) for small anchors up to 3 tonnes (3.3 tons) weight, 4 mm (0.16 inch) for anchors up to 5 tonnes (5.5 tons) weight, 6 mm (0.24 inch) for anchors up to 7 tonnes (7.7 tons) weight and is not to exceed 12 mm (0.47 inch) for larger anchors. The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0.5 mm (0.02 inch) for pins up to 57 mm (2.24 inch) and 1.0 mm (0.04 inch) for pins of larger diameter.

In order to prevent horizontal movement, the trunnion pin is to be a snug fit within the chamber and be long enough. The gap is to be less than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, Refer Figure 2.11.1.

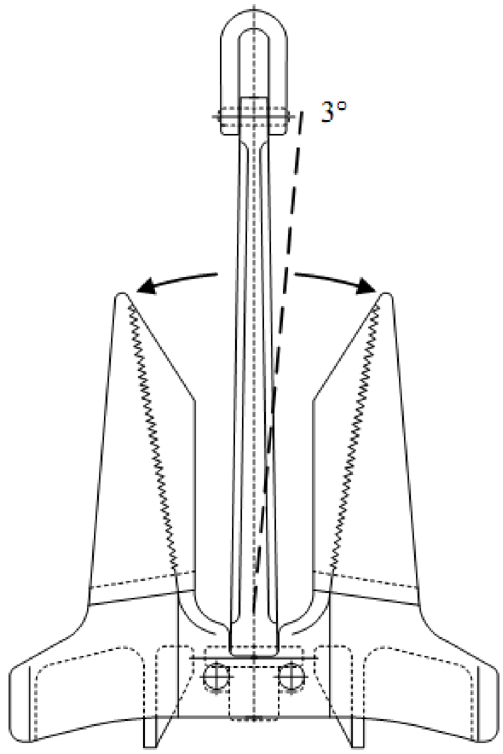


Figure 2.11.1: Allowable lateral movement of shank

11.3.2. Welding of anchors

In accordance with [Chapter-3, Sec-2 & Sec-5], welded construction of fabricated anchors is to be with approved procedures. In accordance with the requirements of Table 2.11.3 or Table 2.11.4 or Table 2.11.5 product tests NDE is to be carried.

11.3.3. Heat treatment

Components for cast or forged anchors are to be heat treated appropriately; fully annealed; normalized or normalized and tempered in accordance with Ch 1, Sec 6, [6.3] or Ch 1, Sec 7, [7.3]. After welding depending upon weld thickness, fabricated anchors may need stress relief. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

The foundry or forge is to provide the Surveyor records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The heat treatment temperature and time is to be based on sensors attached to the furnace charge. The time lag between the thermocouples on the furnace charge and wall/interior of the furnace is to be determined in order to assess that the heating and soaking times are sufficient.

Integrally cast or forged coupons are to be of sufficient size to represent the heat transfer experienced in the cast or forged component itself during the complete heat treatment cycle.

11.3.4. Surface cleanliness

All parts are to have a clean surface consistent with the method of manufacture and intended method of inspection.

11.3.5. Repairs

Any necessary repairs to forged and cast anchors are to be agreed to by the Surveyor and carried out in accordance with the repair criteria indicated in Ch 1, Sec 6, [6.7] and Ch 1, Sec 7,[7.6.5]. The restrictions of [11.4.3.7] of this section - Repair Criteria, also apply.

The manufacturer is to maintain complete records with details of the extent and location of all weld repairs made to each casting or forging and details of applied weld procedures and heat treatments. These records are to be made available to the Surveyor and copies to be provided on request.

Repairs to fabricated anchors are to be agreed to by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

11.3.6. Anchor assembly

Assembly and fitting are to be done in accordance with the design details. Securing of the anchor pin, shackle pin or swivel nut, by welding, is to be in accordance with an approved procedure.

11.4 Testing and certification

11.4.1. All anchors are to be inspected and tested in the presence of the Surveyor, the proof testing is to be carried out in a machine recognized for such purposes. The Surveyor is to be satisfied that all testing machines, including material testing machines, are maintained in a satisfactory condition, and is to keep a record of the dates and by whom the machines were rechecked and calibrated.

11.4.2. **Proof Load Testing of anchors**

Proof load testing for ordinary and SHP anchors is to be carried out by an approved testing facility.

11.4.2.1. Proof load testing of ordinary anchors

Before application of proof test load, the anchors are to be visually examined and all defects are to be removed. If required, welding repairs can be done prior to testing. Proof tests are to be carried out on all anchors after being temporarily assembled. The proof tests are to be in accordance with the values given in Table 2.11.6. The proof load in accordance with Table 2.11.6 is to be applied on the fluke at a location one third of the distance from the tip of the fluke to the center of the crown as shown in Figure 2.11.2.

In the case of stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

After proof load testing the anchors are to be examined for cracks and other defects, and for excessive deformation due to seating.

Once the proof load tests are completed, anchors made in more than one piece are to be examined for free rotation of their heads over the complete angle. The anchor shackle that underwent proof load testing is to be fitted to the anchor before shipping to the customer.

The gauge lengths (Refer Figure 2.11.2) under a load equal to one-tenth of the proof test load are to be determined before and after the application of full proof load on each side. The gauge length after the application of full proof load is to be not more than 1% in excess of the corresponding gauge length before the application of full proof load.

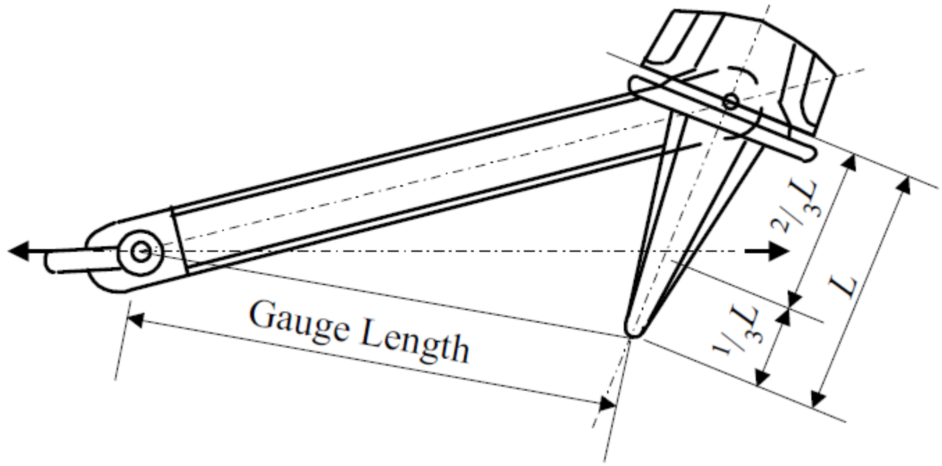


Figure 2.11.2: Proof load application

11.4.2.2. Proof load testing of SHP anchors

SHP anchors are to be proof tested with loads required by Table 2.11.6 for an anchor mass equal to 1.33 times the actual mass of the SHP anchor. The proof loading procedure and examination procedure for SHP anchors are to comply with those for ordinary anchors, described in [11.4.2].

11.4.2.3. Testing of SHP anchors for restricted service with 4 times holding power of ordinary anchors

These anchors are to be proof tested with the load required by Table 2.11.6 for an anchor mass equal to 2 times the actual mass of the SHP anchor. The proof loading procedure and examination procedure for SHP anchors are to comply with those for ordinary anchors, described in [11.4.2].

11.4.2.4. SHP full scale anchor holding power tests at sea

In addition to proof tests, SHP anchors are subject to anchor holding power sea tests on various types of sea bottom, using anchors representative of the full range of anchor size proposed.

11.4.3. Product tests

11.4.3.1. Product test programs

There are two test programs, which apply to anchor manufacture:

a) Program A, or

b) Program B.

Table 2.11.1: Applicable Test Programs for each Product Form

Product test	Product Form		
	Cast components	Forged components	Fabricated/Welded components
Program A	Applicable (1)	Not Applicable	Not Applicable
Program B	Applicable (1)	Applicable (2)	Applicable (2)

Notes:

1. CVN impact tests are to be carried out to demonstrate at least 27 J average at 0°C (2.8 kgf-m at 0°C, 20 ft-lbs at 32°F).
2. The Drop test requirement in Program B is not applicable for Forged Components or Fabricated/Welded Components.

Table 2.11.2: Product test requirements for program A and B

Program A	Program B
Drop test	Drop test
Hammering test	---
Visual inspection	Visual inspection
General NDE	General NDE
---	Extended NDE

11.4.3.2. Drop test

Each anchor fluke and shank is to be individually raised to a height of 4 m (13.1 ft.) and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

11.4.3.3. Hammering test

After the drop test, hammering tests are to be carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg (6.6 lbs.) mass is to be used.

11.4.3.4. Visual inspection

After proof loading, all accessible surfaces are to be visually inspected for any visual defects.

11.4.3.5. General nondestructive examination

General NDE is to be carried out, after proof loading as indicated in Table 2.11.3 and Table 2.11.4.

Table 2.11.3: General NDE for ordinary and SHP anchors

Location	Method of NDE
In way of feeders of castings	PT or MT
In way of risers of castings	PT or MT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT
Note: Chapter-7, Section 5 is regarded as an example of an acceptable standard for surface and volumetric examination.	

Table 2.11.4: General NDE for SHP anchors for restricted service with 4 times holding power of ordinary anchors

Location	Method of NDE
In way of feeders of castings	PT or MT and UT
In way of risers of castings	PT or MT and UT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT
Note: Chapter-7, Section 5 is regarded as an example of an acceptable standard for surface and volumetric examination.	

11.4.3.6. Extended nondestructive examination

Extended NDE is to be carried out, after proof loading, as indicated in Table 2.11.5.

Table 2.11.5: Extended NDE for Ordinary and all SHP Anchors

Location	Method of NDE
In way of feeders of castings	PT or MT and UT
In way of risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Random areas of castings	UT
In way of weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT
Note: Chapter-7, Section 5 is regarded as an example of an acceptable standard for surface and volumetric examination.	

11.4.3.7. Repair criteria

Where defects are detected by NDE, they are to be repaired in accordance with [11.3.5] above. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

11.4.4. Mass and dimensional inspection

The responsibility of verification of mass and dimensions lies with the manufacturer, unless otherwise agreed. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is an integral component.

11.4.5. Retests

Mechanical retest is permitted in accordance with the requirements of Ch 1, Sec 6, [6.2.2] and Ch 1, Sec 6,[6.2.2].

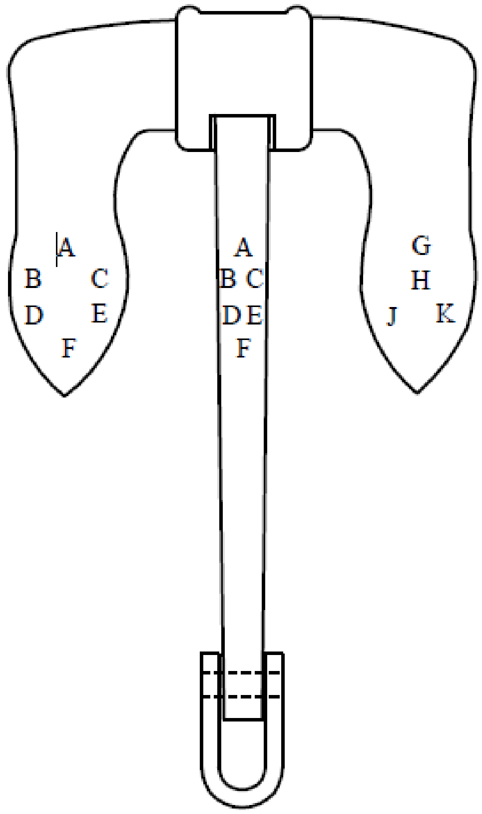
11.5 Marking for anchors

11.5.1. Markings

When anchors have satisfactorily passed the above test requirements, they are to be clearly stamped by the manufacturer, as shown in Figure 2.11.3.

11.5.2. Provisions for marks

One side of the anchor is to be reserved solely for the above marks and the other side used for the maker's name or other trademarks that may be desired. If the design of the anchor does not permit the above marks being placed or grouped as indicated, a suitable boss is to be cast on each arm on which the marks are to be stamped. The Maltese Cross, is to be stamped at positions "B" & "J" along with the witnessing Surveyor's initials per Figure 2.11.3.



A	The number of Certificate. (Furnished by the Surveyor)	00-PA-123
B	The INTLREG Stamp (with Maltese Cross) and the Initials of the Surveyor who witnesses the Proof Test	X.Y.X.
C	Month and Year of Test	1-00
D	Proof Test applied	49500
E	Signifying that the Testing Machine is recognized by the Committee of the International Register of Shipping	IR
F	The Weight of Anchor	3200
G	Signifying that Anchor Head has been verified by a Surveyor to the INTLREG	IR
H	The Weight of Anchor Head	1920
J	The INTLREG Stamp and the Initials of the Surveyor who witnesses the Drop Test	X.Y.X.
K	Month and Year of Drop Test	6-00

Figure 2.11.3: Stockless anchor

11.6 Certification

11.6.1. Anchors which meet the requirements of this section are to be certified by INTLREG. The following items that are to be included in the certificate:

a) Manufacturer’s name
b) Type
c) Mass
d) Fluke and Shank identification numbers
e) Grade of materials
f) Proof test loads
g) Heat treatment;
h) Markings applied to anchor.

11.7 Painting

11.7.1. All types of anchor are to remain unpainted until all tests and inspections have been completed.

Table 2.11.6: Proof tests for anchors

Note Refer also Pt 4, Ch 3, Sec 4

SI Units

Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN	Mass of Anchor kg	Proof Test kN
50	23	500	116	2000	349	4500	622	7000	804	15000	1260	38000	2330
55	25	550	125	2100	362	4600	631	7200	818	15500	1270	40000	2410
60	27	600	132	2200	376	4700	638	7400	832	16000	1300	42000	2490
65	29	650	140	2300	388	4800	645	7600	845	16500	1330	44000	2570
70	31	700	149	2400	401	4900	653	7800	861	17000	1360	46000	2650
75	32	750	158	2500	414	5000	661	8000	877	17500	1390	48000	2730
80	34	800	166	2600	427	5100	669	8200	892	18000	1410		
90	36	850	175	2700	438	5200	677	8400	908	18500	1440		
100	39	900	182	2800	450	5300	685	8600	922	19000	1470		
120	44	950	191	2900	462	5400	691	8800	936	19500	1490		
140	49	1000	199	3000	474	5500	699	9000	949	20000	1520		
160	53	1050	208	3100	484	5600	706	9200	961	21000	1570		
180	57	1100	216	3200	495	5700	713	9400	975	22000	1620		
200	61	1150	224	3300	506	5800	721	9600	987	23000	1670		
225	66	1200	231	3400	517	5900	728	9800	998	24000	1720		
250	70	1250	239	3500	528	6000	735	10000	1010	25000	1770		
275	75	1300	247	3600	537	6100	740	10500	1040	26000	1800		
300	80	1350	255	3700	547	6200	747	11000	1070	27000	1850		
325	84	1400	262	3800	557	6300	754	11500	1090	28000	1900		
350	89	1450	270	3900	567	6400	760	12000	1110	29000	1940		
375	93	1500	278	4000	577	6500	767	12500	1130	30000	1990		
400	98	1600	292	4100	586	6600	773	13000	1160	31000	2030		
425	103	1700	307	4200	595	6700	779	13500	1180	32000	2070		
450	107	1800	321	4300	604	6800	786	14000	1210	34000	2160		
475	112	1900	335	4400	613	6900	794	14500	1230	36000	2250		

Table 2.11.6: (continued) Proof tests for anchors

Note Refer also Pt 4, Ch 3, Sec 4

Metric Units

Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf	Mass of Anchor kg	Proof Test kgf
50	2370	500	11800	2000	35600	4500	63400	7000	82000	15000	128000	38000	238000
55	2570	550	12700	2100	36900	4600	64300	7200	83400	15500	130000	40000	246000
60	2760	600	13500	2200	38300	4700	65100	7400	84800	16000	133000	42000	254000
65	2950	650	14300	2300	39600	4800	65800	7600	86200	16500	136000	44000	262000
70	3130	700	15200	2400	40900	4900	66600	7800	87800	17000	139000	46000	270000
75	3300	750	16100	2500	42200	5000	67400	8000	89400	17500	142000	48000	278000
80	3460	800	16900	2600	43500	5100	68200	8200	91000	18000	144000		
90	3700	850	17800	2700	44700	5200	69000	8400	92600	18500	147000		
100	3990	900	18600	2800	45900	5300	69800	8600	94000	19000	150000		
120	4520	950	19500	2900	47100	5400	70500	8800	95400	19500	152000		
140	5000	1000	20300	3000	48300	5500	71300	9000	96800	20000	155000		
160	5430	1050	21200	3100	49400	5600	72000	9200	98000	21000	160000		
180	5850	1100	22000	3200	50500	5700	72700	9400	99400	22000	165000		
200	6250	1150	22800	3300	51600	5800	73500	9600	100600	23000	170000		
225	6710	1200	23600	3400	52700	5900	74200	9800	101800	24000	175000		
250	7180	1250	24400	3500	53800	6000	74900	10000	103000	25000	180000		
275	7640	1300	25200	3600	54800	6100	75500	10500	106000	26000	184000		
300	8110	1350	26000	3700	55800	6200	76200	11000	109000	27000	189000		
325	8580	1400	26700	3800	56800	6300	76900	11500	111000	28000	194000		
350	9050	1450	27500	3900	57800	6400	77500	12000	113000	29000	198000		
375	9520	1500	28300	4000	58800	6500	78200	12500	115000	30000	203000		
400	9980	1600	29800	4100	59800	6600	78800	13000	118000	31000	207000		
425	10500	1700	31300	4200	60700	6700	79400	13500	120000	32000	211000		
450	10900	1800	32700	4300	61600	6800	80200	14000	123000	34000	220000		
475	11400	1900	34200	4400	62500	6900	81000	14500	125000	36000	229000		

Table 2.11.6: (continued) Proof tests for anchors

Note Refer also Pt 4, Ch 3, Sec 4

US Units

Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf	Mass of Anchor lb	Proof Test lbf
100	5000	1000	24100	3000	57700	5000	86500	7000	110500	9000	131500	28000	256000	56000	400000
125	5900	1100	25900	3100	59200	5100	87800	7100	112000	9500	136000	29000	262000	58000	410000
150	6800	1200	27700	3200	60700	5200	89100	7200	113000	10000	140500	30000	266000	60000	419000
175	7600	1300	29500	3300	62200	5300	90400	7300	114000	11000	148500	31000	272000	62000	428000
200	8300	1400	31200	3400	63700	5400	91700	7400	115000	12000	156000	32000	275000	64000	437000
250	9700	1500	32900	3500	65200	5500	93000	7500	116000	13000	163500	33000	281000	66000	446000
300	10900	1600	34600	3600	66700	5600	94300	7600	117000	14000	170500	34000	287000	68000	455000
350	12000	1700	36300	3700	68200	5700	95500	7700	118000	15000	177000	35000	292000	70000	464000
400	13000	1800	38000	3800	69700	5800	96700	7800	120000	16000	185000	36000	298000	75000	486000
450	14000	1900	39700	3900	71200	5900	97900	7900	120500	17000	192000	37000	303000	80000	507000
500	15000	2000	41400	4000	72600	6000	99100	8000	121500	18000	200000	38000	309000	85000	528000
550	16000	2100	43100	4100	74100	6100	100500	8100	122500	19000	208000	39000	314000	90000	549000
600	16900	2200	44700	4200	75500	6200	101500	8200	123500	20000	214000	40000	320000	95000	569000
650	17800	2300	46400	4300	76900	6300	102500	8300	124500	21000	221000	42000	330000	100000	590000
700	18700	2400	48000	4400	78300	6400	104000	8400	125500	22000	227000	44000	341000	105000	610000
750	19600	2500	49700	4500	79700	6500	105000	8500	126500	23000	232000	46000	351000	110000	630000
800	20500	2600	51300	4600	81100	6600	106500	8600	127500	24000	239000	48000	361000		
850	21400	2700	52900	4700	82500	6700	107500	8700	128500	25000	243000	50000	371000		
900	22300	2800	54500	4800	83800	6800	108500	8800	129500	26000	247000	52000	381000		
950	23200	2900	56100	4900	85200	6900	109500	8900	130500	27000	251000	54000	390000		

SECTION 12 ANCHOR CHAIN

Contents

12.1. Anchor chain...186

12.1. Anchor chain

12.1.1. Scope

Three grades of stud-link anchor chain are covered, and are described in Table 2.12.1 below.

Table 2.12.1

Strength Level	Grade	Method of Manufacture
Normal Strength	1	Flash Butt-welded
High Strength	2a	Flash Butt-welded or Drop-forged Cast Steel
	2b	
Extra-high Strength	3a	Flash Butt-welded or Drop-forged Cast Steel
	3b	

12.1.2. General

All anchor chains should have a proper workmanlike finish and be free from injurious defects. There is to be an odd number of links in each shot of anchor chain cable so that the shackles leading over the windlass are in the same position.

12.1.3. Specially approved chain

Steel chain manufactured by processes or to requirements varying from those shown in Table 2.12.2 and certain types of drop-forged chain will be subject to special consideration.

12.1.4. Qualification of manufacturers

12.1.4.1. General

Anchor chain and chain accessories are to be produced by manufacturers approved by INTLREG. For approval purposes, the manufacturer is to furnish details of manufacturing procedure specification, applicable material grades, and dimensions of chain/accessories along with a test plan for INTLREG review. The approval tests, as a minimum, are to comprise: chemical analyses, proof and break load tests, tensile/impact tests, metallographic examinations, dimensional measurements, visual and non-destructive examinations. An attending Surveyor shall witness the approval tests and the test-data are to be submitted to INTLREG for review and acceptance. The approval is valid for a maximum of 5 years.

Table 2.12.2: Chain materials – mechanical properties

Chain grade	Grade 1	Grade 2	Grade 3
Yield Point N/mm^2 (kgf/mm^2, ksi)	-	295 (30, 42.8)	410 (42, 60)
Tensile Range N/mm^2 (kgf/mm^2, ksi)	370-490 (38-51, 53.7-71.1)	490-690 (50-70, 71.1-99.6)	690 min. (70, 99.6) min.
Elongation (5D), min %	25	22	17
Reduction of Area, min %	-	-	40
Average Impact Value at 0°C (32°F), J (kgf-m, ft-lbf)			
base metal	-	27$^{(1)}$ (2.8, 20)	60 (6, 43)
at weld center	-	27$^{(1)}$ (2.8, 20)	50 (5, 36)
Bend Test			
mandrel dia. (Refer Note 2)	2T	3T	
Angle (degree)	180	180	

Notes:

1 Impact test for Grade 2 chain material is required for flash butt welded chain to be delivered in as-welded condition.

2 T = diameter or thickness of test specimen.

12.1.4.2. Locking pins in accessories

Locking pins in detachable connecting links are to have taper contact at both top and bottom in the link halves. Generally, lead or other acceptable material is to be used for plugging the locking pin hole which is to have an appropriate undercut recess or equivalent arrangement to secure the plug.

12.1.4.3. Stud attachment

Studs are to be affixed securely by press fitting or welding with an approved procedure. When the stud is welded in place, the weld is to be opposite the flash butt weld in the chain. The welding is to be carried out in the horizontal position at least on both faces of the link for a length sufficient to hold the stud securely in place. An approval from the attending Surveyor is required for any welding of chain after the approved manufacturing process. Welding of studs is to be in compliance with an approved procedure subject to the following conditions:

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

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

12.1.5. **Chain dimensions and tolerances**

12.1.5.1. Shape

Each link is to be uniform and is to be symmetrical; The link is to have smooth internal radii that are to be at least 0.65 times the chain diameter.

12.1.5.2. Dimensions

The dimensions, shape and proportions of links and accessories must be in compliance with an approved recognized standard, such as ISO 1704, or the designs are to be specially approved. After proof testing, measurements are to be taken on at least one link per each 27.5 m (15 fathoms) of chain tested and are to conform to the dimensions shown below.

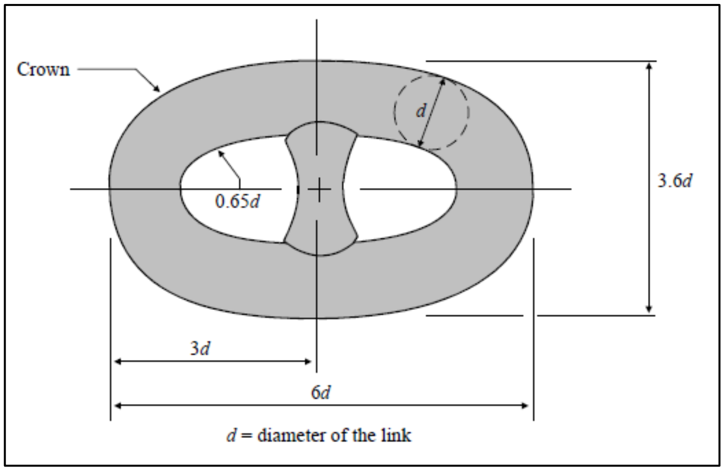


Figure 2.12.1: Common link

12.1.5.3. Tolerances

The minus tolerances on the diameter in the plane of the link at the crown are acceptable to the extent shown in Table 2.12.3 below, provided that the cross-sectional area of the link at that point is at least the theoretical area of the nominal diameter:

Table 2.12.3

Chain Diameter in mm (in.)		Crown Minus Tolerance
Over	Up to	in mm (in.)
—	40 (1- 9/16)	1 (1/32)
40 (1-9/16)	84 (3-5/16)	2 (1/16)
84 (3-5/16)	122 (4-3/4)	3 (1/8)
122 (4-3/4)	162 (6-3/8)	4 (5/32)

No minus tolerance on the diameter is allowed at locations other than the crown.

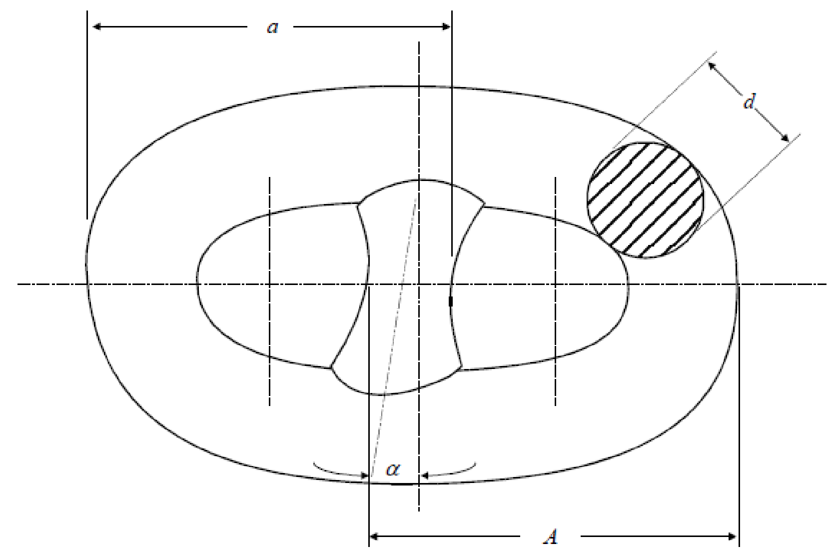
The plus tolerance on the diameter is not to go beyond 5% of the nominal diameter., The manufacturer's specification for plus tolerance in way of weld is to be submitted for approval.

Subject to [12.1.5.4] below, the tolerances on other dimensions in [12.1.5.2] above are not exceed ±2.5%.

Location of the Studs is to be in the links centrally and at right angles to the sides of the link, except that the studs for the final link at each end of any length may be located off-center to facilitate the insertion of the joining shackle. The following tolerances are acceptable, provided that the stud fits snugly and its ends lie practically flush against the inside of the link.

Maximum off-center distance “X”	10% of the nominal diameter, *d*
Maximum deviation angle “α” from the 90° position	4°

The tolerances are to be measured, as given in Figure 2.12.2.



Off-center distance, $X = \frac{A - a}{2}$

Figure 2.12.2: Final link

12.1.5.4. Length over five links

The length over five links is to be measured after completion of the proof testing, while applying a tension of approximately 10% of the applied proof load. The Surveyor is to confirm the length over a five link measurement from at least three locations per each 27.5 m (15 fathoms) of chain tested. The permissible tolerance for the length over any five common links is 0.0% of the chain diameter below, and 55% of the chain diameter above the length given in Table 2.12.6.

12.1.6. **Material for chain**

12.1.6.1. For the manufacture of chain, the steel used is to be made by the open-hearth, basic-oxygen, electric-furnace or such other process as may be specially approved. Rimmed steel is not acceptable for any grade of chain.

12.1.6.2. Chemical composition

For the production of the chain, the chemical composition of the material is to be determined by the steelmaker on samples taken from each ladle of each heat and is to conform to the approved specification of the chain manufacturer.

12.1.7. Material testing

12.1.7.1. Heat treatment of test specimens

In the same manner as planned for the finished chain, test samples are to be taken from material heat-treated except that in the case of Grades 1 and 2a flash butt-welded chain, test specimens may be taken from material in either the as-rolled or heat-treated condition.

12.1.7.2. Number of tests

One set of tests consisting of one tension, and one bend or three impact test specimens, as required in Table 2.12.2, are to be taken from the largest casting or drop forging from each lot of 50 tons or fraction thereof from each heat.

12.1.7.3. Tension test specimens

Machined type specimens, for cast or drop-forged links are to be used. As illustrated in Figure 2.12.3, they are to be cut and notched. The tension-test results for stud-link anchor chain materials are to comply with the applicable requirements tabulated in Table 2.12.2.

Based on specimens having gauge lengths equal to 5 times the diameter, the required minimum percentage elongation values are given in Table 2.12.2. For specimens having other gauge lengths, the equal elongation value is to be calculated by the following equation:

$$n = 2\,E\left(\sqrt{A}/L\right)^{0.4}$$

Where,

- n = Equivalent minimum elongation;
- A = Actual cross-sectional area of the specimen;
- L = Actual gauge length;
- E = Specified minimum percentage elongation for specimens having a gauge length of 5 times the diameter.

The above equation is not applicable to quenched and tempered steel, for which the specimen is to have a gauge length of 5 times the specimen diameters.

12.1.7.4. Bend test specimens

For cast or drop-forged links, machined type specimens are to be used. As per the specifications provided in Table 2.12.2., each specimen is to withstand, without fracture, cold bending around a mandrill diameter and through the angle specified in Table 2.12.2.

12.1.7.5. Impact test specimens

Impact test specimens are to be in accordance with Ch 1, Sec 1, [1.6.6]. They are to be cut and notched as shown in Figure 2.12.3. The average value of 3 specimens is to conform to the requirements of Table 2.12.2.

12.1.7.6. Additional tests before rejection

Retest may be permitted, as applicable when a specimen fails to meet the requirements of Table 2.12.2, in accordance with Ch 1, Sec 2, [2.5.5], [2.5.6], [2.6.4] and [2.6.5]

12.1.7.7. Manufacturer's option

The chain manufacturer may opt to waive the above material tests (normally conducted prior to chain fabrication) provided the required test specimens representative of each heat are taken from finished links after final heat treatment, if any, and in the same proportion of number of tests to tonnage, as outlined in [12.1.7.2] above.

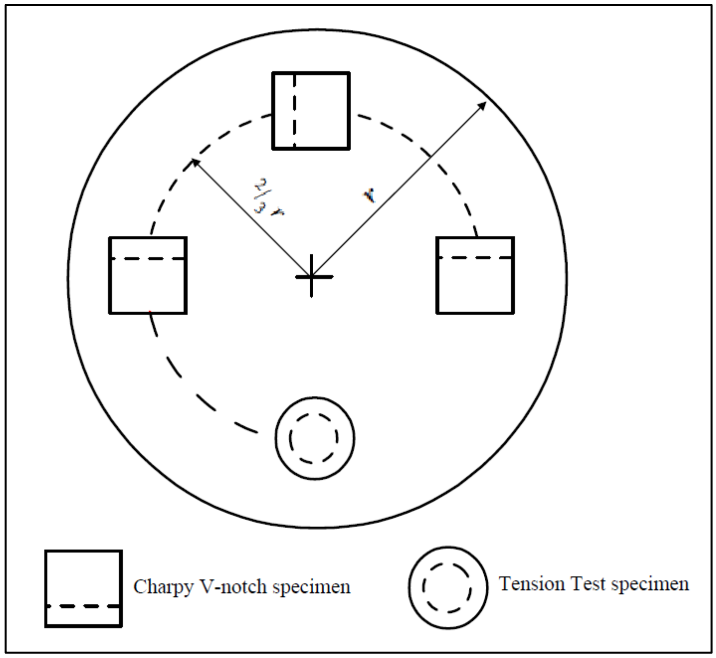


Figure 2.12.3: Location and orientation of test specimens

12.1.8. Heat treatment of chain lengths

12.1.8.1. Flash butt-welded chain

Supply of Grades 1 and 2a flash butt-welded chain may be supplied in either the as-welded or normalized condition.

12.1.8.2. Drop-forged, cast-steel and extra-high-strength chain

In accordance with the manufacturer's approved specification, Grade 2a drop-forged chain, Grade 2b cast-steel chain and Grades 3a and 3b extra-high-strength chain are to be normalized, normalized and tempered or quenched and tempered.

12.1.8.3. Sequence of heat treatment

Prior to the proof and breaking tests, heat treatment is to be completed.

12.1.9. Testing and inspection of chain lengths

12.1.9.1. General

Prior to the test and inspection, the chain is to be free from paint or other coating which would tend to conceal defects. All anchor chain is to be subjected to breaking and proof tests in the presence of the Surveyor. The surveyor is to satisfy himself that the testing machines are maintained in an accurate condition and is to keep a record of the dates and by whom the machines were rechecked or calibrated. After proof testing, careful examination of the links is needed for workmanship, concentricity, distortion, stud attachment, test grip damage, surface appearance and alignment of butt welds.

Provided their depth is not greater than 5% of the link diameter, surface discontinuities may be removed by grinding and blending to a smooth contour. The cross-sectional area in way of the grinding is to be not less than the theoretical area of nominal chain diameter. Links repaired by grinding are to undergo magnetic particle or dye penetrant inspection.

12.1.9.2. Chain identification

In order to identify each shot through the various processes of testing, gauging, measuring, examining, repairing and weighing, it is to be stamped with a distinctive mark. In the event of the Surveyor being in attendance at the works while forged chains are being fabricated, which will ultimately be submitted for testing, the break test specimens will be selected as far as possible during the process of fabrication.

12.1.9.3. Testing precautions

Proper care is to be taken that arrangements are made for each link to be tested at least once. The gripping arrangements are to be such that they do not put any stress on the end links of the portion under test, except such stress is equally applied to every link tested.

12.1.9.4. Weighing of tested chain

Once chains have satisfactorily passed the requirements, they are to be weighed, together with the shackles forming the outfit, and this actual weight will be declared on the certificate of test.

12.1.9.5. Testing of used chain

When a chain, which has been in use, is submitted for testing or retesting, the size for testing purposes is to be of the original chain diameter. The certificate issued for such chain will include the original chain diameter as well as the mean diameter of the part most worn, and will be marked, “This chain is not new, and has been previously used’’.

12.1.10. **Details of tests on chain lengths**

12.1.10.1. Breaking test

A break-test sample comprising of at least three links is to be taken from the chain or manufactured at the same time and the same way as the chain. Where produced separately, the specimen is to be securely fastened to the chain during any heat treatment. One specimen is to be taken from each four 27.5 m (15 fathoms) lengths or less of flash butt-welded or drop-forged chain and one from each heat treatment batch with a minimum of one from each four 27.5 m (15 fathoms) lengths or less of cast-steel chain. Each specimen is to be subjected to the applicable breaking load given in Table 2.12.6 (stud-link chain).The breaking load test is to be carried out in the presence of a Surveyor and is to be maintained for a minimum of 30 seconds. If there is no sign of fracture after application of the required load in the specimen, then it is considered to have successfully passed the test. Special attention is to be given to the visual inspection of the flash butt weld.

One more specimen may be cut out and subjected to the breaking load, where the first test is not satisfactory. If this test fails, the shot is to be rejected, and from each of the three remaining shots of 27.5 m (15 fathoms) or less additional specimens are to be cut and subjected to the breaking load. In such cases, each shot from which the satisfactory break specimens have been taken is to be rejoined and may be accepted, provided it passes the necessary proof test. All breaking test specimens are to be subsequently discarded.

Alternative test procedures to the required breaking test of chain of Grades 2a, 2b, 3a, and 3b may be accepted. This alternative procedure consists of additional mechanical tests and the preparation of macro sections on a two or three link sample of chain taken from every four lengths of 27.5 m (15 fathoms) or less of completed chain. In the case of Grade 3a or 3b chain, the two or three link sample is not to be taken from the same length of chain as that length from which the link to be mechanically tested, according to [12.1.10.3] below, is taken.

12.1.10.2. Proof test

Each shot of chain of 27.5 m (15 fathoms) length or less and the entire length of chain when manufactured in lengths longer than 27.5 m (15 fathoms) is to endure the applicable proof load as indicated in Table 2.12.6 (stud-link chain). Upon special request and when approved by INTLREG, detachable links may be subjected to a greater proof load than required for the chain.

After the proof test, the length of chain is to be ascertained and the chain carefully examined. Any link showing surface defects or excessive deformation is to be taken out and the chain repaired, after which the proof test is again to be performed and the chain reexamined. If one link breaks under the proof test, a joining link is to be inserted and the proof test again performed; if a second link breaks, the shot or length under test is to be rejected. For chain manufactured in long continuous lengths, if more than one link breaks under proof test, the entire length is to be rejected unless approved otherwise.

12.1.10.3. Mechanical tests on completed chain

One link from every four lengths of 27.5 m (15 fathoms) or less of Grade 2a flash butt welded chain delivered in as welded condition, and Grades 3a or 3b chain

is to be subjected to a set of mechanical tests consisting of one tension and three impact tests. The mechanical tests are to be carried out in presence of the Surveyor.

In the case of a welded chain, the above mentioned test specimens are to be taken from the base metal of the link opposite to the weldment. Additionally, three impact specimens are to be taken with notches at the weld center. The results of the tests are to be in compliance with the requirements given in Table 2.12.2. When the results of the original tests fail to meet the requirements, retests in accordance with Ch 1, Sec 2, [2.5.5] may be permitted.

12.1.10.4. Mechanical and breaking tests on chain produced in long continuous lengths

When manufacturing of the chain is carried out in lengths longer than 27.5 m (15 fathoms), the test frequency for the mechanical and breaking tests required in [12.1.10.1] and [12.1.10.3] above are to be based on tests at regular intervals in accordance with Table 2.12.4.

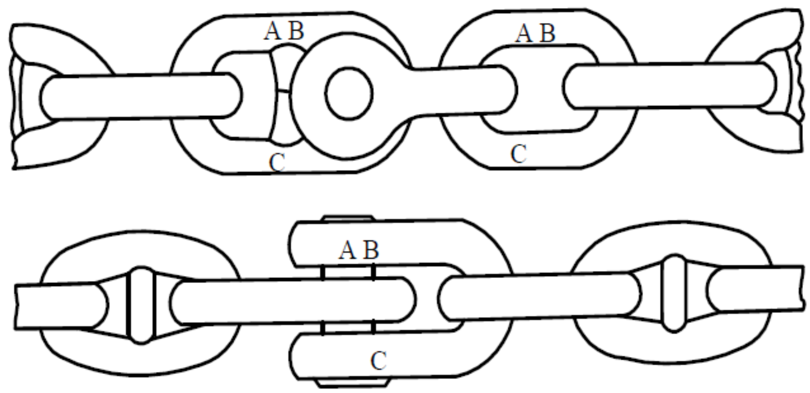
If an order or a fraction of an order is less than the stated length, then that length is to be subjected to all tests required for a full length.

Table 2.12.4:

Nominal chain size		Maximum specified length to obtain samples	
mm	in.	m	ft.
Min to 48	Min to 1-7/8	91	300
50 to 60	2 to 2-3/8	110	360
64 to 73	2-1/2 to 2-7/8	131	430
76 to 85	3 to 3-3/8	152	500
87 to 98	3-1/2 to 3-7/8	175	575
102 to 111	4 to 4-3/8	198	650

12.1.11. **Marking for chain**

The shackles and the end links of each length and one link in every 27.5 m (15 fathoms) of stud-link chain, made in a continuous length without joining shackles, are to be clearly stamped by the manufacturer as shown in Figure 2.12.4 in location A, B and C. When Kenter shackles are used, the marking is to be clearly stamped on the Kenter shackle and on both adjoining common links. Testing of any accessory to a break load for a lower grade chain, as permitted in [12.1.12.7] below is to be marked with the grade of the chain to which it is tested.



A	The Number of the Certificate (Furnished by the Surveyor)	78 PT1234
B	Signifying that the Chain has been satisfactorily tested to the INTLREG Requirements and the Grade as Applicable	IR/1, IR/2 or IR/3
C	Nominal Chain Diameter in mm or in. (When chain manufacturers emboss the chain diameter in a permanent manner by some suitable means such as forging or casting, marking of the chain diameter in location C may be omitted.)	

Figure 2.12.4: Marking for chain

12.1.12. **Anchor chain accessories**

12.1.12.1. Dimensions and dimensional tolerances

The dimensions of anchor chain accessories are to be in compliance with a recognized standard such as ISO 1704. The following tolerances are applicable to anchor chain accessories:

Nominal diameter : + 5%, -0%

Other dimensions : ± 2.5%

12.1.12.2. Material testing

Either from finished accessories or from special test bars, test specimens are to be taken as indicated in [12.1.12.3] and [12.1.12.4] below. In all cases, the specimens are to be taken from pieces representing the largest diameter accessory in the lot. A lot is defined as the accessories of the same grade, made from the same heat of steel and heat-treated in the same furnace charge where the diameter does not differ by more than 25 mm (1 in.). Test results are to satisfy

Table 2.12.2 or such other specification as may be specially approved. When the results of original tests fail to meet the requirements, retests may be permitted in accordance with Ch 1, Sec 2, [2.5.5] and [2.6.4],, as applicable.

12.1.12.3. Cast accessories

Test specimens may be taken from integrally or separately cast test blocks, heat-treated together with the accessories represented.

12.1.12.4. Forged accessories

Test specimens may be taken from a special forging, representative of the accessories in the lot. In such cases, the special forging is to be subjected to approximately the same amount of working and reduction as the forging represented, and is to be heat-treated with the forgings represented.

12.1.12.5. Inspection

In order to assure freedom from injurious surface defects, all accessories are to be thoroughly inspected by magnetic particle or other suitable method. Special attention is to be given to welds.

12.1.12.6. Hardness test

All accessories are to be subjected to a Brinell hardness test to meet the following:

Table 2.12.5

Grade	**Brinell Hardness Number minimum10 mm ball, 3000 kg load**
1	120
2	145
3	207

12.1.12.7. Break test

Break tests are to be conducted on 1 out of 25 accessories (or 1 out of 50 in the case of Kenter shackles) representative of the same type, grade and heat treatment procedure, but not essentially representative of each heat of steel, heat treatment charge or individual purchase order. When the range of Brinell hardness readings of these accessories in the batch exceed 30 Brinell hardness numbers, the accessories represented by the lowest and highest Brinell hardness readings are to be tested. This requirement may be waived, when the range of properties represented by the Brinell hardness numbers is established to the satisfaction of the Surveyor. The Surveyor may reduce the number of break tests for accessories from the same lot ,Refer [12.1.12.2], to a minimum of two per lot. All parts of the accessory subjected to a break test required by this subparagraph are to be subsequently discarded, except where further use is permitted by [12.1.12.8] below.

12.1.12.7.1 Use of break tested parts

Where it is demonstrated by either one of the following methods that the accessories can endure at least 140% of the breaking test load as tabulated in Table 2.12.6 for the chain in which they are intended, such accessories may be used in service provided:

- The material of the accessories is of higher grade than the chain (e.g., grade 3 accessories of grade 2 size in grade 2 chain), or
- Where an accessory of increased dimension is specially approved for the particular application and a procedure test is completed at 140% of the Table 2.12.6 break test load. All parts of the accessories used in this procedure test are to be subsequently discarded.

In any case, each accessory requiring a break test is to be tested to 100% of the Table 2.12.6 break load for the chain in which it is intended to be used.

12.1.12.8. Proof tests

In accordance with [12.1.10.2,] each accessory is to be undergo to a proof test.

12.1.12.9. Markings

On each accessory, the certificate number, **INTLREG/Chain Grade**, and nominal chain diameter are to be steel die stamped. The stamping of the nominal chain diameter may be omitted, provided the nominal chain diameter is cast or forged into the accessory. Markings are to be positioned in such a manner as to be readily visible when completely assembled together with the chain.

12.1.13. **Unstudded short-link chain**

12.1.13.1. General

Unstudded short-link chain is to meet the requirements specified in [12.1.2] and [12.1.6]. Material is to be in line with the manufacturer's specification which is to be the equivalent of normal strength Grade 1 requirements of Table 2.12.2.

12.1.13.2. Testing

Breaking and proof testing are to be compliant with [12.1.10] and subjected to the applicable testing loads as detailed in Table 2.12.7.

12.1.13.3. Marking

One link, including the end link in every 4.5 m (2.5 fathoms), is to be steel die stamped by the manufacturer as prescribed in locations A, B and C as shown in Figure 2.12.3. In special cases, shots of relatively small size may be marked or stenciled in lieu of die stamping or the markings may be shown on a metal tag attached at every 4.5 m (2.5 fathoms).

Table 2.12.6 (a): Stud-link anchor-chain proof and break tests (SI Units)

Chain Diameter mm	**Length of Five Links** mm	**Normal Strength**		**High Strength**		**Extra-high Strength**		**Mass kilograms per 27.5 meters**, Kg
		Grade 1		**Grade 2**		**Grade 3**		
		Proof Load, kN	Breaking Load, kN	Proof Load, kN	Breaking Load, kN	Proof Load, kN	Breaking Load, kN	
12.5	275	46.1	65.7	65.7	92.2	92.2	132.4	110
14	308	57.9	82.4	82.4	115.7	115.7	164.8	130
16	352	75.5	106.9	106.9	150.0	150.0	215.7	170
17.5	385	89.3	127.5	127.5	179.5	179.5	260.8	180
19	418	104.9	150.0	150.9	210.8	210.8	301.1	220
20.5	451	122.6	174.6	174.6	244.2	244.2	349.1	260
22	484	140.2	200.1	200.1	280.5	280.5	401.1	300

Chain Diameter mm	Length of Five Links mm	Normal Strength Grade 1 Proof Load, kN	Normal Strength Grade 1 Breaking Load, kN	High Strength Grade 2 Proof Load, kN	High Strength Grade 2 Breaking Load, kN	Extra-high Strength Grade 3 Proof Load, kN	Extra-high Strength Grade 3 Breaking Load, kN	Mass kilograms per 27.5 meters, Kg
24	528	166.7	237.3	237.3	332.4	332.4	475.6	340
26	572	194.2	277.5	277.5	389.3	389.3	556.0	420
28	616	224.6	320.7	320.7	449.1	449.1	642.3	480
30	660	256.9	367.7	367.7	513.9	513.9	734.5	550
32	704	291.3	416.8	416.8	582.5	582.5	832.6	610
34	748	327.5	467.8	467.8	655.1	655.1	936.5	700
36	792	365.8	522.7	522.7	731.6	731.6	1049.3	790
38	836	406.0	580.6	580.6	812.0	812.0	1157.2	880
40	880	448.2	640.4	640.4	896.3	896.3	1284.7	970
42	924	492.3	703.1	703.1	980.7	980.7	1402.3	1070
44	968	538.4	768.8	768.8	1078.7	1078.7	1539.6	1170
46	1012	585.5	836.5	836.5	1167.0	1167.0	1676.9	1270
48	1056	635.5	908.1	908.1	1274.9	1274.9	1814.2	1380
50	1100	686.5	980.7	980.7	1372.9	1372.9	1961.3	1480
52	1144	739.4	1059.1	1059.1	1480.8	1480.8	2108.4	1600
54	1188	794.3	1137.6	1137.6	1588.7	1588.7	2265.3	1720
56	1232	851.2	1216.0	1216.0	1706.4	1706.4	2432.0	1850
58	1276	909.1	1294.5	1294.5	1814.2	1814.2	2598.8	1990
60	1320	968.9	1382.7	1382.7	1941.7	1941.7	2765.5	2120
62	1364	1029.7	1471.0	1471.0	2059.4	2059.4	2942.0	2250
64	1408	1098.3	1559.3	1559.3	2186.9	2186.9	3128.3	2440
66	1452	1157.2	1657.3	1657.3	2314.4	2314.4	3304.8	2590
68	1496	1225.8	1745.6	1745.6	2451.7	2451.7	3501.0	2750
70	1540	1294.5	1843.7	1843.7	2579.1	2579.1	3687.3	2910
73	1606	1392.5	1990.7	1990.7	2794.9	2794.9	3991.3	3180
76	1672	1500.4	2147.6	2147.6	3010.6	3010.6	4295.3	3470
78	1716	1578.9	2255.5	2255.5	3157.7	3157.7	4501.3	3650
81	1782	1686.7	2412.4	2412.4	3383.3	3383.3	4824.9	3930
84	1848	1804.4	2579.1	2579.1	3608.8	3608.8	5158.3	4250
87	1914	1922.1	2745.9	2745.9	3854.0	3854.0	5501.5	4560
90	1980	2049.6	2922.4	2922.4	4089.4	4089.4	5844.8	4860
92	2024	2128.0	3040.1	3040.1	4256.1	4256.1	6080.1	5100
95	2090	2255.5	3226.4	3226.4	4511.0	4511.0	6443.0	5400
97	2134	2343.8	3344.1	3344.1	4677.8	4677.8	6688.1	5670
98	2156	2383.0	3402.9	3402.9	4766.0	4766.0	6815.6	5750
100	2200	2471.3	3530.4	3530.4	4942.6	4942.6	7060.8	6010
102	2244	2559.5	3657.9	3657.9	5119.1	5119.1	7315.8	6250

Chain Diameter mm	**Length of Five Links** mm	**Normal Strength**		**High Strength**		**Extra-high Strength**		**Mass kilograms per 27.5 meters**, Kg
		Grade 1		**Grade 2**		**Grade 3**		
		Proof Load, kN	Breaking Load, kN	Proof Load, kN	Breaking Load, kN	Proof Load, kN	Breaking Load, kN	
105	2310	2696.8	3854.0	3854.0	5393.7	5393.7	7698.2	6600
107	2354	2785.1	3981.5	3981.5	5570.2	5570.2	7963.0	6820
108	2376	2834.1	4040.3	4040.3	5658.4	5658.4	8090.4	6950
111	2442	2971.4	4246.3	4246.3	5942.8	5942.8	8482.8	7290
114	2508	3108.7	4442.4	4442.4	6227.2	6227.2	8894.6	7640
117	2574	3255.8	4648.4	4648.4	6511.6	6511.6	9296.7	7980
120	2640	3492.9	4854.3	4854.3	6805.8	6805.8	9718.4	8310
122	2684	3501.0	5001.4	5001.4	7001.9	7001.9	9993.0	8620
124	2728	3599.0	5138.7	5138.7	7198.1	7198.1	10277.4	8920
127	2794	3746.1	5354.4	5354.4	7492.3	7492.3	10708.9	9380
130	2860	3903.0	5570.2	5570.2	7796.3	7796.3	11140.4	9840
132	2904	4001.1	5717.3	5717.3	8002.2	8002.2	11424.7	10140
137	3014	4256.1	6080.1	6080.1	8512.2	8512.2	12160.2	10910
142	3124	4520.9	6452.8	6452.8	9031.9	9031.9	12905.6	11670
147	3234	4785.6	6835.2	6835.2	9561.5	9561.5	13660.7	12440
152	3344	5050.4	7217.7	7217.7	10100.8	10100.8	14425.6	13200
157	3454	5325.0	7600.2	7600.2	10640.2	10640.2	15200.3	14000
162	3564	5599.6	8002.2	8002.2	11199.2	11199.2	15994.6	14700

Note: The weight of chain is not to be more than $2^1/_2$ % under the weight specified.

Table 2.12.6 (b): Stud-link anchor-chain proof and break tests (MKS Units)

Chain Diameter mm	Length of Five Links mm	Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass kilograms per 27.5 meters, Kg
		Proof Load, kgf	Breaking Load, kgf	Proof Load, kgf	Breaking Load, kgf	Proof Load, kgf	Breaking Load, kgf	
12.5	275	4700	6700	6700	9400	9400	13500	110
14	308	5900	8400	8400	11800	11800	16800	130
16	352	7700	10900	10900	15300	15300	22000	170
17.5	385	9100	13000	13000	18300	18300	26100	180
19	418	10700	15300	15300	21500	21500	30700	220
20.5	451	12500	17800	17800	24900	24900	35600	260
22	484	14300	20400	20400	28600	28600	40900	300
24	528	17000	24200	24200	33900	33900	48500	340
26	572	19800	28300	28300	39700	39700	56700	420
28	6126	22900	32700	32700	45800	45800	65500	480
30	660	26200	37500	37500	52400	52400	74900	550
32	704	29700	42500	42500	59400	59400	84900	610
34	748	33400	47700	47700	66800	66800	95500	700
36	792	37300	53300	53300	74600	74600	107000	790
38	836	41400	59200	59200	82800	82800	118000	880
40	880	45700	65300	65300	91400	91400	131000	970
42	924	50200	71700	71700	100000	100000	143000	1070
44	968	54900	78400	78400	110000	110000	157000	1170
46	1012	59700	85300	85300	119000	119000	171000	1270
48	1056	64800	92600	92600	130000	130000	185000	1380
50	1100	70000	100000	100000	140000	140000	200000	1480
52	1144	75400	108000	108000	151000	151000	215000	1600
54	1188	81000	116000	116000	162000	162000	231000	1720
56	1232	86800	124000	124000	174000	174000	248000	1850
58	1276	92700	132000	132000	185000	185000	265000	1990
60	1320	98800	141000	141000	198000	198000	282000	2120
62	1364	105000	150000	150000	210000	210000	300000	2250
64	1408	112000	159000	159000	223000	223000	319000	2440
66	1452	118000	169000	169000	236000	236000	337000	2590
68	1496	125000	178000	178000	250000	250000	357000	2750
70	1540	132000	188000	188000	263000	263000	376000	2910
73	1606	142000	203000	203000	285000	285000	407000	3180
76	1672	153000	219000	219000	307000	307000	438000	3470
78	1716	161000	230000	230000	322000	322000	459000	3650
81	1782	172000	246000	246000	345000	345000	492000	3930
84	1848	184000	263000	263000	368000	368000	526000	4250
87	1914	196000	280000	280000	393000	393000	561000	4560

Chain Diameter mm	Length of Five Links mm	Normal Strength Grade 1		High Strength Grade 2		Extra-high Strength Grade 3		Mass kilograms per 27.5 meters, Kg
		Proof Load, kgf	Breaking Load, kgf	Proof Load, kgf	Breaking Load, kgf	Proof Load, kgf	Breaking Load, kgf	
90	1980	209000	298000	298000	417000	417000	596000	4860
92	2024	217000	310000	310000	434000	434000	620000	5100
95	2090	230000	329000	329000	460000	460000	657000	5400
97	2134	239000	341000	341000	477000	477000	682000	5670
98	2156	243000	347000	347000	486000	486000	695000	5750
100	2200	252000	360000	360000	504000	504000	720000	6010
102	2244	261000	373000	373000	522000	522000	746000	6250
105	2310	275000	393000	393000	550000	550000	785000	6600
107	2354	284000	406000	406000	568000	568000	812000	6820
108	2376	289000	412000	412000	577000	577000	825000	6950
111	2442	303000	433000	433000	606000	606000	865000	7290
114	2508	317000	453000	453000	635000	635000	907000	7640
117	2574	332000	474000	474000	664000	664000	948000	7980
120	2640	347000	495000	495000	694000	604000	991000	8310
122	2684	357000	510000	510000	714000	714000	1019000	8620
124	2728	367000	524000	524000	734000	734000	1048000	8920
127	2794	382000	546000	546000	764000	764000	1092000	9380
130	2860	398000	568000	568000	795000	795000	1136000	9840
132	2904	408000	583000	583000	816000	816000	1165000	10140
137	3014	434000	620000	620000	868000	868000	1240000	10910
142	3124	461000	658000	658000	921000	921000	1316000	11670
147	3234	488000	697000	697000	975000	975000	1393000	12440
152	3344	515000	736000	736000	1030000	1030000	1471000	13200
157	3454	543000	775000	775000	1085000	1085000	1550000	14000
162	3564	571000	816000	816000	1142000	1142000	1631000	14700

Note: The weight of chain is not to be more than $2^1/_2$ % under the weight specified.

Table 2.12.6 (c): Stud-link Anchor-chain Proof and Break Tests (US Units)

Chain Diameter inch.	Length of Five Links		Normal Strength		High Strength		Extra-high Strength		Mass pounds per 15 fathoms, lb.
			Grade 1		Grade 2		Grade 3		
	ft.	inch.	Proof Load, lbf	Breaking Load, lbf	Proof Load, lbf	Breaking Load, lbf	Proof Load, lbf	Breaking Load, lbf	
1/2	-	11	10700	15300	15300	21400	21400	30600	230
9/16	1	0 3/8	13500	19300	19300	27000	27000	38600	290
5/8	1	1 3/4	16600	23700	23700	33200	33200	47500	370
11/16	1	3 1/8	20100	28600	28600	40100	40100	57300	410
3/4	1	4 1/2	23800	34000	34000	47600	47600	68000	480
13/16	1	5 7/8	27800	39800	39800	55700	55700	79500	570
7/8	1	7 1/4	32200	46000	46000	64400	64400	91800	660
15/16	1	8 5/8	36800	52600	52600	73700	73700	105000	760
1	1	10	41800	59700	59700	83600	83600	119500	860
1 1/16	1	11 3/8	47000	67200	67200	94100	94100	135000	970
1 1/8	2	0 3/4	52600	75000	75000	105000	105000	150000	1080
1 3/16	2	2 1/8	58400	83400	83400	116500	116500	167000	1220
1 1/4	2	3 1/2	64500	92200	92200	129000	129000	184000	1350
1 5/16	2	4 7/8	70900	101500	101500	142000	142000	203000	1490
1 3/8	2	6 1/4	77500	111000	111000	155000	155000	222000	1630
1 7/16	2	7 5/8	84500	120500	120500	169000	169000	241000	1780
1 1/2	2	9	91700	131000	131000	183500	183500	262000	1940
1 9/16	2	10 3/8	99200	142000	142000	198500	198500	284000	2090
1 5/8	2	11 3/4	108000	153000	153000	214000	214000	306000	2240
1 11/16	3	1 1/8	115000	166500	166500	229000	229000	327000	2410
1 3/4	3	2 1/2	123500	176000	176000	247000	247000	352000	2590
1 13/16	3	3 7/8	132000	188500	188500	264000	264000	377000	2790
1 7/8	3	5 1/4	140500	201000	201000	281000	281000	402000	2980
1 15/16	3	6 5/8	149500	214000	214000	299000	299000	427000	3180
2	3	8	159000	227000	227000	318000	318000	454000	3360
2 1/16	3	9 3/8	168500	241000	241000	337000	337000	482000	3570
2 1/8	3	10 3/4	178500	255000	255000	357000	357000	510000	3790
2 3/16	4	0 1/8	188500	269000	269000	377000	377000	538000	4020
2 1/4	4	1 1/2	198500	284000	284000	396000	396000	570000	4250
2 5/16	4	2 7/8	209000	299000	299000	418000	418000	598000	4490
2 3/8	4	4 1/4	212000	314000	314000	440000	440000	628000	4730
2 7/16	4	5 5/8	231000	330000	330000	462000	462000	660000	4960
2 1/2	4	7	242000	346000	346000	484000	484000	692000	5270
2 9/16	4	8 3/8	254000	363000	363000	507000	507000	726000	5540
2 5/8	4	9 3/4	265000	379000	379000	530000	530000	758000	5820
2 11/16	4	11 1/8	277000	396000	396000	554000	554000	792000	6110
2 3/4	5	0 1/2	289000	413000	413000	578000	578000	826000	6410
2 13/16	5	1 7/8	301000	431000	431000	603000	603000	861000	6710
2 7/8	5	3 1/4	314000	449000	449000	628000	628000	897000	7020
2 15/16	5	4 5/8	327000	467000	467000	654000	654000	934000	7330

Chain Diameter inch.	**Length of Five Links**		**Normal Strength Grade 1**		**High Strength Grade 2**		**Extra-high Strength Grade 3**		**Mass pounds per 15 fathoms**, lb.
	ft.	inch.	Proof Load, lbf	Breaking Load, lbf	Proof Load, lbf	Breaking Load, lbf	Proof Load, lbf	Breaking Load, lbf	
3	5	6	340000	485000	485000	679000	679000	970000	7650
3 1/16	5	7 3/8	353000	504000	504000	705000	705000	1008000	7980
3 1/8	5	8 3/4	366000	523000	523000	732000	732000	1046000	8320
3 3/16	5	10 1/8	380000	542000	542000	759000	759000	1084000	8660
3 1/4	5	11 1/2	393000	562000	562000	787000	787000	1124000	9010
3 5/16	6	0 7/8	407000	582000	582000	814000	814000	1163000	9360
3 3/8	6	2 1/4	421000	602000	602000	843000	843000	1204000	9730
3 7/16	6	3 5/8	435000	622000	622000	871000	871000	1244000	10100
3 1/2	6	5	450000	643000	643000	900000	900000	1285000	10500
3 9/16	6	6 3/8	465000	664000	664000	929000	929000	1327000	10900
3 5/8	6	7 3/4	479000	685000	685000	958000	958000	1369000	11300
3 3/4	6	10 1/2	509000	728000	728000	1019000	1019000	1455000	12000
3 7/8	7	1 1/4	540000	772000	772000	1080000	1080000	1543000	12900
3 15/16	7	2 5/8	556000	794000	794000	1111000	1111000	1587000	13300
4	7	4	571000	816000	816000	1143000	1143000	1632000	13700
4 1/8	7	6 3/4	603000	862000	862000	1207000	1207000	1724000	14600
4 1/4	7	9 1/2	636000	908000	908000	1272000	1272000	1817000	15400
4 3/8	8	0 1/4	669000	956000	956000	1338000	1338000	1911000	16200
4 1/2	8	3	703000	1004000	1004000	1405000	1405000	2008000	17100
4 5/8	8	5 3/4	737000	1053000	1053000	1474000	1474000	2105000	18000
4 3/4	8	8 1/2	772000	1102000	1102000	1543000	1543000	2204000	18900
4 7/8	8	11 1/4	807000	1153000	1153000	1613000	1613000	2305000	19900
5	9	2	842000	1203000	1203000	1685000	1685000	2407000	20900
5 1/8	9	4 3/4	878000	1255000	1255000	1757000	1757000	2509000	22000
5 3/8	9	10 1/4	951000	1359000	1359000	1903000	1903000	2718000	24000
5 5/8	10	3 3/4	1026000	1466000	1466000	2052000	2052000	2932000	26100
5 3/4	10	6 1/2	1064000	1520000	1520000	2128000	2128000	3039000	27000
6	11	0	1140000	1629000	1629000	2280000	2280000	3257000	29100
6 1/8	11	2 3/4	1179000	1684000	1684000	2357000	2357000	3367000	30200
6 3/8	11	8 1/4	1256000	1795000	1795000	2512000	2512000	3589000	32400

Note: Also Refer [12.1.5].
The weight of chain is not to be more than $2^1/_2$ % under the weight specified.

Table 2.12.7: Unstudded Short-link Chain

Diameter of common links,	Breaking test		Proof test	
(mm)	(kN)	(kgf)	(kN)	(kgf)
6	11.6	1180	5.8	590
8	22.6	2300	11.3	1150
10	35.9	3660	17.9	1830
12	52.8	5380	26.4	2690
14	71.5	7290	35.8	3650
16	93.6	9540	46.8	4770
18	119.2	12150	59.9	6110
20	147.7	15060	74.4	7590
22	178.6	18210	89.7	9150
24	212.5	21670	106.5	10860
26	249.9	25480	125	12750
28	288.9	29460	144.5	14730
30	332.6	33920	166.8	16960
32	379.6	38710	189.5	19320
34	427.5	43590	213.6	21780
36	477.2	48660	239.3	24400
38	534.1	54460	267.1	27240

Table 2.12.7: Unstudded Short-link Chain (Continued)

Diameter of common links,	Breaking test	Proof test
(inch.)	(lbf)	(lbf)
$^{5}/_{16}$	5040	2520
$^{3}/_{8}$	7280	3640
$^{7}/_{16}$	10080	5040
$^{1}/_{2}$	13440	6720
$^{9}/_{16}$	16800	8400
$^{5}/_{8}$	20720	10360
$^{11}/_{16}$	25200	12600
$^{3}/_{4}$	30240	15120
$^{13}/_{16}$	35392	17696
$^{7}/_{8}$	40880	20440
$^{15}/_{16}$	47040	23520
1	53760	26880
$1^{1}/_{16}$	60480	30240
$1^{1}/_{8}$	67760	33880
$1^{3}/_{16}$	75712	37856
$1^{1}/_{4}$	84000	42000
$1^{5}/_{16}$	92400	46200
$1^{3}/_{8}$	101360	50680
$1^{7}/_{16}$	110880	55440
$1^{1}/_{2}$	120960	60480

12.1.1. **Material Hardness for Windlass-Wildcats and Gypsy Wheels**

a) Wear and Abrasion

For wear and abrasion considerations, the type of material used for windlass-wildcats and gypsy wheels will depend upon the grade of chain used in the system. Refer to ASTM F765, Standard Specification for Wildcats, Ship Anchor Chain and to API 2S Design of Windlass Wildcats for Floating Offshore Structures. These construction Standards contain a number of types of wildcats or gypsy wheels, from Type I, II, III, IV.

b) Approximate Hardness Values for Wildcats and Gypsy Wheels

ASTM Type	Steel Grade	Brinnel Hardness (approx.)
I and III	Medium Strength (ASTM A27)	150 HB
II and IV	High Strength (ASTM A148)	300 HB

Selection of the suitable material type has to be made in accordance with the chain grade applied.

Actual chain hardness is typically in the following ranges.

Chain Grade	Brinell Hardness
1	120 - 140
2	130 - 150
3	210 - 250

Typical hardness values of chain Grade 3 are in the range of 210 – 250 Brinell. Accordingly, Types II and IV are to be selected to avoid accelerated wear of the wildcat or gypsy wheel.

c) Cladding and Hard facing

Weld cladding or hard facing may be carried out to build up chain contact surfaces, if the chain fit is offset or wear has occurred during service. The carbon content and carbon equivalent influence the weldability of the material. Weld build-up procedures are to be properly qualified on material with similar weldability to the wildcat or gypsy wheel to be welded. Weld procedures are to be properly qualified and welding is to be carried out under controlled conditions, to the satisfaction of the attending Surveyor.

The aim hardness of weld build-up should be the same as the material base metal. A higher, build-up hardness, may be acceptable subject to the following restriction:

ASTM Type	Weld Build-up Maximum Increase in Brinell Hardness (approx.)
I and III	150 + 25 HB
II and IV	300 + 50 HB

SECTION 13 SEAMLESS-STEEL PRESSURE VESSELS

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13.4. Hydrostatic test 207
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13.6. Marking 207

13.1. General

The manufacturing material and the finished seamless pressure vessels are to be free from cracks, seams or other defects. Before the necking-down process, test specimens are to be cut from each cylinder, stamped with the identification mark of the Surveyor and receive all heat treatments along with the cylinders.

13.2. Tension test

From each cylinder a standard test specimen cut either longitudinally or circumferentially is to show the material to have a minimum tensile strength of 415 N/mm^2 (42 kgf/mm^2, 60,000 psi), maximum yield point of 70% of the tensile strength and a minimum elongation of 10% in 200 mm (8 “).

13.3. Flattening test

From each cylinder, a ring 200 mm (8“) long is to be cut and is to stand flattening without any signs of fracture until the outside distance over the parallel sides is not more than six times the thickness of the material.

13.4. Hydrostatic test

Each cylinder is to be subjected to a hydrostatic pressure of not less than one and one-half times the working pressure while immersed in a water jacket for a period of at least thirty seconds. The permanent volumetric expansion is not to exceed 5% of the total volumetric expansion at the recommended test pressure. This test is to be carried out without previously subjecting the cylinder to any pressure in excess of one-third of the working pressure.

13.5. Inspection

All cylinders are to be properly annealed and be free from dirt and scale. Before necking-down, the Surveyor is to examine the cylinders carefully for defects and gauge the cylinder walls to ensure that the thickness of the material is as per the approved plan.

13.6. Marking

Upon satisfactory compliance with the above requirements, the cylinders will be stamped **IR** with the identification mark of the Surveyor, the serial number, hydrostatic pressure and the date of acceptance.

SECTION 14 BOILER RIVET AND STAYBOLT STEEL AND RIVETS

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14.1. Process of manufacture

The steel is to be manufactured by one or more of the following process: open-hearth, basic-oxygen or electric furnace. When specially requested by the purchaser, all such bars and rivets will be inspected carefully at the mills by the Surveyor. They are to be defect free and have a workmanlike finish.

14.2. Marking and retests

14.2.1. Manufacturer’s markings

When loaded for shipment, the bars and rivets, are to be properly separated in bundles or containers marked with the name or brand of the manufacturer, the letter specifying the grade of steel and the heat number of identification.

14.2.2. INTLREG markings

The INTLREG markings, designating satisfactory compliance with the Rule requirements, and as provided by the Surveyor, are to be marked on the material or on each bundle or container near the marking specified in [14.2.1] above.

14.2.3. Retests

When the result of any of the physical tests specified for any of the material do not comply with the requirements two additional specimens may, at the request of the manufacturer, be taken from the same lot and tested in the manner specified, but in such case, both of the specimens must conform to the requirements. In the case of tension tests, this retest is to be allowed only when the percent of elongation attained is less than required.

14.3. Tensile properties

For tensile properties the material shall conform to the requirements given in Table 2.14.1.

Table 2.14.1: Tensile Properties

	Grade A	Grade B
Tensile Strength N/mm^2 (kgf/mm^2, psi)	310–380 (31.5–39, 45000–55000)	400–470 (41–48, 58000–68000)
Yield Point, min., N/mm^2 (kgf/mm^2, psi)	155 (16, 23000)	195 (20, 29000)
Elongation in 200 mm (8 in), min., %	27	22

14.4. Bending properties

The test specimen for Grade A steel is to stand being bent cold through 180 degrees flat on itself without cracking on the outside of the bent portion. The test specimen for Grade B steel is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows:

a) For material 19.1 mm (0.75 “) and under in diameter, around an inside diameter which is equal to one-half the diameter of the specimen;
b) For material over 19.1 mm (0.75 “) in diameter, around an inside diameter which is equal to the diameter of the specimen.

14.5. Test specimens

The tension test and bend test specimens are to be the full diameter of the bars as rolled and, in the case of rivet bars which have been cold-drawn, the test specimens shall be normalized before testing.

14.6. Number of tests

From each heat, two tension and two cold-bend tests are to be carried out.

14.7. Tests of finished rivets

14.7.1. Bending properties

The rivet shank of Grade A steel is to stand being bent cold through 180 degrees flat on itself without cracking on the outside of the bent portion. The rivet shank of Grade B steel is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as mentioned below:

i) for material 19.1 mm (0.75 in.) and under in diameter, around an inside diameter which is equal to the diameter of the shank;

j) for material over 19.1 mm (0.75 in.) in diameter, around an inside diameter which is equal to one and one-half times the diameter of the shank.

14.7.2. Flattening tests

While hot, the rivet head is to stand being flattened, to a diameter two and one-half times the diameter of the shank without cracking at the edges.

14.7.3. Number of tests

In each lot of rivets offered, three bend and three flattening tests are to be prepared from each size.

SECTION 15 BOILER AND SUPERHEATER TUBES

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15.1. Scope

15.1.1. The following specifications below details thirteen grades of super-heater tubes and boilers designated D, F, G, H, J, K, L, M, N, O, P, R, and S.

15.2. General

15.2.1. Grades D and F
Grades D and F deal with electric-resistance-welded tubes made of carbon steel and intended for boiler flues, boiler tubes, super-heater flues and safe ends. Grade F tubes are not suitable for safe-ending by forge-welding.

15.2.2. Grade G
Grade G covers electric-resistance-welded, steel boiler, and super-heater tubes intended for high-pressure service.

15.2.3. Grade H
Grade H covers seamless carbon-steel boiler tubes and super-heater tubes meant for high-pressure service.

15.2.4. Grade J
Grade J covers seamless medium carbon-steel boiler tubes and super-heater tubes, boiler flues including arch and stay tubes, and safe ends. Grade J tubes are not suitable for safe-ending by forge-welding.

15.2.5. Grades K, L and M
Grades K, L and M cover super-heater tubes and seamless carbon-molybdenum alloy-steel boiler.

15.2.6. Grades N, O and P
Grades N, O and P cover super-heater tubes and seamless chromium-molybdenum alloy-steel boiler.

15.2.7. Grades R and S
Grades R and S cover seamless austenitic stainless steel super-heater tubes.

15.2.8. ASTM Designation
The following Grades are in agreement with ASTM:

Table 2.15.1

Grade	ASTM Designation
D	A178, Grade A
F	A178, Grade C
G	A226
H	A192
J	A210, Grade A-1
K	A209, Grade T1
L	A209, Grade T1a
M	A209, Grade T1b
N	A213, Grade T11
O	A213, Grade T12
P	A213, Grade T22
R	A213, Grade TP321
S	A213, Grade TP347

15.3. Process of manufacture

15.3.1. Grades D, F, and G

The steel is to be manufactured by one or more of the following procedures: basic-oxygen furnace, open-hearth or electric furnace. Other processes may be specially considered, subject to such supplementary requirements or limits on application as will be specifically determined in each case. Grade G is to be killed steel. All tubes of Grade D, F, and G are to be manufactured by electric-resistance welding and are to be normalized at a temperature above the upper critical temperature.

15.3.2. Grades H, J, K, L, and M

The steel is to be killed steel manufactured by one or more of the following procedures: basic-oxygen furnace, open-hearth or electric furnace. For manufacturing tubes, the seamless process is to be used and is to be either hot finished or cold-drawn. Cold-drawn tubes are to be heat-treated by isothermal annealing or by full annealing at a temperature of 650°C (1200°F) or higher. Cold-drawn tubes of Grades H and J may also be heat treated by normalizing. Cold-drawn tubes of Grades K, L, and M may also be heat-treated by normalizing and tempering at 650°C (1200°F) or higher. Hot-finished Grades J and H tubes need not be heat-treated. Other hot-finished Grades K, L and M tubes are to be heat-treated at a temperature of 650°C (1200°F) or higher.

15.3.3. Grades N, O, and P

The steel is to be manufactured by the electric-furnace or other approved process, except that Grade N may be prepared by the basic oxygen process and Grade O by open hearth or basic-oxygen process. Tubes are to be produced by the seamless process and are to be either cold-drawn or hot-finished. All the material is to be furnished in the heat-treated condition. The heat treatment for Grades N and P is to consist of isothermal annealing, full annealing, or normalizing and tempering, as necessary to meet the requirements. The tempering temperature following normalizing is to be 650°C (1200°F) or higher for Grade N and 680°C (1250°F) or higher for Grade P. The hot-rolled or cold-drawn tubes Grade O, as a final heat treatment, are to be process annealed at 650°C (1200°F) to 730°C (1350°F).

15.3.4. Grades R and S

The steel is to be manufactured by the electric-furnace or other approved process. Tubes are to be made by the seamless process and are to be either cold-drawn or hot-finished. Tubes are to be solution annealed at a minimum of 1040°C (1900°F) after the completion of mechanical working, and then quenched in water or rapidly cooled by other means. Solution annealing above 1065°C (1950°F) may damage resistance to inter-granular corrosion after subsequent exposure to sensitizing conditions. Subsequent to the initial high temperature solution anneal, a stabilization or resolution anneal at 815°C to 900°C (1500°F to 1650°F) may be used to meet the requirements.

15.4. Marking

Identification markings are to be legibly stenciled on each tube 31.8 mm (1.25 in.) in outside diameter or over, provided the length is not below 900 mm (3 ft.). For Grades R and S tubes, the ID tags, marking fluid and securing wire are not to have any harmful metal or metal salt such as lead, zinc or copper, which cause corrosive attack upon heating. For tubes less than 31.8 mm (1.25 in.) in outside diameter and all tubes less than 900 mm (3 ft.) in length, the necessary markings are to be provided on a tag securely attached to the bundle or box in which the tubes are shipped. The markings are to comprise of: the name or brand of the manufacturer; either the INTLREG grade or the ASTM designation and grade for the material from which the tube is made; the hydrostatic test pressure or the letters NDET; whether electric-resistance-welded or seamless, hot-finished or cold-drawn; also the INTLREG markings as furnished by the Surveyor and specifying satisfactory compliance with the Rule requirements. The markings are to be arranged as mentioned below:

- The name or brand of the manufacturer;
- The INTLREG markings from the Surveyor;

- The test pressure or the letters Non-Destructive Electric Test (NDET);
- The INTLREG grade or ASTM designation and type or grade;
- The method of forming (i.e., seamless cold-drawn or hot-finished or electric-resistance-welded).

15.5. Chemical composition

15.5.1. Ladle analysis

In order to evaluate the percentages of the elements specified, an analysis of each heat is to be carried out. The chemical composition thus determined is to be reported to the Surveyor and is to comply with the requirements of Table 2.15.1.

Table 2.15.1: Chemical composition for tubes

INTLREG Grades	Maxima or Permissible range of Chemical Composition in %							
	C	Mn	P	S	Si	Cr	Mo	Ni
D	0.06-0.18	0.27-0.63	0.035	0.035	–	–	–	–
F	0.35	0.80	0.035	0.035	–	–	–	–
G	0.06-0.18	0.27-0.63	0.050	0.060	0.25	–	–	–
H	0.06-0.18	0.27-0.63	0.035	0.035	0.25	–	–	–
J	0.27	0.93	0.035	0.035	0.10 (min)	–	–	–
K	0.1 – 0.2	0.30-0.80	0.025	0.025	0.1 – 0.5	–	0.44-0.65	–
L	0.15-0.25	0.30-0.80	0.025	0.025	0.1 – 0.5	–	0.44-0.65	–
M	0.14	0.30-0.80	0.025	0.025	0.1 – 0.5	–	0.44-0.65	–
N	0.05-0.15	0.30-0.60	0.025	0.025	0.5 – 1.0	1.0-1.5	0.44-0.65	–
O	0.05-0.15	0.30-0.60	0.025	0.025	0.50	0.8-1.25	0.44-0.65	–
P	0.05-0.15	0.30-0.60	0.025	0.025	0.50	1.9-2.6	0.87-1.13	–
R(1)	0.08	2.00	0.040	0.030	0.75	17.0-20.0	–	9.0 -13.0
S(2)	0.08	2.00	0.040	0.030	0.75	17.0-20.0	–	9.0 -13.0

Note:

1. Grade R is to contain a titanium content of not more than 0.60% and not less than five times the carbon content.

2. Grade S is to contain a columbium (niobium) plus tantalum content of not more than 1.00% and not less than ten times the carbon content.

15.6. Check analysis

15.6.1. General

For Grades K, L, M, N, O, P, R, and S, a check analysis is required. Check analysis for other grades may also be made where required by the purchaser. The check analysis is to be as per the following requirements and the chemical composition is to be in compliance with the requirements in Table 2.15.1.

15.6.2. Samples

Samples for check analysis are to be taken by drilling several points around each tube selected for analysis or, when taken from the billet, they are to be obtained by drilling parallel to the axis at any point midway between the outside and center of the piece, or the samples may be taken as prescribed in ASTM E59 (Method of Sampling Steel for Determination of Chemical Composition).

15.6.2.1. Grades D, F, G, and H

For these Grades, the supplier is required to conduct the check analysis from one tube per heat or from one tube per lot.

Note: A lot consists of 250 tubes of sizes 76.2 mm (3.0 in.) and under or 100 tubes of sizes over 76.2 mm (3.0 in.) prior to cutting length.

15.6.2.2. Grades J, K, L, M, N, O, P, R, and S

For these Grades, the supplier needs to carry out the check analysis from one tube or billet per heat.

15.6.2.3. Retests for seamless tubes

If the original test for check analysis for Grades H, J, K, L, M, N, O, P, R, or S tubes fails retesting of two additional billets or tubes are to be done. Both the retests are to meet the requirements; else rest of the material in the heat or lot is to be rejected or, at the option of the supplier, each billet or tube may be individually tested for acceptance.

15.6.2.4. Retests for electric-resistance-welded tubes

For Grades D, F, or G tubes where the original test for check analysis fails, retests of two additional lengths of flat-rolled stock or tubes are to be carried out. Both retests, for the elements in question, are to meet the requirements. Otherwise, the remaining material in the heat or lot is to be rejected or at the option of the supplier, each length of flat-rolled stock or tube may be individually tested for acceptance.

15.7. Mechanical tests required

15.7.1. The type and number of mechanical tests are to be in line with the Table 2.15.2. For a description and requirements of each test, Refer [15.9] through [15.17]. For retests Refer [15.18].

Table 2.15.2: Mechanical tests

Grade	Type of test	Number of tests
D	Flattening	One test on specimens from each of two tubes from each lot (1) or fraction thereof and from each 610 m (2000 ft.) or fraction thereof of safe-end material.
	Flanging	As for flattening test.
	Crushing	As for flattening test when required by the Surveyor.
	Reverse Flattening	One test per 460 m (1500 ft.) of finished welded tubing.
	Hydrostatic or NDET(3)	All tubes.
F	Flattening	One test on specimens from each of two tubes from each lot (1) or fraction thereof.
	Flanging	As for flattening test.

	Reverse Flattening	One test per each 460 m (1500 ft.) of finished welded tubing.
	Tension	As for flattening test.
	Hydrostatic or NDET (3)	All tubes.
G	Flattening	One test on specimens from each of two tubes from each lot (1) or fraction thereof.
	Flanging	As for flattening test.
	Reverse Flattening	One test per each 460 m (1500 ft.) of finished welded tubing.
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET(3)	All tubes.
H	Flattening	One test on specimens from each end of two tubes from each lot(1) or fraction thereof but not the same tube used for the flaring test.
	Flaring	As for flattening test, but not the same tube used for the flattening test.
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat-treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET(3)	All tubes.
J, K, L, M, N, O, P	Flattening	One test on specimens from each end of one finished tube per lot(2), but not the same tube used for the flaring test.
	Flaring	One test on specimens from each end of one finished tube per lot(2), but not the same tube used for flattening test.
	Tension	One test on one specimen from one tube from each lot(2)
	Hardness	One Brinell or Rockwell hardness determination on 5% of the tubes when heat-treated in a batch-type furnace or 1% of the tubes when heat-treated in a continuous furnace, but in no case less than 5 tubes.
	Hydrostatic or NDET (3)	All tubes.
R, S	Flattening	One test on specimens from each end of one finished tube per lot(2), but not the same tube used for the flaring test.
	Flaring	One test on specimens from each end of one finished tube per lot(2), but not the same tube used for flattening test.
	Tension	One test on one specimen for each lot of 50 tubes or less. One test on one specimen from each of two tubes for lots(4) of more than 50 tubes.
	Hardness	One Brinell or Rockwell hardness determination on two tubes from each lot(4)
	Hydrostatic or NDET(3)	All tubes.
Notes:		

1. A lot consists of 250 tubes for sizes 76.2 mm (3.0 in.) and under and of 100 tubes for sizes over 76.2 mm (3.0 in.) before cutting to length.
2. Here the term lot applies to all the tubes before cutting to length of the same nominal size and wall thickness which are taken from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot is to include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot is to be determined from the size of the tubes as specified Table 2.15.3 below.

Table 2.15.3: Size of Lot

<table>
<tr><th colspan="2">Size of tube</th><th rowspan="2">Size of lot</th></tr>
<tr><th>Outside Diameter
in mm (in.)</th><th>Wall Thickness
in mm (in.)</th></tr>
<tr><td>OD ≥ 50.8 (2.0)</td><td>T ≥ 5.1 (0.2)</td><td>Not more than 50 tubes</td></tr>
<tr><td>25.4 (1.0) OD < 50.8 (2.0)</td><td rowspan="2">T < 5.1 (0.2)</td><td rowspan="2">Not more than 75 tubes</td></tr>
<tr><td>OD ≤ 25.4 (1.0)</td></tr>
<tr><td>OD ≤ 25.4 (1.0)</td><td>-</td><td>Not more than 125 tubes</td></tr>
<tr><td colspan="3">In lieu of the hydrostatic pressure test, a nondestructive electric test may be used. Refer 15.17 below</td></tr>
<tr><td colspan="3">The term lot, used here, applies to all tubes prior to cutting to length of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a heat-treatment lot is to include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot is to include all tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at heat and furnace speed.</td></tr>
</table>

15.8. Test specimens

15.8.1. Selection of specimens

Test specimens necessary for the flanging, flattening, flaring, tension, crushing and reverse flattening tests are to be taken from the ends of drawn tubes after any heat treatment and straightening, but before upsetting, expanding, swaging or other forming operations, or being cut to length. They are to be smooth on the ends and free from defects and burrs.

15.8.2. Tension test specimens

If practicable and desirable tension tests may be conducted on full sections of the tubes up to the capacity of the testing machine. For larger-size tubes, the tension test specimen is to comprise of a strip cut longitudinally from the tube not flattened between gauge marks. The sides of this specimen are to be parallel between gauge marks; the width, regardless of the thickness, is to be 25 mm (1 in.); the gauge length is to be 50 mm (2 in.).

15.8.3. All specimens are to be tested at room temperature.

15.9. Tensile properties

The material is to be in compliance the requirements as to tensile properties in the grades specified in Table 2.15.4.

Table 2.15.4: Tensile properties of tubes

Grade	**Tensile Strength**, min			**Yield Strength**, min			Elongation in 50 mm (2in.), min %	Deduction in elongation for each 0.8 mm (0.031in.) decrease in wall thickness below 7.9 mm (0.313 in.) on longitudinal strip tests
	N/mm^2	Kgf/mm^2	psi	N/mm^2	Kgf/mm^2	psi		
F	415	42	60000	225	26	37000	30	1.50
G, H (Refer Note)	325	33	47000	180	18.5	26000	35	-
J	415	42	60000	255	26	37000	30	1.50
K	380	39	55000	205	21	30000	30	1.50
L	415	42	60000	220	22.5	32000	30	1.50
M	365	37.5	53000	195	19.5	28000	30	1.50
N, O, P	415	42	60000	205	21	30000	30	1.50
R,S	519	53	75000	205	21	30000	35	-
Note: For these grades, no tensile tests are required and the data is given for design purposes only.								

15.10. Flattening test

15.10.1. Seamless and electric-resistance-welded tubes

For all Grades of tubing, a section of tube, not less than 65 mm (2.5 in.) in length for seamless and not less than 100 mm (4 in.) in length for welded, is to be flattened cold between parallel plates in two steps. During first step, which is a test for ductility, no cracks or breaks on the outside, inside or end surfaces of seamless tubes, or on the outside or inside surfaces of electric-resistance-welded tubes is to take place until the distance between the plates is less than the value *H* obtained from the following equation:

$$H = \frac{(1+e)\, t_{sp}}{\left(e + {t_{sp}}/{D}\right)}$$

Where,

H = distance between flattening plates, in mm (in.);
t_{sp} = specified wall thickness of tube, in mm (in.);
D = specified outside diameter of tube, in mm (in.);
e = deformation per unit length, constant for a given grade as follows:
= 0.09 for Grades D, G, H, R, and S
= 0.08 for Grades K, L, M, N, O, and P
= 0.07 for Grades F and J

In the second step, which is a test for soundness, the flattening is to be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of unfinished weld that is revealed during the entire flattening test is to be reason for rejection. Superficial ruptures that are consequences of surface imperfections are not to be reasons for rejection.

15.10.2. Electric-resistance-welded tubes

In the case of Grades D, F, and G tubes, the weld is to be placed at 90 degrees from the line of direction of the applied force.

15.11. Reverse flattening test

15.11.1. For Grades D, F, and G tubes, a section of 100 mm (4 in.) length is to be picked from every 460 m (1500 ft.) of finished welded tubing and it is to be split longitudinally, 90 degrees on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There is to be no indication of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

15.12. Flange test

15.12.1. For Grades D, F, and G tubes, a section of tube is to be capable of having a flange turned over at a right angle to the body of the tube without cracking or developing defects. The width of the flange is not to be less than the following.

Table 2.15.5: Width of flange

Outside diameter of tube, mm (in.)	**Width of flange**	
	Grade D, G	**Grade F**
> 19.1 mm (0.75 in.) ≤ 63.5 mm (2.50 in.)	15% of outside diameter	75% of that required for Grades D and G
> 63.5 mm (2.5 in.) ≤ 95.3 mm (3.75 in.)	12.5 % of outside diameter	
> 95.3 mm (3.75 in.)	10% of outside diameter	

15.13. Flaring test

For Grades H, J, K, L, M, N, O, P, R, and S tubes, a section of tube almost 100 mm (4 in.) in length is to stand being flared with a tool having a 60-degree included angle until the tube at the mouth of the flare has been expanded to the percentages given in Table 2.15.6, without developing defects or cracks etc.

Table 2.15.6.

Ratio of Inside Diameter to Outside Diameter (Refer Note)	**Minimum Expansion of Inside Diameter, %**	
	H, J, K, L, M, R, S	**N, O, P**
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

Note:

While determining the ratio of inside diameter to outside diameter, the inside diameter is to be considered as the actual mean inside diameter of the material to be tested.

15.14. Crush test

15.14.1. when required by the Surveyor, crushing tests are to be carried out , for Grade D tubes, on sections of tube 65 mm (2.5 in.) in length which are to stand crushing longitudinally, without splitting, cracking or opening at the weld, as shown in the Table 2.15.7. For tubing less than 25.4 mm (1.0 in.) in outside diameter, the length of the specimen is to be 2½ times the outside diameter of the tube. Slight surface checks are not to be reason for rejection.

Table 2.15.7.

Wall thickness	Height of section after crushing
≤ 3.43 mm (0.135 in.)	19.1 mm (0.75 in.) or until outside folds are in contact
> 3.43 mm (0.135 in.)	31.8 mm (1.25 in.)

15.15. Hardness test

15.15.1. Type of test

Hardness tests are to be carried out on Grades G, H, J, K, L, M, N, O, P, R, and S tubes. For tubes 5.1 mm (0.2 in.) and over in wall thickness, the Brinell hardness test is to be carried out and on tubes having wall thicknesses from 5.1 mm (0.2 in.) to 9.5 mm (0.375 in.) exclusive, a 10 mm ball with a 1,500 kg load, or a 5 mm ball with a 750 kg load may be used, at the discretion of the manufacturer. For tubes less than 5.1 mm (0.2 in.) in wall thickness, the Rockwell hardness test is to be used, except that for tubes with wall thickness less than 1.65 mm (0.065 in.) no hardness tests are required. In making the Brinell and Rockwell hardness tests, reference should be made to the Standard Methods and Definitions for the Mechanical Testing of Steel Products ASTM 370.

15.15.2. Brinell hardness test

The Brinell hardness test may be carried out on the outside of the tube near the end or on the outside of a specimen cut from the tube, at the option of the manufacturer.

15.15.3. Rockwell hardness test

The Rockwell hardness test is to be carried out on the inside of a specimen cut from the tube.

15.15.4. Tubes with formed ends

As prescribed in [15.15.1], for tubes furnished with swaged, upset, or otherwise formed ends, the hardness test is to be carried out on the outside of the tube near the end after the forming operation and heat treatment.

15.15.5. Maximum permissible hardness

Hardness-numbers of the tubes are not to exceed the values given in Table 2.15.8.

Table 2.15.8. Maximum Permissible Hardness

Tube Grade	**Brinell hardness number** for Tubes 5.1 mm (0.2 in) and over in wall thickness	**Rockwell hardness number** for Tubes less than 5.1 mm (0.2 in) in wall thickness
G	125	B 72
H	137	B 77
J	143	B 79
K	146	B 80
L	153	B 81
M	137	B 77
N, O, P	163	B 85
R, S	192	B 90

15.16. Hydrostatic test

15.16.1. General

Hydrostatical test of each tube is to be carried out at the mill or be subjected to a nondestructive electrical test as per [15.17] of this section. The test may be conducted before swaging, upsetting, expanding, bending or other forming operation. The hydrostatic test pressure is to be determined by the equation given in [15.16.2] below, but is not to exceed the values given in Table 2.15.9, except as provided in [15.16.4.2] below.

Table 2.15.9: Hydrostatic Test Pressure

Outside Diameter of tubes, mm (in.)	**Test Pressure,** Bar (kgf/cm^2, psi)
OD < 25.4 (1.0)	69 (70.3, 1000)
25.4 (1.0) ≤ OD < 38.1 (1.5)	103 (105, 1500)
38.1 (1.5) ≤ OD < 50.8 (2.0)	140 (140, 2000)
50.8 (2.0) ≤ OD < 76.2 (3.0)	170 (175, 2500)
76.2 (3.0) ≤ OD < 127 (5.0)	240 (245, 3500)
OD > 127.0 (5.0)	310 (315, 4500)

15.16.2. Maximum hydrostatic test pressure

SI Units	**MKS Units**	**US Units**
$P = \frac{20\,S\,t}{D}$ $S = \frac{P\,D}{20\,t}$	$P = \frac{200\,S\,t}{D}$ $S = \frac{P\,D}{200\,t}$	$P = \frac{2\,S\,t}{D}$ $S = \frac{P\,D}{2\,t}$

Where,

P = Hydrostatic test pressure, in bar (kgf/cm^2, psi)

S = Allowable fiber stress of 110 N/mm^2 (11 kgf/mm^2, 16000 psi)

t = Specified wall thickness, in mm (in.)

D = Specified outside diameter, in mm (in.)

15.16.3. Duration of test

The test pressure is to be held for a minimum of 5 seconds.

15.16.4. Alternate tests

15.6.4.1. On purchaser's request and as stated in the order, tubes are to be tested to one and one-half times the specified working pressure (when one and one-half times the specified working pressure exceeds the test pressure prescribed in [15.16.1] above), provided the fiber stress corresponding to those test pressures does not exceed 110 N/mm^2 (11 kgf/mm^2, 16,000 psi) calculated as per 15.16.2 above.

15.6.4.2. On purchaser's request and as stated in the order, or at the option of the manufacturer tubes are to be tested at pressures calculated in accordance with [15.16.1] above corresponding to a fiber stress of more than 110 N/mm^2 (11 kgf/mm^2, 16,000 psi), but not more than 165 N/mm^2 (17 kgf/mm^2 24,000 psi).

15.16.5. Rejection

Any tube with leaks during the hydrostatic test is to be rejected.

15.17. Non-Destructive Electric Test (NDET)

15.17.1. General

When specified by the purchaser, each ferrite steel tube, Grades D, F, G, H, J, K, L, M, N, O, and P, is to be tested in accordance with the following:

ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing or

ASTM E309, for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

ASTM E570, for Flux Leakage Examination of Ferromagnetic Steel Tubular Products, or another approved standard.

When specified by the purchaser, each austenitic stainless-steel tube, Grades R and S, is to be tested in accordance with:

ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing or

ASTM E426, for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys, or another approved standard.

This test is intended to reject tubes having defects and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner.

15.17.2. Ultrasonic calibration standards

Notches on the inside or outside surfaces may be used. The depth of the notch is not to exceed 12.5% of the specified wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed two times the depth.

15.17.3. Eddy-current calibration standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques and manufacturing practices employed, any one of the below mentioned calibration standards may be adopted as per the manufacturer's choice to establish a minimum sensitivity level for rejection. For welded tubing, if visible, they are to be placed in the weld.

15.17.3.1. Drilled hole

Three or more holes are drilled radially and completely through tube wall and care is taken to avert any distortion of the tube while drilling. These holes are not to be larger than 0.785 mm (0.031 in.) in diameter and should also be equally spaced about the pipe circumference and also adequately separated longitudinally to ascertain a separately distinguishable response. Alternatively, one hole may be used, provided that the calibration tube is scanned at least at three locations, each 120 degrees apart, or more frequent scans with smaller angular increments, provided that the entire 360 degrees span of the eddy current coil is examined.

15.17.3.2. Transverse tangential notch

A notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube using a round tool or file of 6.35 mm (0.25 in.) diameter. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater.

15.17.3.3. Longitudinal notch

A notch 0.785 mm (0.031 in.) or less in width is to be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding12.5% of the nominal wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

15.17.4. Flux leakage calibration standards

The depth of longitudinal notches on the inside and outside surfaces is not to exceed 12.5% of the specified wall thickness of the tube or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed the depth, and the length of the notch is not to exceed 25.4 mm (1.0 in.). Outside and inside surface notches are to be located sufficiently apart in order to allow distinct identification of the signal from each notch.

15.17.5. Rejection

Tubing producing a signal equal to or greater than the calibration defect is to be subject to rejection.

15.17.6. Affidavits

During the process of manufacture, when each tube is subjected to an approved nondestructive electrical test as a regular procedure, an affidavit covering this test may be accepted by the Surveyor.

15.18. Retests

If the results of the mechanical tests do not comply with the requirements for all grades of tubes, retests may be carried out on additional tubes from the same lot, double the original number specified, each of which is to conform to the requirements. If heat-treated tubes fail to fulfill the test requirements, the individual tubes, lots or groups of tubes represented, may be re-heat-treated and resubmitted for retest, as specified. Only two reheat treatments will be permitted.

15.19. Finish

Before fabrication or installation, tubes of all grades are to be examined by the Surveyor, and are to be considerably straight and have smooth ends free from burrs. For the applicable grade of steel, the finished tubes are to be visually inspected at the same frequency as that required for the flattening test specified in Table 2.15.2. They are to be freed from defects and are to have a workmanlike finish. Grade R and S tubes are to be freed from scale by pickling or by the use of bright annealing. Minor flaws may be removed by grinding, provided the wall thicknesses are not decreased beyond the permissible variations in dimensions. Welding repair to any tube is not to be carried out without prior approval from the purchaser and is to be to the Surveyor’s satisfaction.

15.20. Permissible variations in dimensions

The finished tubes are to be measured at the same frequency as that needed for the flattening test specified in Table 2.15.2 for the applicable grade, as a minimum.

15.20.1. Wall thickness

The permissible variations in wall thickness for all tubes are based on the ordered thickness and should conform to that given in the applicable ASTM designation for acceptance. But the minimum thickness for all tubes is not to be less than that required by the Rules for a specific application regardless of such prior acceptance.

15.20.2. Outside diameter

Variations from the ordered outside diameter are not to exceed the amounts prescribed in Table 2.15.10.

Table 2.15.10: Permissible variations in outside diameter for tubes (1)

Outside diameter, in mm (inch.)	**Outside diameter variation** Including out-of-roundness	
	Over	**Under**
Seamless, Hot-finished Tubes:		
OD ≤ 101.6 (4.0)	0.4 (1/64)	0.8 (1/32)
101.6 (4.0) < OD ≤ 190.5 (7.5)	0.4 (1/64)	1.2 (3/64)
190.5 (7.5) < OD ≤ 228.6 (9.0)	0.4 (1/64)	1.6 (1/16)
Seamless, Cold-drawn Tubes (2) and **Welded Tubes**:		
OD < 25.4 (1.0)(3)	0.10 (0.004)	0.10 (0.004)
25.4 (1.0) ≤ OD ≤ 28.1 (1.5)(3)	0.15 (0.006)	0.15 (0.006)
28.1 (1.5) < OD < 50.8 (2.0)(3)	0.20 (0.008)	0.20 (0.008)
50.8 (2.0) ≥ OD < 63.5 (2.5)	0.25 (0.010)	0.25 (0.010)
63.5 (2.5) ≥ OD < 76.2 (3.0)	0.30 (0.012)	0.30 (0.012)
76.2 (3.0) ≥ OD ≤ 101.6 (4.0)	0.38 (0.015)	0.38 (0.015)
101.6 (4.0) > OD ≤ 190.5 (7.5)	0.38 (0.015)	0.63 (0.025)
190.5 (7.5) > OD ≤ 228.6 (9.0)	0.38 (0.015)	1.14 (0.045)

Notes:

1. The allowable variations in outside diameters apply only to those tubes as rolled or drawn and before expanding, swaging, bending, polishing or other fabricating operations.

2. Thin wall tubes usually develop visible ovality during straightening or final annealing. Thin wall tubes are those with a wall of 0.5 mm (0.020 in.) or less, with a specified outside diameter equal to or less than 50.8 mm (2 in.) and with a wall thickness of 2% of the specified outside diameter or less, and with a specified outside diameter of greater than 50.8 mm (2 in.) and with a wall thickness of 3% of the specified outside diameter or less. The ovality allowance is 2% of the specified outside diameter for tubes over 25.4 mm (1 in.) and is 0.5 mm (0.020 in.) for tubes with the specified outside diameter equal to and less than 25.4 mm (1 in.). In all such cases, the average outside diameter must comply with the permissible variation allowed by this table.

3. An ovality allowance applies to Grade R and S austenitic stainless steel tube for all sizes less than 50.8 mm (2 in.) outside diameter. The allowance provides that the maximum and minimum diameter at any cross section is not to deviate from the nominal diameter by more than ±0.25 mm (±0.010 in.). In case of a conflict between the permissible variation allowed by this note and note 2, the larger ovality tolerance will apply. In all such cases, the average outside diameter must conform to the permissible variation allowed by this table.

SECTION 16 CONDENSER AND HEAT EXCHANGER TUBES

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16.1. Scope

16.1.1. The specifications below cover two grades of seamless copper-nickel tube designated CNA and CNB.

16.2. General

16.2.1. Grades CNA and CNB

Grades CNA, and CNB deal with seamless copper-nickel tube intended for use in condensers, evaporators and heat exchanger which may use sea water as the cooling medium. Tube ordered under these grades is considered appropriate for welding, and suitable for forming operations containing coiling, bending, flaring and tube rolling. As per the specifications of the purchaser, tube is to be ordered to outer diameter and wall thickness and approved for the application.

16.2.2. ASTM Designation

The grades are in accordance with ASTM, as follows:

INTLREG Grade	ASTM Designation
CNA	B111, UNS C70600
CNB	B111, UNS C71500

16.3. Process of manufacture

16.3.1. Grade CNA

Grade CNA tube is to be cold worked to the specified size. The tube may be supplied either in the annealed temper (O61) or in the light drawn temper (H55).

16.3.2. Grade CNB

Grade CNB tube is to be cold worked to the specified size. The tube may be supplied either in the annealed temper (O61) or in the drawn and stress relieved temper (HR50).

All grades of tube shall be round, straight, clean, smooth and free from harmful defects and deleterious films in the bore.

16.4. Marking

On each length of pipe, identification markings are to be legibly stenciled, or suitably marked In the case of small-diameter pipe which is bundled the required markings are to be placed on a tag securely attached to the bundle. The markings are to be arranged and are to include the following information:

a) Name or brand of the manufacturer

b) INTLREG Grade or ASTM Designation and Grade

c) Temper number

d) Tube diameter

e) Wall thickness

f) Test Pressure or the letters NDET

g) INTLREG markings by the Surveyor

16.5. Chemical composition

16.5.1. Chemical requirements

The material is to comply with the applicable requirements as to chemical composition as shown in Table 2.16.1.

Table 2.16.1: Chemical composition for copper nickel pipe and tube

Element	Grade CNA/ CN1/ CN3	Grade CNB/ CN2/ CN4
Copper	Remainder	Remainder
Nickel + Cobalt	9.0 to 11.0	29.0 to 33.0
Iron	1.0 to 1.8	0.40 to 1.0
Manganese	1.0	1.0
Zinc	0.50	0.50
Lead	0.02	0.02
Carbon	0.05	0.05
Sulfur	0.02	0.02
Phosphorus	0.02	0.02
Note: Single values are maximum		

16.5.2. Chemical analysis sampling

In accordance with sampling detailed in [16.1.1] of this section, samples may be taken at the time the metal is cast or may be taken from semi-finished product, or from finished product.

16.6. Tension test

16.6.1. Tension test specimens

Specimens for Tensile test are to be a full section of the tube. For larger sizes, tension test specimens are to comprise of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

16.6.2. Tensile properties

The material is to comply with the applicable requirements as to tensile properties shown in Table 2.16.2.

Table 2.16.2: Tensile properties for seamless copper nickel pipe and tube

Grade	Temper designation	**Tensile Strength**, min. N/mm^2 (kgf/mm^2, ksi)	**Yield Strength**, min. N/mm^2 (kgf/mm^2, ksi)	**Elongation**, min. percent
CNA	061	275 (28,40)	105 (11,15)	—
CNA	H55	310 (32,45)	240 (25,35)	—
CNB	061	360 (36,52)	125 (13,18)	—
CNB	HR50	495 (51,72)	345 (35,50)	12(1) 15(2)

Notes:
1. For wall thickness 1.21 mm (0.048 in.) and less.
2. For wall thickness over 1.21 mm (0.048 in.).

16.7. Expansion test

In accordance with ASTM B153, specimens chosen for testing for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30 percent for annealed temper (O61) tube and to 20 percent for drawn temper (H55 or HR50) tube. The expanded tube is to show no cracking or rupture visible to the unaided eye.

16.8. Flattening test

The specimen selected for testing is to be at least 450 mm (18 in.) in length, and is to be flattened so that a gauge set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested should not develop cracks or defects visible to the unaided eye as a result of this test. In carrying out the flattening test, the specimens are to be slowly flattened by one stroke of the press. Specimens not initially in the annealed temper (O61) are to be annealed prior to flattening.

16.9. Non-Destructive Electric Test (NDET)

According to ASTM E243, all tubes are to be eddy-current tested, for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes or, alternatively, when mentioned, may be hydrostatically tested in accordance with [16.10] of this section. A calibration reference standard is to be made from a length of tube of the same type, wall thickness, and outside diameter as that to be tested. In accordance with the dimensions shown, the standard is to have transverse notches or drilled holes. Tubing producing a signal equal to or greater than the calibration defect is to be rejected.

Table 2.16.3: Diameter of drilled hole

Tube OD, in mm (in.)	**Diameter, in mm (in.)**
6.0 (0.25) ≤ OD ≤ 19.0 (0.75)	0.635 (0.025)
19.0 (0.75) < OD ≤ 25.4 (1.0)	0.785 (0.031)
25.4 (1.0) < OD ≤ 31.8 (1.25)	0.915 (0.036)
31.8 (1.25) < OD ≤ 38.1 (1.5)	1.07 (0.042)
38.1 (1.5) < OD ≤ 44.4 (1.75)	1.17 (0.046)
44.4 (1.75) < OD ≤ 50.8 (2.0)	1.32 (0.052)

Table 2.16.4: Notch depth

Tube Wall Thickness, (T) in mm (in.)	**Tube OD,** in mm (in.)		
	6.4 (0.25) ≤ ≤ 19.1 (0.75)	19.1 (0.75) < ≤ 31.8 (1.25)	31.8 (1.25) < ≤ 80 (3.125)
0.43 (0.17) < T < 0.8 (0.032)	0.127 (0.005)	0.152 (0.006)	0.179 (0.007)
0.80 (0.032) < T < 1.24 (0.049)	0.152 (0.006)	0.152 (0.006)	0.191 (0.0075)
1.24 (0.049) < T < 2.10 (0.083)	0.179 (0.007)	0.191 (0.0075)	0.216 (0.008)
2.10 (0.083) < T < 2.77 (0.109)	0.191 (0.0075)	0.216 (0.0085)	0.241 (0.0095)
2.77 (0.109) < T < 3.05 (0.120)	0.229 (0.009)	0.229 (0.009)	0.279 (0.011)

16.10. Hydrostatic test

16.10.1. Limiting test pressures

Hydrostatic testing may be conducted as an alternate to the eddy-current test. Each tube that is tested is to stand, without showing indication of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi), determined by the following equation for thin hollow cylinders under tension. Unless so specified, the tube is not to be tested at a hydrostatic pressure of over 69 bar (70.3 kgf/cm^2, 1000 psi).

$$P = \frac{KSt}{(D - 0.8t)}$$

Where,

P = Pressure in bar (kgf/cm^2, psi)
S = Allowable unit stress of the material, 48 N/mm^2(4.92 kgf/mm^2, 7000 psi)
t = Thickness of pipe wall, in mm (in.)
D = Outside diameter of the pipe, in mm (in.)
K = 20 (200, 2)

16.10.2. Affidavits of tests

At the time of the process of manufacture, where each tube is hydrostatically tested as a regular procedure, the surveyor may accept an affidavit covering this test.

16.11. Number of tests

The lot is to contain tubes of the same size and temper. The lot size is to be 4540 kg (10,000 lb.) or a fraction thereof. As given in following Table 2.16.5., sample pieces are to be taken for test purposes at random from each lot,

Table 2.16.5.

Number of pieces in lot	Number of sample pieces to be taken
1 to 50	1
51 to 200	2
201 to 1500	3
over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be carried out on each of the sample pieces selected for test. Each length of pipe is to be subjected to the eddy-current test or the hydrostatic test.

16.12. Retests

If the results of the mechanical tests on one of the specimens, made to determine the mechanical properties, do not comply with the requirements, for all grades of pipe, retests may be carried out on each of two additional specimens taken from different pieces, and the result of both of these tests is to comply with the requirements. Failure of more than one specimen to meet the requirements for a particular property is to be cause for rejection of the entire lot.

16.13. Finish

Tubes which are chosen for testing are to be checked for finish and workmanship. Tubes are to be free from cracks, injurious surface flaws, and similar imperfections to the extent identifiable by visual or NDET examination. Tubes are to be clean and free of any foreign material that would render the tubes unfit for the intended use. Cut ends of tubes are to be deburred.

16.14. Dimensions and tolerances

For testing, tubes which are selected are to be measured and examined for dimensions and tolerances.

16.14.1. Diameter

The tube outside diameter is to not differ from the specified values by more than the amounts shown in Table 2.16.6.

Table 2.16.6: Diameter tolerances, mm (inches)

Outside Diameter, mm (in)	**Wall thickness,** mm (in)				
	0.51 to 0.71 (0.020 to 0.028) (Refer Note)	0.81 (0.032)	0.89 (0.035)	1.07 (0.042)	≥ 1.24 (≥ 0.049)
OD ≤ 12.5 (0.50)	0.076 (0.003)	0.064 (0.0025)	0.064 (0.0025)	0.064 (0.0025)	0.064 (0.0025)
12.5 < OD ≤ 19.0 (0.50 < OD ≤ 0.74)	0.102 (0.0040)	0.102 (0.004)	0.102 (0.004)	0.089 (0.0035)	0.076 (0.003)
19.0 < OD ≤ 25.4 (0.74 < OD ≤ 1.00)	0.152 (0.0060)	0.152 (0.006)	0.127 (0.005)	0.114 (0.0045)	0.102 (0.004)
25.4 < OD ≤ 31.8 (1.00 < OD ≤ 1.25)	… …	0.229 (0.009)	0.203 (0.008)	0.152 (0.006)	0.114 (0.0045)
31.8 < OD ≤ 35.0 (1.25 < OD ≤ 1.375)	… …	… …	… …	0.203 (0.008)	0.127 (0.005)
35.0 < OD ≤ 50.8 (1.375 < OD ≤ 2.00)	… …	… …	… …	… …	0.152 (0.006)

Note:
Tolerances in this column are applicable to light and drawn tempers only. Tolerances for annealed tempers are to be as agreed upon between the manufacturer and the purchaser.

16.14.2. Wall Thickness Tolerances

For tubes ordered to minimum wall, no tube wall at its thinnest point is to be less than the specified wall thickness and no tube at its thickest point is to have a plus deviation greater than twice the value shown. For tubes ordered to nominal wall thickness, the maximum plus and minus deviation in inches from the nominal wall at any point is to not exceed the values shown in Table 2.16.7.

Table 2.16.7: Wall Thickness Tolerances, mm (inches)

Wall Thickness, mm (inch)	**Outside Diameter,** mm (inch)		
	3.2 < OD ≤ 15.9 (0.125 < OD ≤ 0.625)	15.9 < OD ≤ 25.4 (0.625 < OD ≤ 1.0)	25.4 < OD ≤ 50 (1.0 < OD ≤ 2.0)
0.51 ≤ T < 0.81 (0.020 ≤ T < 0.032)	0.076 (0.003)	0.076 (0.003)	…
0.81 ≤ T < 0.89 (0.032 ≤ T < 0.035)	0.076 (0.003)	0.076 (0.003)	0.102 (0.004)
0.89 ≤ T < 1.47 (0.035 ≤ T < 0.058)	0.102 (0.004)	0.114 (0.0045)	0.114 (0.0045)
1.47 ≤ T < 2.11 (0.058 ≤ T < 0.083)	0.114 (0.0045)	0.127 (0.005)	0.127 (0.005)
2.11 ≤ T < 3.05 (0.083 ≤ T < 0.120)	0.127 (0.005)	0.165 (0.0065)	0.165 (0.0065)
3.05 ≤ T < 3.40 (0.120 ≤ T < 0.134)	0.179 (0.007)	0.179 (0.007)	0.191 (0.0075)

16.14.3. Length

The length of tubes is to be more than that mentioned when measured at a temperature of 20°C (68°F) and may exceed the specified values by the amounts shown in Table 2.16.8.

Table 2.16.8: Length Tolerances, mm (inches)

Specified Length, m (feet)	**Tolerance, All Plus,** mm (inch)
L ≤ 4.5 (15)	2.4 (3/32)
4.5 < L ≤ 6.0 (15 < L ≤ 20)	3.2 (1/8)
6.0 < L ≤ 10 (20 < L ≤ 30)	4.0 (5/32)
10 < L ≤ 18 (30 < L ≤ 60)	9.5 (3/8)
18 < L ≤ 30 (60 < L ≤ 100) (Refer Note)	13.0 (1/2)
Note: Length tolerances for wall thickness 0.51 mm (0.020 in.) to 0.81 mm (0.032 in.) are to be as agreed upon between the manufacturer or supplier and the purchaser	

16.14.4. Squareness of cut:

The departure from squareness of the end of the tube is to not exceed the values given in Table 2.16.9.

Table 2.16.9.

Specified Outside Diameter, mm (inch)	**Tolerance**
≤ 15.9 (5/8 in.)	0.25 mm (0.010 in.)
> 15.9 (5/8 in.)	0.016 mm/mm (0.016 in./in.) of diameter

SECTION 17 STEEL PIPING

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17.1. Scope

Thirteen grades of steel pipe designated 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 and 14 have been covered in the following specifications.

17.2. General

17.2.1. Grades 1, 2 and 3

Pipes of grades 1, 2 and 3 includes seamless and welded steel pipe. Pipe ordered under these grades is of a nominal (average) wall thickness suitable for welding and forming operations including coiling, bending and flanging, subject to the following limitations: Grade 1 furnace-butt-welded pipe is not intended for flanging; when seamless or electric-resistance-welded pipe is required for close-coiling or cold-bending, Grade 2 should be specified; this provision is not intended to prohibit cold-bending of Grade 3 pipe. When pipe is required for close-coiling, this is to be specified on the order. Electric-resistance-welded Grades 2 and 3 may be supplied either non-expanded or cold-expanded at the option of the manufacturer. The amount of expansion is not to exceed 1.5% of the outside diameter pipe size, when pipe is cold expanded.

17.2.2. Grades 4 and 5

Pipes of grades 4 and 5 cover seamless carbon-steel pipe for high-temperature service. Pipe ordered to these grades is of a nominal (average) wall thickness and is to be suitable for bending, flanging and similar forming operations. Grade 4 pipe should be preferred to use instead Grade 5 for close-coiling, cold-bending or forge welding; this provision is not intended to prohibit the cold-bending of Grade 5 pipe.

17.2.3. Grade 6

Pipes of grade 6 covers seamless carbon-molybdenum alloy-steel pipe for high-temperature service. The pipe ordered to this grade is of a nominal (average) wall thickness and is to be suitable for bending, flanging (vans toning) and similar forming operations, and for fusion-welding.

17.2.4. Grades 7, 11, 12, 13 and 14

Pipes of grades 7, 11, 12, 13 and 14 cover seamless chromium-molybdenum alloy-steel pipe for high-temperature service. Pipe ordered to these grades is of a nominal (average) wall thickness and is to be suitable for bending, flanging (vans toning) and similar forming operations, and for fusion-welding.

17.2.5. Grades 8 and 9

Pipes of grades 8 and 9 cover electric-resistance-welded steel pipe 762 mm (30 in.) and under in diameter. Pipe ordered to these grades is of a nominal (average) wall thickness and is intended for conveying liquid, gas or vapor. For flanging and bending, only Grade 8 is adapted; this provision is not intended to prohibit the cold-bending of Grade 9 pipe. The pipe may be supplied either cold-expanded or non-expanded.

17.2.6. ASTM Designations

The various grades are in substantial compliance with ASTM, as given in Table 2.17.1 below.

Table 2.17.1: INTLREG Grades

INTLREG Grade	ASTM Designation
1	A53, Grade A, Furnace-welded
2	A53, Grade A Seamless or Electric-resistance-welded
3	A53, Grade B Seamless or Electric-resistance-welded
4	A106, Grade A
5	A106, Grade B
6	A335, Grade P1
7	A335, Grade P2
8	A135, Grade A
9	A135, Grade B
11	A335, Grade P11
12	A335, Grade P12
13	A335, Grade P22
14	A335, Grade P5

17.3. Process of manufacture

17.3.1. Grades 1, 2 and 3

One or more of the following processes must be followed in order to make the steel for welded or seamless steel pipe in these Grades: open-hearth, basic-oxygen or electric-furnace. Other processes may be specially considered, subject to such supplementary requirements or limits on application as are to be specially determined in each case.

17.3.2. Grades 4 and 5

The steel for seamless steel pipe in these Grades is to be killed steel made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Pipe that is 60.3 mm in outside diameter (2 in. nominal diameter) and over is to be, unless otherwise specified, furnished hot-finished. Annealing is not required for hot-finished pipe. After the final cold-draw pass at a temperature of 650°C (1200°F) or higher, cold-drawn pipe is to be process-annealed.

17.3.3. Grades 6 and 7

The steel for seamless steel pipe is to be made by either or both the open-hearth or electric furnace process or other approved process. In order to secure freedom from injurious piping and undue segregation, a sufficient discard is to be made from each ingot. Unless otherwise specified, pipe that is 60.3 mm in outside diameter (2 in. nominal size) and over is to be furnished hot-finished, and pipe under 60.3 mm O.D. (2 in. diameter) may be produced either hot-finished or cold-drawn. As a final heat treatment, the hot-rolled or cold-drawn pipe Grades 6 and 7 are to be stress-relief-annealed at 650°C (1200°F) to 705°C (1300°F). The steel from which Grade 7 pipe is made is to be a coarse grained steel having a carburized austenitic grain size of 1 to 5 as determined in accordance with the Methods for Estimating the Average Grain Size of Metals (ASTM E112) and its Plate IV, by carburizing at 925°C (1700°F) for 8 hours. The specimen is to be taken from the bloom or billet.

17.3.4. Grades 8 and 9

In these Grades, the steel for electric-resistance-welded steel pipe is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. .

17.3.5. Grades 11, 12, 13 and 14

The electric-furnace process or other approved procedure is to be followed in order manufacture steel for seamless alloy steel pipe except that Grade 12 may be manufactured by the open-hearth method. In order to secure freedom from injurious piping and undue segregation, a sufficient discard is to be made from each ingot. Pipe that is 60.3 mm in outside diameter (2 in. nominal diameter) and over is to be, unless otherwise specified, furnished hot-finished, and pipe under 60.3 mm O.D. (2 in. nominal diameter) may be furnished either hot-finished or cold-drawn. Coarse-grain melting practice is to be followed to manufacture the steel for Grade 12 pipes. Grades 11, 13 and 14 pipe are to be reheated and furnished in the full-annealed, isothermal annealed or normalized and tempered condition; if furnished in the normalized and tempered condition, or if cold drawn pipe is furnished, the temperature for tempering following normalizing or cold drawing is to be 677°C (1250°F) or higher for Grades 13 and 14, and 650°C (1200°F) or higher for Grade 11. The hot-rolled or cold-drawn Grade 12 pipe, as a final heat treatment, is to be given a stress-relieving treatment at 650°C (1200°F) to 705°C (1300°F).

17.4. Marking

On each length of pipe, identification markings are to be clearly stenciled, stamped, or rolled. The required markings are to be placed on a tag securely attached to the bundle, in case of small-diameter pipe which is bundled. The markings are to be prepared and are to consist of the following information:

- Name or brand of the manufacturer;
- INTLREG Grade or ASTM Designation and Type or Grade. Heat number or manufacturer's number by which the heat can be identified (For Grades 6, 7, 11, 12, 13 and 14 pipe only);
- Test pressure or the letters NDE;
- Method of forming (i.e., butt-welded, lap-welded, electric-resistance-welded or seamless hot-finished or cold-drawn);
- "EXS" for extra strong or "EXXS" for double-extra strong (when applicable for Grades 1, 2 and 3 pipe only);
- INTLREG markings by the Surveyor.

17.5. Chemical composition

The material for pipe is to comply with the applicable requirements as to chemical composition shown in Table 2.17.2.

Table 2.17.2: Maximum or permissible range of chemical composition in percent for pipe

Grades	C	Mn	P	S	Si	Cr	Mo	Ni	Cu	Vn
1	0.30	1.20	0.050	0.045		0.40	0.15	0.40	0.40	0.08
2	0.25	0.95	0.050	0.045		0.40	0.15	0.40	0.40	0.08
3	0.30	1.20	0.050	0.045		0.40	0.15	0.40	0.40	0.08
4	0.25	0.27 - 0.93	0.035	0.035	0.10 (min)	0.40	0.15	0.40	0.40	0.08
5	0.30	0.29 - 1.06	0.035	0.035	0.10 (min)	0.40	0.15	0.40	0.40	0.08
6	0.10 - 0.20	0.30 - 0.80	0.025	0.025	0.1 - 0.5		0.44 - 0.65			
7	0.10 - 0.20	0.30 - 0.61	0.025	0.025	0.1 - 0.3	0.50 - 0.81	0.44 - 0.65			
8	0.25	0.95	0.035	0.035						
9	0.30	1.20	0.035	0.035						
11	0.05 - 0.15	0.30 - 0.60	0.025	0.025	0.50 - 1.00	1.00 - 1.50	0.44 - 0.65			
12	0.05 - 0.15	0.30 - 0.61	0.025	0.025	0.50	0.80 - 1.25	0.44 - 0.65			
13	0.05 - 0.15	0.30 - 0.60	0.025	0.025	0.50	1.90 - 2.60	0.87 - 1.13			
14	0.15	0.30 - 0.60	0.025	0.025	0.50	4.00 - 6.00	0.45 - 0.65			

17.6. Ladle analysis

For Grades 4, 5, 6, 7, 8, 9, 11, 12, 13 and 14, a report showing the ladle analysis of each heat of steel from which the pipe has been made and the chemical composition is to comply with the requirements specified in [17.5] is to be submitted by the manufacturer. In lieu of a report of the ladle analysis, a report of check analysis as described in [17.7] below will be acceptable.

17.7. Check analysis

17.7.1. General

A check analysis may be made where so specified by the purchaser. The chemical composition thus determined is to be in compliance with the requirements specified in [17.5] above. Where check analyses are made, they are to be in compliance with the following requirements.

17.7.2. Samples

Samples for check analysis are to be taken by drilling several points around each pipe. These pipes are to be chosen for analysis or when taken from the billet, they are to be obtained by drilling parallel to the billet axis at a point midway between the outside and center. When samples are taken from a broken tension test specimen, they are to be taken in such way that it represents the entire cross section of the specimen.

17.7.3. **Grades 1, 2 and 3**

For these grades, analyses of two pipes from each lot of 500 lengths or fraction thereof are to be made.

17.7.4. **Grades 4 and 5**

For these grades, analyses of two pipes from each lot of 400 lengths or fraction thereof, of each size and heat 60.3 mm O.D. (2 in. nominal diameter) up to, but not including 168.3 mm O.D. (6 in. nominal diameter), and from each lot of 200 lengths or fraction thereof of each size and heat 168.3 mm O.D. (6 in. nominal diameter) and over, are to be made.

17.7.5. **Grades 6, 7, 11, 12, 13 and 14**

For these grades, as specified in Table 2.17.3, analyses of two pipes from each lot and heat, are to be made.

Table 2.17.3: Lot sizes for pipe Grades 6, 7, 11, 12, 13 and 14

Outside diameter	Lengths of pipe in lot
Under 60.3 mm (2 in.) *	400 or fraction thereof
60.3 mm to 141.3 mm incl. (2 in. to 5 in. incl.) *	200 or fraction thereof
168.3 mm and over (6 in. and over) *	100 or fraction thereof
Note: Dimensions refer to nominal pipe diameter	

17.7.6. **Grades 8 and 9**

For these grades, analyses of two pipes from each lot of 400 lengths or fraction thereof of each size under 168.3 mm O.D. (6 in. nominal), from each lot of 200 lengths or fraction thereof of each size 168.3 mm O.D. (6 in. nominal diameter) to 508 mm (20 in.) O.D., and from each lot of 100 lengths or fraction thereof of each size over 508 mm (20 in.) O.D. to 762 mm (30 in.) O.D. are to be made. The analysis may be made of the skelp with the Surveyor's permission and the number is to be determined in the same manner as when taken from the finished pipe.

17.7.7. Retests for **Grades 1, 2, 3, 4 and 5**

For these grades, if an analysis does not comply with the requirements specified, analyses are to be carried out on additional pipes of double the original number from the same lot, each of which is to comply with the requirements.

17.7.8. Retests for **Grades 6, 7, 11, 12, 13 and 14**

Where a check or ladle analysis for these grades does not comply with the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe complying with the requirements are to be accepted.

17.7.9. Retests for **Grades 8 and 9**

For these grades, if the analysis of either length of pipe or length of skelp does not conform to the requirements, analyses of two additional lengths from the same lot are to be conducted each of which is to conform to the requirements specified.

17.8. Mechanical tests required

The type and number of mechanical tests are to be in compliance with Table 2.17.4. For a description and the requirements of each test, Refer [17.9] to [17.15] below. For retests, Refer [17.17].

Table 2.17.4: Mechanical tests for pipe

Grade	Type of test	Number of tests
1, 2, 3	Tension (Longitudinal)	One test on one length of pipe from each lot of 500 lengths or fraction thereof of each size.
	Transverse Weld Tension (1)	As for tension test, only for electric-resistance-welded pipe 219.1 mm in outside diameter (8 in. nominal diameter) and over.
	Bend (1)	As for tension test, only for pipe 60.3 mm in outside diameter (2 in. nominal diameter) and under, except not required for double-extra- strong-pipe over 42.2 mm in outside diameter (1.25 in. nominal diameter).
	Flattening	As for tension test except: 1. Not required for pipe 60.3 mm in outside diameter (2 in. nominal diameter) and under. 2. Not required for double-extra strong pipe. 3. In the case of welded pipe ordered for flanging and electric-resistance-welded pipe, the crop ends cut from each length are to be subjected to this test. 4. When pipe is produced in multiple lengths, tests are required on the crop ends from the front and back ends of each coil and on two tests are required on the crop ends from the intermediate rings representing each coil.
	Hydrostatic (1)	All pipes.
4, 5	Tension (Longitudinal or Transverse) *(Refer note 1)*	One test on one length of pipe from each lot (2) of 400 lengths or fraction thereof of each size under 168.3 mm in outside diameter (6 in. Nominal diameter) and one test on one length of pipe from each lot of 200 lengths or fraction thereof of each size 168.3 mm in outside diameter (6 in. nominal diameter) and over.
	Bend (1)	One test on one length of pipe from each lot (2) of 400 lengths or fraction thereof of each size 60.3 mm in outside diameter (2 in. nominal diameter) and under, except not required for double-extra-strong pipe over 42.2 mm in outside diameter (1.25 in. nominal diameter.)
	Flattening	As for tension test, only for pipe over 60.3 mm in outside diameter (2 in. diameter).
	Hydrostatic (1)	All pipes.
6, 7, 11, 12, 13, 14	Tension (Longitudinal or Transverse (5)	One test on 5% of the pipe in a lot. For the pipe heat-treated in a batch-type furnace, at least one pipe from each heat-treated lot (3). For pipe heat-treated by continuous process, at least two pipes from each heat-treated lot (3) are to be tested.
	Flattening	As for tension test.
	Hydrostatic (1)	All pipes.
8, 9	Tension (Longitudinal)	One test on one length of pipe from each of 400 lengths or fraction thereof of each size 168.3 mm in outside diameter (6 in. nominal diameter) and one test on one length of pipe from each lot of 200 lengths or fraction thereof of each size from 168.3 mm in outside diameter (6 in. nominal diameter) to and including 508 mm (20 in.) in outside diameter and one test on one length of pipe from each lot of 100 length or fraction thereof of each size over 508 mm (20 in.) in outside diameters (4).
	Transverse (1) Weld Tension	As for tension test, only for pipe 168.3 mm in outside diameter (6 in. nominal diameter) and over (4).
	Flattening	One test on each of both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.
	Hydrostatic (1)	All pipes.

Notes:
1. Pipes intended for structural use, such as stanchions, need not be subjected to this test.
2. A lot, in this case, consists of all pipe of the same size and wall thickness from any one heat.
3. The term "lot" used here applies to all pipe of the same nominal size and wall thickness which is produced from the same heat of steel and subjected to the same finishing heat treatment in a continuous furnace. When the final heat treatment is in a batch-type furnace, the lot is to include only that pipe which is heat-treated in the same furnace charge. When no heat treatment is performed following the forming operations, the lot is to include hot- rolled material only or cold-drawn material only.
4. When taken from the skelp, the number of tests is to be determined in the same manner as when taken from finished pipe.
5. The transverse tension test may not be made on pipe under 219.1 mm in outside diameter (8 inch nominal diameter).

17.9. Tension test specimens

17.9.1. Grades 1, 2 and 3

For these grades, tension test samples are to be cut longitudinally from the end of the pipe and not flattened between gauge marks. The sides of strip specimens are to be parallel between gauge marks; the width is to be 38 mm (1.5 in.) and the gauge length 50 mm (2 in.). If desired, tension test specimens may comprise of a full section of pipe. The tension test specimen shown in Sec-1, Figure 2.1.2 may be used when it is not practical to pull a test specimen in full thickness. From electric-resistance-welded Grade 2 and Grade 3 pipe, the transverse-weld tension test specimens are to be taken with the weld at the center of the specimen and are to be 38 mm (1.5 in.) wide in the gauge length.

17.9.2. Grades 4, 5, 6, 7, 11, 12, 13 and 14

The tension test specimens are to be cut longitudinally, for these grades, but may be cut transversely for pipe 219.1 mm in outside diameter (8 in. nominal diameter) and over.

17.9.2.1. Longitudinal tension test specimens

The longitudinal tension test may be prepared in full section of the pipe, up to the capacity of the testing machine. Tension test specimens are to comprise of strips cut from the pipe for larger sizes; the width of these samples is to be 38 mm (1.5 in.) and they are to have a gauge length of 50 mm (2 in.). The tension test specimen shown in Sec-1, Figure 2.1.2 may be used when the pipe-wall thickness is 19.1 mm (0.75 in.) and over. Longitudinal tension test specimens are not to be flattened between gauge marks. The sides of the specimens are to be parallel between gauge marks.

17.9.2.2. Transverse tension test specimens

Specimens of Transverse tension test may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. Test specimens are to comprise of strips cut transversely from the pipe; the width of the specimens is to be 38 mm (1.5 in.) and their gauge length 50 mm (2 in.). When the pipe-wall thickness is 19.1 mm (0.75 in.) and over, the tension test specimen shown in Sec 1, Figure 2.1.2 may be used. It is required that the samples cut from the ring section are to be flattened cold and are to be parallel between gauge marks. Specimens from Grades 6, 7, 11, 12, 13 and 14 pipes are to be flattened cold and heat-treated in the similar process as the pipe. To secure uniform thickness, test specimens of transverse tension may be machined off on either or both surfaces.

17.9.3. Grades 8 and 9

For Grades 8 and 9, the specimens of tension test are to be cut longitudinally from the end of the pipe. It can also be done by the agreement between the manufacturer and the Surveyor that the specimens may be taken from the skelp, at a point approximately 90 degrees from the weld. The specimens are not to be flattened between the gauge marks. Transverse tension test specimens are to be taken across the weld and from the same end of the pipe as the longitudinal test specimens. The sides of each strip specimen are to be parallel between gauge marks; the width is to be 38 mm (1.5 in.) and the gauge length 50 mm (2 in.). When it is not practical to pull a test specimen in full thickness, the tension test samples shown Sec 1, Figure 2.1.2 may be used.

17.10. Bend and flattening test specimens

For the bend and flattening tests, test specimens are to comprise of sections cut from a pipe and the specimens for flattening tests are to be smooth on the ends and free from burrs, unless they are made on crop ends.

17.11. Testing temperature

All tests are to be carried out at room temperature.

17.12. Tensile properties

The material is to comply with the applicable requirements as to tensile properties shown in Table 2.17.5 below.

Table 2.17.5: Tensile Requirements of Pipe (SI Units)

	INTLREG Grades								
	1	**2**	**3**	**4**	**5**	**6, 7**	**8**	**9**	**11, 12, 13, 14**
Yield Strength, min N/mm^2 (kgf/mm^2)	170 (17.5)	205 (21)	240 (24.5)	205 (21)	240 (24.5)	205 (21)	205 (21)	240 (24.5)	205 (21)
Tensile Strength, min N/mm^2 (kgf/mm^2)	310 (31.5)	330 (33.7)	415 (42)	330 (33.7)	415 (42)	380 (39)	330 (33.7)	415 (42)	415 (42)
Elongation in 200mm, min, %	200[(a)]								
Elongation in 50 mm. min., percent. Basic minimum elongation for walls 7.9 mm and over, strip tests, and for all small sizes tested in full section									
Transverse/ Longitudinal		-/ 35	-/ 30	25/ 35	16.5/ 30	20/ 30	-/ 35	-/ 30	20/ 30
When standard round 50 mm gauge length test specimen is used.									
Transverse/Longitudinal	-/ 30	-/ 28	-/ 22	20/ 28	12/ 22	14/ 22			14/ 22
Deduction in elongation for each 0.8 mm decrease in wall thickness below 7.9 mm for strip test.									
Transverse/ Longitudinal		-/ 1.75	-/ 1.50	1.25/ 1.75	1.00/ 1.50	1.00/ 1.50	-/ 1.75	-/ 1.5	1.00/ 1.50

Notes:

a) The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade pipe ordered. This test will not be required for pipe under 168.3 mm in outside diameter.

b) The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade of pipe ordered. This test will not be required for pipe under 219.1 mm in outside diameter.

c) Gauge distances for measuring elongation of pipe of 26.70 mm OD and smaller are to be as follows:

OD 26.7 mm & 21.3 mm, Gauge Length = 150 mm

OD 17.1 mm & 13.7 mm, Gauge Length = 100 mm

OD 10.3 mm, Gauge Length = 50 mm

Table 2.17.5: Tensile Requirements of Pipe (US Units)

	INTLREG Grades								
	1	**2**	**3**	**4**	**5**	**6, 7**	**8**	**9**	**11, 12, 13, 14**
Yield Strength, min (ksi)	45	48	60	48	60	55	48	60	60
Tensile Strength, min (ksi)	25	30	35	30	35	30	30	35	30
Elongation in 8 in., min, %	20[(a)]								
Elongation in 2 in.. min., percent. Basic minimum elongation for walls 5/16 in.and over, strip tests, and for all small sizes tested in full section									
Transverse/ Longitudinal		-/ 35	-/ 30	25/ 35	16.5/ 30	20/ 30	-/ 35	-/ 30	20/ 30
When standard round 50 mm gauge length test specimen is used.									
Transverse/Longitudinal	-/ 30	-/ 28	-/ 22	20/ 28	12/ 22	14/ 22			14/ 22
Deduction in elongation for each 1/32 in. decrease in wall thickness below 5/16 in. for strip test.									
Transverse/ Longitudinal		-/ 1.75	-/ 1.50	1.25/ 1.75	1.00/ 1.50	1.00/ 1.50	-/ 1.75	-/ 1.5	1.00/ 1.50

Notes:

a) The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade pipe ordered. This test will not be required for pipe under 6 in. in nominal diameter.

b) The test specimen taken across the weld is to show a tensile strength not less than the minimum specified for the grade of pipe ordered. This test will not be required for pipe under 8 in. in nominal diameter.

c) Gauge distances for measuring elongation of pipe of ¾ in, OD and smaller are to be as follows:

OD ¾ in & ½ in., Gauge Length = 6 in.

OD 3/8 in. & ¼ in., Gauge Length = 4 in.

OD 1/8 in., Gauge Length = 2 in.

17.13. Bend test

17.13.1. General

For Grades 1, 2, 3, 4 and 5 pipe having outside diameters of 60.3 mm (2 in. nominal diameter) and under, except that double-extra-strong pipe over 42.2 mm in outside diameter (1.25 in nominal diameter) need not go through a bend test.

17.13.2. Details of test

Bend test is to be carried out on sufficient length of pipe is to stand being bent cold around a cylindrical mandrel, without developing cracks at any portion or without opening the weld. The requirements for bending angle, mandrel diameter, and pipe diameter are tabulated in Table 2.17.6 below.

Table 2.17.6.

Pipe grade	Bending angle in degrees	Ratio of mandrel Diameter to nominal pipe Diameter
1, 2, 3, 4, 5	90	12
1, 2, 3, 4, 5 for close-coiling	180	8

17.14. Flattening test

17.14.1. General

For all Grades of pipe, flattening tests are to be to be carried out except Grades 1, 2 and 3 double extra strong and Grades 1, 2, 3, 4 and 5 in sizes 60.3 mm in outside diameter (2 in. nominal diameter) and under. The test is to comprise of flattening cold a section of pipe between parallel plates.

17.14.2. Furnace-welded pipe

For furnace welded pipes of Grade 1, test section is not to be less than 100 mm (4 in.) in length and the weld is to be positioned 45 degrees from the line of direction of the applied force. The test is to be made in three steps.

i. Test step no. 1

In the first step, which is a test for quality of the weld, no cracks or breaks on the inside, outside or end surfaces are to develop until the distance between the plates is less than three-fourths of the original outside diameter.

ii. Test step no. 2

In the second step, which is a test for ductility exclusive of the weld, the flattening is to be continued and no cracks or breaks on the inside, outside or end surfaces are to develop until the distance between the plates is less than 60% of the original outside diameter for butt-welded pipe.

iii. Test step no. 3

In the third step, which is a test for soundness, the flattening is to be continued until the test specimen breaks or the opposite walls of the pipe meet. During the entire flattening test, indication of laminated or unsound material or of incomplete weld that is revealed is to be cause for rejection. Superficial ruptures, as a result of surface imperfections are not to be cause for rejection.

17.14.3. Electric-resistance-welded pipe

At least 100mm (4 in.) in length, cut from each end of each single length of pipe are to be flattened for electric-resistance-welded pipes of Grade 2,3,8, and 9. The tests from each end are to be made alternatively with the welds at 0 degrees and 90 degrees from the line of direction of force. Flattening tests are required from each end of each multiple length or coil with the weld at 90 degrees from the line of direction of force, when manufactured in multiple lengths. In addition, tests are to be made on two intermediate rings cut from each multiple length or coil with the weld at 0 degrees from the line of direction of force. The test is to be made in three steps:

i. Test step no. 1

In the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces are to develop until the distance between the plates are less than two-thirds of the original outside diameter of the pipe.

ii. Test step no. 2

In the second step, which is a test for ductility exclusive of the weld, the flattening is to be continued until the distance between the plates is less than one-third of the original outside diameter of the pipe. During the flattening, no cracks or breaks on the inside or outside surfaces are to develop , elsewhere than in the weld.

iii. Test step no. 3

In the third step, which is a test for soundness, the flattening is to be continued until the test specimen breaks or the opposite walls of the pipe meet. Any indication of laminated, burned or unsound material or of an incomplete weld that is revealed during the entire flattening test is to be cause for rejection. Superficial ruptures as a result of surface imperfections are not to be cause for rejection.

17.14.4. Seamless pipe

The test section is not to be less than 63.5 mm (2.5 in.) in length for seamless pipe of Grades 2, 3, 4, 5, 6, 7, 11, 12, 13 and 14. The test is to be carried out in two steps.

i. Test Step No. 1

In the first step, which is a test for ductility, no cracks or breaks on the inside or outside or end surfaces are to develop until the distance between the plates is less than the value of H attained from the following equation:

$$H = \frac{(1+e)t}{(e+\frac{t}{D})}$$

Where,

H = Distance between flattening plates, in mm (in.)
t = Specified wall thickness of pipe, in mm (in.)
D = Specified outside diameter of pipe, in mm (in.)
e = Deformation per unit length, constant for a given Grade as follows:
= 0.09 for Grade 2
= 0.08 for Grades 4, 6, 7, 11, 12, 13 and 14
= 0.07 for Grades 3 and 5

ii. Test Step No. 2

In the second step, which is a test for soundness, the flattening is to be continued until the specimen breaks or the opposite wall of the pipe meet. Indication of laminated, burned or unsound material that is revealed during the entire flattening test is to be reason for rejection.

17.15. Hydrostatic test

17.15.1. General

In accordance with the following requirements each length of pipe of all grades is to be hydrostatically tested at the mill, except when intended for structural use, such as stanchions. When specified by the purchaser, seamless pipe is also to be subjected to a nondestructive electrical test in accordance with [17.16] of this section. When each pipe is hydrostatically tested as a regular procedure during the process of manufacture, the surveyor may accept an affidavit covering this test.

17.15.2. Grades 1, 2 and 3

As shown in Table 2.17.7, for these grades, each pipe is to withstand an internal hydrostatic pressure. This does not prohibit testing at a higher pressure, but the maximum fiber stress induced by the test is not to exceed 90% of the minimum specified yield strength of the material. Welded pipe that is 60.3 mm O.D. (2 in. nominal diameter) and larger is to be jarred near one end, while under test pressure. For all sizes of seamless and electric-welded pipe, hydrostatic pressure is to be maintained for a minimum duration of 5 seconds.

17.15.3. Grades 4, 5, 6, 7, 11, 12, 13 and 14

For these grades, each pipe is to withstand an internal hydrostatic test pressure which will produce in the pipe wall a stress of not less than 60% of the minimum specified yield point at room temperature. The equation given in [17.15.5] below determines this pressure. The hydrostatic test pressure determined by the equation is to be rounded to the nearest 5 bar (5 kgf/cm^2, 50 psi) for pressures below 70 bar (70 kgf/cm^2, 1000 psi) and to the nearest 10 bar (10 kgf/cm^2, 100 psi) for pressures 70 bar (70 kgf/cm^2, 1000 psi) and above. Irrespective of the pipe wall stress determined by the equation in [17.15.5] below, the minimum hydrostatic test pressure required to satisfy this requirement need not exceed 170 bar (170 kgf/cm^2, 2500 psi) for sizes 88.9 mm O.D. (3 in. nominal diameter) and under, or 190 bar (190 kgf/cm^2, 2800 psi) for all sizes over 88.9 mm O.D. (3 in. nominal diameter). This does not prohibit testing at a higher pressure, but the maximum fiber stress induced by the test is not to exceed 90% of the minimum specified yield strength of the material. The hydrostatic pressure is to be maintained for a minimum duration of 5 seconds.

17.15.4. Grades 8 and 9

Each pipe is to withstand an internal hydrostatic test pressure for these grades. The test procedure shall be determined from the equation given in [17.15.5] below. The maximum test pressure is not to exceed 172 bar (176 kgf/cm^2, 2500 psi). For pipe with a wall thickness greater than 3.9 mm (0.154 in.), the pipe is to be jarred near both ends with a 1 kg (2 lb.) hammer or its equivalent while under the test pressure. The hydrostatic pressure is to be maintained for a minimum duration of 5 seconds.

17.15.5. Test pressures

For applicable grades, the test pressures are to be determined by the following equation.

$$P = \frac{K\,S\,t}{D}$$

Where,

P = maximum hydrostatic-test pressure, in bar (kgf/cm^2, psi)
t = specified thickness of pipe wall, in mm (in.)
D = specified outside diameter of pipe, in mm (in.)
K = 20 N/mm^2 (200 kgf/cm^2, 2 psi)
S = permissible fiber stress:
- = 0.60 times the specified yield point, in N/mm^2 (kgf/mm^2, psi) for INTLREG Grades 4, 5, 6, 7, 11, 12, 13 and 14.
- = 110 N/mm^2 (11 kgf/cm^2, 16000 psi) to 125 N/mm^2 (12.5 kgf/ mm^2, 18000 psi), but in no case is the stress induced is to exceed 80% of the specified yield point for INTLREG Grade 8.
- = 140 N/mm^2 (14 kgf/cm^2, 20000 psi) to 150 N/mm^2 (15.5 kgf/ mm^2, 22000 psi), but in no case is the stress induced is to exceed 80% of the specified yield point for INTLREG Grade 9.

17.15.6. Exceptions

Special consideration will be given to the maximum test pressure for special service pipes, such as diesel engine high pressure fuel injection piping. For the piping, the manufacturer is to submit the proposed maximum test pressure along with technical justification and manufacturing control process. The justification is to include pipe fiber stress analysis and substantiating prototype test results.

Table 2.17.7: Hydrostatic-test Pressure for Welded and Seamless Plain-end Steel Pipe

Outside Diameter, mm	Pressure, in bar (kgf/cm^2)								
	Standard weight			Extra-strong			Double Extra-strong		
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
10.3 to 33.4	48 (49.2)	48 (49.2)	48 (49.2)	59 (59.8)	59 (59.8)	59 (59.8)	69 (70.3)	69 (70.3)	69 (70.3)
42.2 and 48.3	69 (70.3)	69 (70.3)	76 (77.3)	90 (91.3)	103 (103)	110 (112)	97 (98.4)	124 (124)	131 (134)
60.3	69 (70.3)	159 (162)	172 (176)	90 (91.4)	172 (176)	172 (176)	97 (98.4)	172 (176)	172 (176)
73.0	69 (70.3)	172 (176)	172 (176)	90 (91.4)	172 (176)	172 (176)	97 (98.4)	172 (176)	172 (176)
88.9	69 (70.3)	152 (155)	172 (176)	90 (91.4)	172 (176)	172 (176)	-	172 (176)	172 (176)
101.6	83 (84.4)	138 (141)	165 (169)	117 (120)	193 (197)	193 (197)	-	-	-
114.3	83 (84.4)	131 (136)	152 (155)	117 (120)	186 (190)	193 (197)	-	193 (197)	193 (197)
141.3	-	117 (120)	131 (136)	-	165 (169)	193 (197)	-	193 (197)	193 (197)
168.3	-	103 (105)	124 (127)	-	159 (162)	186 (190)	-	193 (197)	193 (197)
219.1	-	90 (91.4)	110 (112)	-	145 (148)	165 (169)	-	193 (197)	193 (197)
273.1	-	83 (84.4)	97 (98.4)	-	117 (120)	138 (141)	-	193 (197)	193 (197)
323.9	-	76 (77.3)	83 (84.4)	-	97 (98.4)	110 (112)	-	193 (197)	193 (197)
355.6	-	66 (66.8)	76 (77.3)	-	90 (91.4)	103 (10 5)	-	-	-
406.4	-	59 (59.8)	69 (70.3)	-	76 (77.3)	90 (91.4)	-	-	-
457.2	-	52 (52.7)	62 (63.3)	-	69 (70.3)	83 (84.4)	-	-	-
508.0	-	48 (49.2)	55 (56.2)	-	62 (63.3)	69 (70.3)	-	-	-
609.6	-	38 (38.7)	45 (45.7)	-	52 (52.7)	62 (63.3)	-	-	-

Table 2.17.7: (continued) Hydrostatic-test Pressure for Welded and Seamless Plain-end Steel Pipe

IPS Size, in.	Pressure, in psi								
	Standard weight			Extra-strong			Double extra-strong		
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
$^1/_8$ to 1	700	700	700	850	850	850	1000	1000	1000
$1^1/_4$ and $1^1/_2$	1000	1000	1100	1300	1500	1600	1400	1800	1900
2	1000	2300	2500	1300	2500	2500	1400	2500	2500
$2^1/_2$	1000	2500	2500	1300	2500	2500	1400	2500	2500
3	1000	2200	2500	1300	2500	2500		2500	2500
$3^1/_2$	1200	2000	2400	1700	2800	2800			
4	1200	1900	2200	1700	2700	2800		2800	2800
5		1700	1900		2400	2800		2800	2800
6		1500	1800		2300	2700		2800	2800
8		1300	1600		2100	2400		2800	2800
10		1200	1400		1700	2000		2800	2800
12		1100	1200		1400	1600		2800	2800
14		950	1100		1300	1500			
16		850	1000		1100	1300			
18		750	900		1000	1200			
20		700	800		900	1000			
24		550	650		750	900			

17.16. Nondestructive Electric Test (NDET) for seamless pipe

17.16.1. General

When specified by the purchaser, seamless pipe is to be tested in accordance with ASTM E213, for Ultrasonic Examination of Metal Pipe and Tubing, or ASTM E309, for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation, or ASTM E570, for Flux Leakage Examination of Ferromagnetic Steel Tubular Products, or other approved standard. This test is carried out to reject defective tubes and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner.

17.16.2. Ultrasonic calibration standards

Notches on the inside or outside surfaces may be used. The depth of the notch is not to exceed 12.5% of the specified wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The width of the notch is not to exceed two times the depth.

17.16.3. Eddy-current calibration standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques in use and manufacturing practices employed, any one of the following calibration standards may be used at the option of the producer to establish a minimum sensitivity level for rejection.

17.16.3.1. Drilled hole

In order to ensure a separately distinguishable response, three or four holes equally spaced about the pipe circumference and sufficiently separated longitudinally are to be drilled radially and entirely through the pipe wall, care being taken to avoid distortion of the pipe wall while drilling. The diameter of the holes is to be as given in Table 2.17.8.

Table 2.17.8: Diameter of Holes

Calibration pipe diameter in mm (inch)	**Hole diameter** in mm (inch)
under 12.5 (0.5)	1.0 (0.039)
12.5 (0.5) to 31.8 (1.25), excl.	1.4 (0.055)
31.8 (1.25) to 50 (2.0), excl.	1.8 (0.071)
50 (2.0) to 125 (5.0), excl.	2.2 (0.087)
125 (5.0) and over	2.7 (0.106)

17.16.3.2. Transverse tangential notch

Using a round file or tool with a 6.35 mm (0.25 in.) diameter, a notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater.

17.16.3.3. Longitudinal notch

A notch 0.785 mm. (0.031 in.) or less in width is to be machined in a radial plane parallel to the pipe axis on the outside surface of the tube to a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

17.16.4. Flux leakage calibration standards

The depth of longitudinal notches on the inside and outside surfaces is not to exceed 12.5% of the required wall thickness of the pipe or 0.1 mm (0.004 in.), whichever is greater. The length of the notch is not to exceed 25.4 mm (1.0 in.), and the width of the notch is not to exceed the depth. In order to allow distinct identification of the signal from each notch, outside and inside surface notches are to be located sufficiently apart.

17.16.5. Rejection

Tubing producing a signal equal to or greater than the calibration defect is to be subject to rejection.

17.16.6. Affidavits

During the process of manufacture, when each tube is subjected to an approved nondestructive electric test as a regular procedure, the Surveyor may accept an affidavit covering this test.

17.17. Retests

17.17.1. General

If the results of the mechanical tests of any lot do not comply with the requirements, for all grades of pipe, retests may be conducted on additional pipe of double the original number from the same lot, each of which is to be in compliance with the requirements specified.

17.17.2. Grades 1, 2, 3, 8 and 9

If any pipe section fails for these grades, when flattening tests are carried out on the crop ends of each length of welded pipe, other pieces from the length may be cut until satisfactory tests are obtained, or else, the length is to be rejected.

17.17.3. Grades 4 and 5

For these grades, one retest may be carried out from the failed end if a crop end of a finished pipe fails in the flattening test. Either before or after the first test, the pipe may be normalized but it is to be subjected to only two normalizing treatments.

17.17.4. Grades 6, 7, 11, 12, 13 and 14

For these grades, should individual lengths of pipe selected to represent any lot fail to conform to the mechanical requirements, the lot may be reheat-treated and resubmitted for test, except that any individual lengths which meet the test requirements before re-treating will be accepted.

17.18. Pipe testing and inspection

17.18.1. Group I Piping

Pipes intended for use in Group I piping systems (Class I and Class II, Refer Pt 5A, Ch 8, Sec 1, 1.2) are to be tested, preferably at the mill, to the satisfaction of the Surveyor. The Surveyor shall examine the material surfaces when specially requested by the purchaser. Refer also Pt 5A, Ch 8, Sec 6, [6.2.3.1].

17.18.2. Group I and II Piping

The pipes are to be reasonably straight, free from defects, and have a workmanlike finish. At a minimum, a visual inspection of the finished pipe is to be carried out at the same frequency as that needed for the tension test specified in Table 2.17.4 for the applicable grade. Without the purchaser’s approval, welding repair to the pipe is not to be carried out and is to be to the Surveyor’s satisfaction.

17.19. Permissible variation in wall thickness

For all pipe, the permissible variations in wall thickness are based on the ordered thickness and are to comply with that given in the applicable ASTM designation for acceptance. The minimum thickness for all pipes is not to be less than that required by the Rules for a specific application irrespective of such prior acceptance. At a minimum, the finished pipe is to be measured at the same frequency as that required for the tension test specified in Table 2.17.4.

17.20. Permissible variations in outside diameter

17.20.1. Grades 1, 2, 3

For pipe of these grades 48.3 mm O.D. (1.5 in. nominal diameter) and under, the outside diameter at any point is not to vary more than 0.4 mm (0.016 in.) over nor more than 0.8 mm (0.131 in.) under the specified diameter. For pipe 60.3 mm O.D. (2 in. nominal diameter) and over, the outside diameter is not to vary more than plus or minus 1% from the specified diameter.

17.20.2. Grades 4, 5, 6, 7, 11, 12, 13 and 14

For these grades, deviation in outside diameter from that specified is not to exceed the amount prescribed in Table 2.17.9.

17.20.3. Grades 8 and 9

For these grades, the outside diameter is not to vary more than plus or minus 1% from the nominal diameter specified.

17.20.4. Inspection

At a minimum, for the applicable grade, the finished pipe is to be measured at the same frequency as that required for the tension test tabulated in Table 2.17.4.

Table 2.17.9: Out-of-roundness variation

Pipe outside diameter, in mm (inch.)	**Out-of-roundness variation,** in mm (inch.)	
	Over	**Under**
10.3 (1/8) ≤ OD ≤ 48.3 (1.5)	0.38 (1/64)	0.79 (1/32)
48.3 (1.5) < OD ≤ 114.3 (4.0)	0.79 (1/32)	0.79 (1/32)
114.3 (4.0) < OD ≤ 219 (8.0)	1.57 (1/16)	0.79 (1/32)
219.1 (8.0) < OD ≤ 457.2 (18.0)	2.36 (3/32)	0.79 (1/32)
457.2 (18.0) < OD ≤ 660.4 (26.0)	3.17 (1/8)	0.79 (1/32)
660.4 (26.0) < OD ≤ 863.6 (34.0)	4.0 (5/32)	0.80 (1/32)
863.6 (34.0) < OD ≤ 1219.2 (48.0)	4.8 (3/16)	0.80 (1/32)

SECTION 18 PIPING, VALVES AND FITTINGS FOR LOW-TEMPERATURE SERVICE

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18.1. Scope

In this section, the following specifications deal with six representative grades of steel for pipes, valves and fittings for use in piping systems designed for temperatures lower than -18°C (0°F). Special Considerations will be given to those steels differing in chemical composition, mechanical properties or heat treatment. The requirements for aluminum alloys or other non-ferrous materials will be specially considered.

18.2. Designation

The various grades are in agreement with ASTM standards as shown below;

Table 2.18.1

Grade	Nominal Composition	ASTM
1L	Carbon Steels	A333 Grades 1 and 6; A334 Grades 1 and 6; A350 Grades LF1 and LF2; A352 Grade LCB; A420 Grade WPL6
2L	1/2 Mo	A352 Grade LC1
3L	21/2 Ni	A333 Grades 7; A334 Grade 7; A352 Grade LC2
4L	31/2 Ni	A333 Grade 3; A334 Grade 3; A350 Grade LF3; A352 Grade LC3; A420 Grade WPL3
5L	9 Ni	A333 Grade 8; A334 Grade 8; A522; A420 Grade WPL8
6L	10 Ni 20 Cr or 20 Ni 25 Cr	A351 Grades CF8C and CK20

18.3. Manufacture

The steel is to be made by the open hearth, basic oxygen or electric furnace process. The steel is to be killed and made with a fine-grain de-oxidation practice.

18.4. Heat treatment

The steel is to be supplied in the normalized condition or as required by the applicable specification.

18.5. Marking

The manufacturer’s name or brand of the manufacturer is to be clearly marked on each pipe, flange and fitting. The INTLREG grade and initials “**IR”** are to be placed on the material near the marking of the manufacturer.

18.6. Chemical composition

The materials selected from [18.2] are to comply with the chemical requirements detailed in the ASTM designation indicated, except as modified by [18.3] or otherwise specially approved.

18.7. Mechanical tests

The materials chosen from [18.2] are to be tested as per the requirements of the applicable ASTM designation as to tension test, flattening test, hydrostatic test etc. unless otherwise specially approved.

18.8. Impact properties

The materials selected from [18.2] are to be in compliance with the toughness requirements of [18.12].

18.9. Steels for service temperatures between -18°C (0°F) and -196°C (-320°F)

For the minimum design service temperature indicated, the below grades in Table 2.18.2 may be used.

Table 2.18.2

Grade	Minimum Design Service Temperature °C (°F)
1L	-34 (-30)
2L	-46 (-50)
3L	-73 (-100)
4L	-101 (-150)
5L & 6L	-196 (-320)

18.10. Steels for service temperatures below -196°C (-320°F)

Steels planned for service temperatures below -196°C (-320°F) are to be austenitic stainless steels. For each application, the chemical composition, heat treatment and tensile properties of these materials are to be submitted.

18.11. Materials for nuts and bolts

Nuts and bolts of ferrtic-alloys shall be in compliance with ASTM A194 Grade 4 and A320 L43 may be used where system service temperatures are not below -101°C (-150°F). Where the design service temperature is not below -196°C (-320°F), austenitic-alloy nuts and bolts complying with ASTM A194 Grades 8T and 8F and A320 Grades B8T, B8F and B8M may be used.

18.12. Toughness

Low temperature notch toughness is to be determined by impact testing using Charpy V-notch specimens. Testing is to comprise of at least three longitudinally oriented specimens from each lot. Lot size is as defined in the applicable ASTM designation, except that at least one set of impact tests is to be carried out from each heat in each heat treatment charge. The energies absorbed by each set of impact specimens for Grades 1L and 2L are to comply with the requirements given below Table 2.18.3.

Table 2.18.3

Specimen Size	Minimum Average		Minimum-One Specimen	
mm	J	(kgf-m, ft-lbf)	J	(kgf-m, ft-lbf)
10 × 10	27.0	(2.8, 20)	18.5	(1.9, 13.5)
10 × 7.5	22.5	(2.3, 16.5)	15	(1.5, 11)
10 × 5.0	18.5	(1.9, 13.5)	12	(1.2, 9)
10 × 2.5	13.5	(1.4, 10)	9	(0.9, 6.5)

The Charpy impact conditions for Grades 3L, 4L and 5L are 125% of the values given above. Charpy impact tests are not required for Grade 6L. Where material thicknesses are such that the quarter size impact specimen cannot be attained, the requirements for toughness testing will be specially considered.

18.13. Impact test temperature

Materials selected from [18.2] are not to be used at temperatures lower than those specified in [18.9] and are to be tested at temperatures at least 5.5°C (10°F) below the minimum design service temperature. Where the test temperature is determined to be below -196°C (-320°F), testing may be carried out at -196°C (-320°F).

18.14. Witnessed tests

Piping intended for temperature below -18°C (0°F) is to be tested in the presence of a surveyor. Testing of the materials which are intended for fabrication of valves fittings and piping are to be carried out by the manufacturers and, upon request, the test results are to be submitted to INTLREG.

For vessels proposed to carry Liquefied Gases in Bulk, Refer Ch 1, [1.1.1].

18.15. Retests

When the materials fail to meet the minimum impact requirements of [18.12] by an amount not more than 15%, retests are permitted as per Ch 1, Sec 2, [2.6.4].

18.16. Welding

Weld procedure is to be approved as per the requirements of Ch 3, Sec 5, [5.3.2]

SECTION 19 MONEL PIPE AND TUBE

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19.1. Scope

This section covers four grades of seamless and welded nickel-copper (Monel) pipe and tube, designated M1, M2, M3, and M4.

19.2. General

19.2.1. Grades M1 and M2

Grades M1 and M2 cover cold-worked, seamless nickel-copper pipe and pipe intended for use in general engineering applications requiring superior seawater corrosion resistance. The pipe and tube ordered under these grades are considered suitable for welding, forming operations involving bending, flaring and flanging. Pipe is to be ordered to ANSI B36.19. Tube is to be ordered to an outer diameter and a nominal or minimum wall thickness specified by the purchaser and approved for the application.

19.2.2. Grades M3 and M4

Grades M3 and M4 cover welded, cold-worked nickel-copper pipe and pipe intended for use in general engineering applications requiring superior seawater corrosion resistance. The Pipe and tube ordered under these grades are considered suitable for welding, forming operations involving bending, flaring and flanging. Pipe is to be ordered to ANSI B36.19. Tube is to be ordered to an outer diameter and a nominal or minimum wall thickness specified by the purchaser and approved for the application.

19.2.3. ASTM designation

The grades are in accordance with ASTM, shown in Table 2.19.1.

Table 2.19.1

INTLREG Grade	Heat Treatment	ASTM Designation	Product Form
M1	Annealed	B165, UNS N04400	Seamless Pipe and Tube
M2	Stress Relieved	B165, UNS N04400	Seamless Pipe and Tube
M3	Annealed	B730, UNS N04400	Welded Pipe and Tube
M4	Stress Relieved	B730, UNS N04400	Welded Pipe and Tube

19.3. Process of manufacture

19.3.1. Grades M1 and M2

These grades are to be finished by cold-working in order to ensure that acceptable corrosion resistance in the weld area and base metal will be developed during heat treatment. These grades of pipe and tube are to be supplied in the annealed, Grade M1 or stress-relieved, Grade M2 condition.

19.3.2. Grades M3 and M4

These grades are to be made by automatic welding process from flat-rolled material without adding any filler metal. After welding but prior to heat treatment, the pipe and tube are to be cold worked in order to ensure that acceptable corrosion resistance in the weld area and base metal will be developed during heat treatment. Heat treatment is to consist of annealing, as Grade M3, or stress-relieving, as Grade M4. Welded pipe and tube are to be furnished with a scale-free finish. When bright annealing is used, descaling is not mandatory.

19.4. Marking

On each length of pipe and tube, identification markings are to be clearly stenciled, or marked. The marking fluid is not to be harmful to the pipe and tube and is not to get smeared or rubbed off in normal handling. The fluid is not to be affected by solvents used in subsequent cleaning and preservation operations, but is to be readily removed by hot alkaline solution. For small-diameter tube or pipe with an outside diameter less than 19.0 mm (¾ in.) which is bundled or boxed, the necessary markings are to be placed on a tag firmly attached to the bundle or box, or on the box. The markings are to be arranged and are to include the following information:

a) Name or brand of the manufacturer;

b) INTLREG Grade or ASTM Specification and Grade;

c) UNS Alloy Number;

d) Heat number or manufacturer's number by which the heat can be identified;

e) Temper designation;

f) Tube diameter/NPS Designation;

g) Wall thickness (specify minimum or nominal)/NPS schedule;

h) Test pressure;

i) NDET if so tested;

j) INTLREG markings by Surveyor;

19.5. Chemical composition

19.5.1. Ladle analysis

The material is to conform to the chemical requirements given below.

Table 2.19.2: Chemical Composition

Element	**Content**, in % (*)
Nickel	63.0 min.
Copper	28.0 to 34.0
Iron	2.5
Manganese	2.0
Carbon	0.3
Silicon	0.5
Sulphur	0.024
Note: (*) Single values are maxima, unless noted.	

19.5.2. Chemical composition – check analysis

As specified by the purchaser, a check analysis may be carried out. The chemical composition determined from the check analysis is to conform to the requirements detailed in [19.5.1], as amended by the product analysis tolerances of the relevant ASTM specification.

19.6. Tension test

19.6.1. Tension test specimens

Specimens of Tensile test are to be full sections of the pipe or tube. For Larger sizes, tension test specimens are to consist of longitudinal strips cut from the pipe or tube, in accordance with ASTM E8, for Tension Testing of Metallic Materials.

19.6.2. Annealed tensile properties

As shown in Table 2.19.3, annealed pipe and tube, Grades M1 and M3, is to comply with the applicable requirements as to the tensile properties.

Table 2.19.3: Tensile Test

Grades	**Outside Diameter** in mm (in.)	**Tensile Strength**, min in N/mm^2 (ksi)	0.2% Offset Yield Strength, min in N/mm^2 (ksi)	Percent Elongation, min, in 50 mm (2 in.), or 4 D
M1 & M3	≤ 127 mm (5 in.)	480 (70)	195 (28)	35
	> 127 mm (5 in.)	480 (70)	170 (25)	35
M2 & M4	All	585 (85)	380 (55)	15

19.6.3. Stress relieved tensile properties

As specified in Table 2.19.3, stress relieved pipe and tube, Grades M2 and M4, is to comply with the applicable requirements.

19.7. Flattening test

Test specimens shall be taken from samples of welded pipe and tube, Grades M3 or M4, having lengths more than three times the specified outside diameter or 102 mm (4 in.), whichever is greater. The specimens are to be flattened under a load applied gradually at room temperature until the distance between the platens is not greater than five times the wall thickness. The weld is to be positioned 90 degrees from the direction of the applied flattening force. When viewed with the unaided eye, the flattened specimen is to show no cracking, breaks or ruptures on any surface.

19.8. Flare test

Grades M1 and M3 pipe and tube 76 mm (3 in.) or less in specified outside diameter are to be subjected to a flare test. The specimen is to be tested by means of an expanding tool having an included angle of 60 degrees until the specified outside diameter has been increased by 30 percent. The expanded specimen is not to show any signs of cracking or rupture visible to the unaided eye.

19.9. Flange test

Test specimens shall be taken from samples of welded pipe and tube, Grade M4, having lengths not less than three times the specified outside diameter or 102 mm (4 in.), whichever is longer, are to be flanged at a right angle to the tube until the width of the flange is not less than 15 percent the diameter of the tube. The flanged specimen is to show no sign of cracking, breaks or ruptures on any surface when viewed with the unaided eye.

19.10. Number of tests

19.10.1. Chemical analysis

For each heat of material, a chemical analysis (ladle) is to be carried out. In order to satisfy this requirement, certificates issued by the material producer may be used.

19.10.2. Other tests

The lot is to comprise of tubulars of the same heat, similar size (diameter and wall), same condition, and heat treated together in the same batch or in a continuous furnace under the same conditions of temperature, time at temperature, furnace speed, and furnace atmosphere. The lot size for continuously heat treated tubulars is to be 9100 kg (20,000 lb.) or a fraction thereof. The lot weight is not to exceed 277 kg (500 lb.), where the material cannot be identified by heat. Sample pieces are to be taken randomly from each lot for test purposes, at the following frequency given in Table 2.19.4 for each of the following tests.

Table 2.19.4

Test or Examination	Frequency
Tension	One
Flattening	One
Flare	One
Flange	One
Hydrostatic	Every Piece
Nondestructive	Every Piece
Finish	1%, minimum of 1, maximum of 10
Dimensions	1%, minimum of 1, maximum of 10

19.11. Hydrostatic test

19.11.1. Limiting test pressures
For the material under test, each pipe or tube is to withstand an internal hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi) without showing any indication of leakage, provided the fiber stress as calculated from the following equation does not exceed the allowable fiber stress.

$$P = \frac{K\,S\,t}{D}$$

Where

P = pressure in bar (kgf/cm^2, psi)

S = allowable fiber stress of the material, N/mm^2(kgf/mm^2, psi), refer to Table 2.19.5

t = thickness of tubular wall, in mm (in.)

D = outside diameter of the tubular, in mm (in.)

K = 20 (200, 2)

Table 2.19.5

Condition	Grade	Outside Diameter	Allowable Fiber Stress, S
Annealed	M1, M3	127 mm (5 in.) and less	120 N/mm^2 , (12 kgf/mm^2, 17,500 psi)
	M1	Over 127 mm (5 in.)	115 N/mm^2, (11.5 kgf/mm^2, 16,700 psi)
	M3	Over 127 mm (5 in.)	120 N/mm^2, (12 kgf/mm^2, 17,500 psi)
Stress Relieved	All	All diameters	145 N/mm^2, (14.5 kgf/mm^2, 21,200 psi)

19.11.2. Exceeding limiting test pressures

The hydrostatic test pressure, when so agreed, may exceed the limits as detailed in Section 5 of this chapter to a maximum of 1.5 times the allowable fiber stress values shown above.

19.11.3. Affidavits of tests

When hydrostatic test is carried out for each tube as a regular procedure during the manufacturing process, the surveyor may accept an affidavit covering this test.

19.12. Nondestructive Electric Test (NDET)

19.12.1. General

When specified by the purchaser, testing of welded pipe or tube is to be carried out in accordance with ASTM E213, for Ultrasonic Inspection of Metal Pipe and Tubing, ASTM E571, for Electromagnetic (Eddy-current) Examination of Nickel and Nickel Alloy Tubular Products, or other approved standard. The intention of these tests is to reject tubes containing defects, and the Surveyor is to be satisfied that the nondestructive testing procedures are carried out in a satisfactory way.

19.12.2. Ultrasonic calibration standards

Longitudinal notches are to be placed in the weld if visible. The notches machined on the outside surface and the inside surface are to be used. The notch depth is to not exceed 12.5% of the specified wall thickness or 0.004 inch (0.10 mm), whichever is greater.

19.12.3. Eddy-current calibration standards

Any one of the following calibration standards may be used at the discretion of the producer so that a minimum sensitivity level for rejection can be established. This will enable to accommodate the various types of nondestructive electrical testing equipment and techniques in use, and manufacturing practices employed. If visible, the holes and notches are to be placed in the weld.

1.1.1.1. Drilled hole

A hole not larger than 0.79 mm (0.031 in.) in diameter is to be drilled radially and completely through tube wall carefully, to avoid distortion of the tube while drilling.

1.1.1.2. Transverse tangential notch

A notch is to be filed or milled using a round file or tool with a 6.4 mm (0.25 in.) diameter tangential to the surface and transverse to the longitudinal axis of the tube. The notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.10 mm (0.004 in.), whichever is greater.

1.1.1.3. Longitudinal notch

A notch 0.79 mm (0.031 in.) or less in width is to be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.10 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

19.12.4. Rejection

Tubulars which produce a signal equal to or greater than the calibration defect are to be subject to rejection.

19.12.5. Affidavits

During the process of manufacture, as a regular procedure, when each tubular is subjected to an approved nondestructive electrical test, an affidavit covering this test may be accepted by the Surveyor.

19.13. Retests

When the results of the test on one of the specimen carried out to determine the mechanical properties fail to meet the requirements, retest must be carried out on each of two additional specimens taken from different pieces from same group or lot, and the results of both of these tests are to conform to the requirements. For a particular property, failure of more than one specimen to meet the requirements is to be cause for rejection of the entire lot.

19.14. Finish

Thorough examinations of pipe or tube selected for testing is needed for finish and workmanship. The samples examined are to be free from cracks, injurious surface flaws and similar defects to the extent determinable by visual or NDET examination. All pipe or tube is to be clean and free of any foreign material that would render the tubulars unfit for the intended use.

19.15. Dimensions and tolerances

Pipe or tube selected for testing is to be examined and measured for dimensions and tolerances.

19.15.1. Diameter

The outside diameter of pipe and tube, including ovality, is not to exceed the permissible variations as tabulated in Table 2.19.6.

Table 2.19.6

Nominal Outside Diameter in mm (in.)	Over and Under Tolerances in mm (in.)
Over 3.2 (0.125) to 16 ($^{5}/_{8}$), excl.	0.13 (0.005)
16 ($^{5}/_{8}$) to 38 ($1^{1}/_{2}$), incl.	0.19 (0.0075)
Over 38 ($1^{1}/2$) to 76 (3), incl.	0.25 (0.010)
Over 76 (3) to 114 ($4^{1}/_{2}$), incl.	0.38 (0.015)
Over 114 ($4^{1}/_{2}$) to 152 (6), incl.	0.51(0.020)
Over 152 (6) to 168 ($6^{5}/_{8}$), incl.	0.64 (0.025)
Over 168 ($6^{5}/_{8}$) to 219 ($8^{5}/_{8}$), incl.	0.79 (0.031)

For pipe and tube which has a nominal wall thickness of 3% or less of the nominal outside diameter, the mean outside diameter is to comply with the above permissible variations and individual measurements (including ovality) are to conform to the over and under values, with the values increased by 0.5% of the nominal outside diameter. For pipe and tube over 114 mm ($4^{1}/_{2}$ in.) in outside diameter with a nominal wall thickness greater than 3% of the nominal outside diameter, the mean outside diameter is to conform to the above permissible variations, and individual measurements are not to exceed twice the above permissible variations.

19.15.2. Wall thickness – Seamless

For seamless pipe and tube, the wall thickness is not to exceed the allowable variations as tabulated in Table 2.19.7 for the type (nominal or minimum) of specified wall thickness ordered.

Table 2.19.7: Wall Thickness Variation (Seamless)

Nominal Outside Diameter in mm (in.)	Variation in Thickness of Specified Nominal Wall		Variation in Thickness of Specified Minimum Wall	
	Over in percent	Under in percent	Over in percent	Under in percent
Over 10 (0.400) to 16 ($^{5}/_{8}$), excl.	15.0	15.0	30	0
16 ($^{5}/_{8}$) to 38 ($1^{1}/_{2}$), incl.	10.0	10.0	22	0
Over 38 ($1^{1}/_{2}$) to 76 (3), incl.	10.0	10.0	22	0
Over 76 (3) to 114 ($4^{1}/_{2}$), incl.	10.0	10.0	22	0
Over 114 ($4^{1}/_{2}$) to 152 (6), incl.	12.5	12.5	28	0
Over 152 (6) to 168 ($6^{5}/_{8}$), incl.	12.5	12.5	28	0
Over 168 ($6^{5}/_{8}$) to 219 ($8^{5}/_{8}$), incl.	12.5	12.5	28	0

19.15.3. Wall thickness – Welded

The wall thickness of welded pipe and tube is not to exceed the permissible variations shown in Table 2.19.8 below for the type (nominal or minimum) of specified wall thickness ordered.

Table 2.19.8: Wall Thickness Variation (Welded)

Nominal Outside Diameter in mm (in.)	Variation in Thickness of Specified Nominal Wall		Variation in Thickness of Specified Minimum Wall	
	Over in percent	Under in percent	Over in percent	Under in percent
Over 3.2 (0.125) to 16 (${}^{5}/_{8}$), excl.	15.0	15.0	30	0
16 (${}^{5}/_{8}$) to 38 ($1{}^{1}/_{2}$), incl.	12.5	12.5	28	0
Over 38 ($1{}^{1}/_{2}$) to 76 (3), incl.	12.5	12.5	28	0
Over 76 (3) to 114 ($4{}^{1}/_{2}$), incl.	12.5	12.5	28	0
Over 114 ($4{}^{1}/_{2}$) to 152 (6), incl.	12.5	12.5	28	0
Over 152 (6) to 168 ($6{}^{5}/_{8}$), incl.	12.5	12.5	28	0
Over 168 ($6{}^{5}/_{8}$) to 219 ($8{}^{5}/_{8}$), incl.	12.5	12.5	28	0

19.15.4. Cut ends
Unless otherwise specified the ends are to be plain or cut and deburred.

19.15.5. Straightness
Pipe and tube are to be reasonably straight and free of bends and kinks.

CHAPTER 3 WELDING AND OTHER JOINING METHODS

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SECTION 1 HULL CONSTRUCTION

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1.1. General

1.1.1. Hull welding

Welding in hull construction is to be compliance with the requirements of this section, unless otherwise specially approved. It is recommended that permanent markings is to be applied on the side shell of welded ships for indicating the location of bulkheads for reference. Under all circumstances, welding procedures and filler metals are to produce sound welds with strength and toughness comparable to the base material.

1.1.2. Plans and specifications

The submitted plans are to clearly indicate the proposed extent of welding to be used in the principal parts of the structure. The welding process, filler metal and joint design indicating full/partial penetration weld are to be shown on the either in detail drawings or in separate specifications/ drawings submitted for approval, which should also distinguish between manual and automatic welding. A planned procedure that is to be followed in the erection and welding of the important structural members is to be prepared and filed by the shipbuilders with the Surveyor.

1.1.3. Workmanship and supervision

All welders and welding operators, to be employed in the construction of the vessels to be classed is to have the appropriate qualification and are experienced in the proposed work, to the satisfaction of the surveyor. The Surveyor should also be satisfied that sufficient number of skilled supervisors are being employed to ensure thorough supervision and control of all welding operations. Inspection of welds employing methods as outlined in [1.3.10] below, is to be carried out to the satisfaction of the Surveyor.

1.1.4. Welding procedures

1.1.4.1. General

Welding procedures are to be qualified to recognized standards such as AWS, EN, , ISO AMSE, MIL and JIS. Also refer to Ch 3, Sec 5.

Prior to the construction, procedures for the welding of all joints are to be established for the welding processes, types of electrodes, welding techniques, edge preparations and positions proposed Refer to Sec 5, [5.3]. The details of the proposed welding procedures and sequences may be required to be submitted for review depending on the intended application.

1.1.4.2. Weld Metal Toughness – Criteria for INTLREG Grades of Steel

For steels shown in Ch 1, Sec 2, Table-1.2.5; Ch 1, Sec 3, Table-1.3.4 of this Part, Approved filler metals appropriate to the grades shown in Ch 3, Sec 6, [6.5] may be used

1.1.4.3. Weld Metal Toughness – Criteria for Other Steels

Weld metal is to exhibit Charpy V-notch toughness values at least equivalent to transverse base metal requirements (2/3 of the longitudinal base metal requirements).

1.1.5. Thermal Mechanically Control Steel Plates (TMCP) – note to users

The fabricator should pay attention to the possible reduction in the mechanical properties when considering thermo-Mechanically controlled steels for further heating during forming or stress relieving, or for high heat input welding. A procedure test using representative material is to be considered.

1.2. Preparation for welding

1.2.1. Edge preparation and fitting

The edge preparation shall be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved joint detail. The Surveyor should be satisfied with the procedures adopted for rectifying the improper fitting. The Surveyor may accept a welding procedure for buildup of each edge not exceeding one half the thickness of the member or 12.5 mm (0.5 in.), whichever is the lesser. The Surveyor may accept edge build up in excess of the above, up to the full thickness of the member on a case-by-case basis, provided the Surveyor is notified of such cases prior to the welding of the members together. A suitable transition taper is to be provided where it is found that the plates to be joined differ in thickness and have an offset on either side of more than 3 mm (1/8 in.). The transition taper length is to be not less than three times the offset in case of the transverse butts in bottom shell, sheer strake, and strength deck plating within the midship portion of the hull, and other joints which may be subject to comparatively high stresses. The transition may be formed by tapering the thicker member or by specifying a weld joint design which will provide the required transition.

1.2.2. Alignment

During the welding operation, means are to be provided for maintaining the parts required to be welded in a correct position and alignment. Generally, strong backs or any other appliances used for this purpose are to be so arranged so as to allow for expansion and contraction during production welding. The removal of such items is to be carried out to the satisfaction of the Surveyor.

1.2.3. Cleanliness

The surfaces that are to be welded should be free from grease, moisture, loose mill scale, excessive rust or paint. Primer coatings with an ordinary thickness, thin coatings of linseed oil or any equivalent coatings may be used provided it is demonstrated that their use will have no adverse effect in the production of satisfactory welds. It is necessary to remove the slag and scale not only from the edges that are to be welded but also from each pass or layer before the deposition of subsequent passes or layers. In order to minimize the possibility of excessive carbon on the scarfed surfaces, weld joints prepared by arc-air gouging may require additional preparation by grinding or chipping and wire brushing before welding. It is important to comply with the cleanliness requirements in the welding of higher-strength steels, particularly those which are quenched and tempered.

1.2.4. Tack welds

Good quality tack welds made with the same grade of filler metal as meant for the production welding and deposited in such a manner which does not interfere with the completion of the final weld, need not be removed, provided that after examination to be thoroughly clean and free from cracks or any other defects. If the materials to be joined are highly restrained, then preheat might be necessary before tack welding. While tack welding higher-strength steels, especially those materials which are quenched and tempered, special consideration is to be given for using the same preheat as that specified in the welding procedure. When making any permanent welded markings, the same precautions are to be followed.

1.2.5. Run-on and run-off tabs

Run-on and run-off tabs are to be designed in a manner so that it minimizes the possibility of high stress concentrations and base metal and weld-metal cracking.

1.2.6. Stud welding

The attachment of pins, hangers, studs, and other related items to ordinary and higher-strength hull structural steels or equivalent by stud welding may be approved at the discretion of the Surveyor. Special approval is required for stud welded attachment to quenched and tempered steel. At the discretion of the Surveyor trial stud welds may be tested for demonstrating that the base material in way of the stud welds is free from cracking and excessively high hardness. For structural attachments, the use of stud welding is to be subjected to special approval. It may also require special procedure tests appropriate to individual application.

1.2.7. Forming

Steel should not be formed between the upper and lower critical temperatures. Forming of ordinary-strength and high-strength steel in the range between 205°C (400°F) and 425°C (800°F) is to be avoided. Forming of high-strength quenched and tempered steel in the range between 260°C (500°F) and 595°C (1100°F) should be avoided. If it is intended to form within these ranges for either of the above steels, the manufacturer should be consulted prior to forming.

If the forming temperature exceeds 650°C (1200°F) for controlled rolled, as-rolled, thermo-mechanical controlled rolled or normalized steels, or is not at least 28°C (50°F) lower than the tempering temperature for quenched and tempered steels, then it is necessary to carry out mechanical tests to ensure that these temperatures have not adversely affected the mechanical properties of the steel. Refer to Sec [2.1.5].

In case of applications where toughness is of particular concern (such as Class III in Pt 3, Ch 2, Table 2.2.2), when steel is formed below 650°C (1200°F) beyond 3% strain* on the outer fiber, supporting data is to be provided to the satisfaction of the Surveyor indicating that after forming, the impact properties meet minimum requirements. After straining, specimens used in Charpy impact tests are to be subjected to an artificial aging treatment of 250°C (480°F) for one (1) hour before testing. Steels as per Ch 1, Sec 2, Table 1.2.6 and Ch 1, Sec 3, Table1.3.5 or equivalent steels used for radius gunwales (in accordance with Pt 3, Ch 2, Table 2.2.2) may be cold formed to a minimum radius of 15 x t (t = plate thickness) without requiring stress relieving or other supporting data.

$$\text{* Calculated on the basis of \% strain} = \frac{65 \text{ x Plate thickness}}{\text{outer radius}}$$

1.3. Production welding

1.3.1.Environment

Proper precautions should be taken to ensure that all welding is carried out under conditions where the welding site is protected against the harmful effects of wind, moisture and extreme cold.

1.3.2. Sequence

The welding is to be planned such that it progresses symmetrically so as t equalize shrinkage on both sides of the structure. At the subassembly stage, the ends of frames and stiffeners should be left unattached to the plating. This should be done until the connecting welds are made in the intersecting systems of plating, framing and stiffeners at the erection stage. Welds are not to be carried across an unwelded joint or beyond an unwelded joint which terminates at the joint being welded unless specially approved.

1.3.3. Preheat

At the time of welding higher strength steels, materials of thick cross-section or materials subject to high restraint, the use of preheat and interpass temperature control are to be considered. When welding is carried out under high humidity conditions or when the temperature of steel is below 0°C (32°F), the base metal is to be preheated to at least 16°C (60°F) or temperature suitable to the alloy and the thickness, whichever is higher. The control of interpass temperature is to be given special consideration at the time of welding quenched and tempered higher-strength steels. When using preheat, the interpass and preheat temperatures are complying with the accepted welding procedure carried out to the satisfaction of the Surveyor. In all cases, the interpass and preheat temperature control are to be sufficient to maintain dry surfaces and minimize the possibility of the formation of fractures.

1.3.4. Low-hydrogen electrodes or welding processes

1.3.4.1. Welding of ordinary and higher strength steel

It is recommended to use low hydrogen electrodes for welding all higher strength steel or ordinary strength steel weldments subjected to high restraint. While using low-hydrogen electrodes or processes, appropriate precautions are to taken to ensure that the electrodes, fluxes and gases used for welding are clean and dry.

1.3.4.2. Welding of quenched and tempered steels

Unless approved otherwise, for welding quenched and tempered steels, matching strength, low-hydrogen electrodes or welding processes are to be used and overmatching should be generally avoided. When welding quenched and tempered steels to other steels, the weld filler metal selection is to be based on the lower strength base material being joined and low hydrogen practice being comparable to that for the higher strength material. Unless approved otherwise and in all cases, the filler metal strength is to be no less than that of the lowest strength member of the joint. The Surveyor should be satisfied with the procedures for handling and baking filler metals and fluxes are commensurate with the low hydrogen practices appropriate to the highest strength steel.

1.3.5. Back gouging

Except as permitted in [2.4.2], grinding, arc-air gouging, chipping or other suitable methods are to be employed at the root or underside of the weld to obtain sound metal prior to the application of subsequent beads for all full-penetration welds. In order to minimize carbon, build up or burning of the weld or base metal, it is recommended to use a selected technique when arc-air gouging is employed. Quenched and tempered steels are not to be flame gouged.

1.3.6. Peening

Peening, when used to rectify distortion, is to be affected immediately after depositing and cleaning each weld pass. In the case of single-pass welds peening is not recommended, the root or cover passes on multi pass welds or on base metal at the edges of the weld, except as outlined in [1.3.7] to enhance fatigue life.

1.3.7. Weld profiling

Weld profiling may be required to be carried out in critical areas, for fatigue life enhancement. Welds may be profiled using TIG dressing, peening or grinding at weld toes to the satisfaction of the attending Surveyor.

1.3.8. Fairing and flame shrinking

Fairing by heating or flame shrinking or other methods of correcting distortion or defective workmanship in fabrication of main strength members within the midship portion of the ship and other plating which may be subject to high stresses is to be carried out only with the approval of Surveyor in advance. In case higher strength steels are involved, such corrective measures are to be kept to an absolute minimum due to the high local stresses and the possible degradation of the mechanical properties of the base material. Refer [2.1.5].

1.3.9. Surface appearance and Weld soundness

1.3.9.1. Surface appearance

Visual examination of the surface of welds is to be carried out. Welds should also be regular and uniform with a minimum amount of reinforcement and free from overlap and undercut. Welds and adjacent base metal are to be free from injurious arc strikes. In seawater ballast tanks as required by IMO Resolution MSC.215 (82) and ISO 8501-3 Grade P2, welds and surrounding areas are to conform as follows:

a) Surfaces should be free from slag;
b) Surfaces should be free from sharp or deep undercut;
c) Surfaces should be free from all kinds of loose and lightly adhering weld spatter;
d) Surfaces are to be dressed (by grinding) for removing irregular and sharp-edged profiles;
e) End craters are to be free from any sharp edges;
f) Surface pores are to be sufficiently open to allow penetration of paint or are to be dressed out.

1.3.9.2. Weld soundness

Throughout the weld cross section, the welds are to be sound and crack free as well as fused to the base material to the satisfaction of the attending Surveyor and should generally be considered on the basis of [2.1.3] “Workmanship and Supervision”, [2.1.4] “Welding Procedure Qualification”, and [1.3.10] “Non-destructive Inspection of Welds”.

1.3.10. Inspection of welds

Approved non-destructive test method such as radiographic, ultrasonic, magnetic-particle or dye-penetrant inspection is to be employed in carrying out inspection of welded joints in important locations. The evaluation of radiographs and ultrasonic indications shall be in compliance with approved International standards. The Evaluation of radiographs and ultrasonic indications is one of the factors in the assessment of shipyard weld quality control. When evaluating the overall soundness of the weld cross section, radiographic or ultrasonic inspection, or both, is to be used. When investigating the outer surface of welds, magnetic particle or dye-penetrant inspection or other approved methods are to be used. The same may also be used as a check in case of intermediate weld passes such as root passes and also to check back-gouged joints prior to depositing subsequent passes. An approved dye-penetrant or magnetic particle method is to be used for the surface inspection of important tee or corner joints in critical locations, to the satisfaction of the Surveyor. Extra high-strength steels [415-690 N/mm^2, (42-70 kgf/mm^{2,} 60,000-100,000 psi) minimum yield strength] may be prone to delayed cracking. When welding these materials, the final non-destructive testing is to be delayed sufficiently for the proper detection of such defects. Weld run-on or run-off tabs may be used where practical and be sectioned for examination. Where a method (such as radiographic or ultrasonic) is selected as the primary nondestructive method of inspection, the acceptance standards of such a method governs. However, if additional inspection by any other method should identify the presence of defects that could have an adverse effect on the integrity of the structure, then removal and repair of such defects are to be to the satisfaction of the attending Surveyor.

1.3.11. Repair welding

Any defective welds and other injurious defects (including base metal defects) determined during visual inspection, non-destructive testing or leakage, they are to be excavated in way of the defects to sound metal and corrected by rewelding. A suitable repair welding procedure consistent with the material being welded shall be employed Removal of minor surface imperfections such as scars, tack welds and arc strikes through grinding shall be permitted at the discretion of the attending surveyor. Special precautions, such as the use of preheat, interpass temperature control, and low-hydrogen electrodes, are to be considered when repairing welds in all higher strength steel, ordinary strength steel of thick cross section, or steel subject to high restraint. Materials which are thicker than approximately 19 mm (¾ in.) are considered to be of thick cross-section. In all cases, preheat and interpass temperature control are to be sufficient to maintain dry surfaces and minimize the possibility of the formation of fractures.

1.3.12. Fillet weld ends

The ends of fillet welds should be seal welded at terminations of structural members and in way of cut-outs or air, drainage, or lightening holes etc.

1.3.13. Post weld heat treatment of welds in dissimilar materials

INTLREG approval is required prior to post weld heat treatment of welds between dissimilar materials, carbon steel to stainless steels or high alloy steels, including weld metal overlay clad base material or parts.

1.4. Butt welds

1.4.1. Manual welding using covered electrodes

For butt welds, manual welding using covered electrodes may be normally employed in members not exceeding 6.5 mm (¼ in.) in thickness without beveling the adjoining edges. Preparations are to be made for those members exceeding 6.5 mm (¼ in.) in thickness for welding in a manner acceptable to the Surveyor by using an appropriate edge preparation, root opening and root face (land) to provide for welding from one or both sides.

Where weld is made from both sides, the root of the first side welded is to be removed to sound metal by an approved method before applying the subsequent weld passes on the reverse side. Where the welding is to be deposited from only one side using ordinary welding techniques, appropriate backing either temporary or permanent is to be provided. The backing is to be fitted such that the spacing between the backing and the members to be joined is in accordance with the established procedures. Unless specially approved, splices in permanent backing strips are to be welded with full penetration welds before making the primary weld.

1.4.2. Submerged arc-welding

In members not exceeding 16 mm (⅝ in.) in thickness, submerged-arc welding, using wire-flux combinations may be ordinarily employed without beveling the abutting edges. Members exceeding 16 mm (⅝ in.) are normally to be prepared for welding in a manner acceptable to the Surveyor by using an appropriate edge preparation, root opening and root face (land) to provide for welding from one or both sides. The provisions of [1.3.5]are not applicable after it is determined that sound welds can be made without back gouging. When ordinary welding techniques are used for depositing metal from one side only, backing (either permanent or temporary) is to be provided and the members are to be beveled and fitted in accordance with established procedures.

1.4.3. Gas metal-arc and flux cored-arc welding

As per specifications made in [1.4.1], in general, automatic or mechanized gas metal-arc welding and flux cored-arc welding using wire-gas combinations and associated processes may be employed utilizing the conditions specified in [1.4.1],, except that specific joint designs may differ between processes. Unless specially approved otherwise Refer Sec 4,[4.6.2] for special requirement for welder qualification), short circuit gas metal arc welding (GMAW-S) is to be restricted to welding thickness up to 6.5 mm (¼ in.).

1.4.4. Electroslag and electro gas welding

The use of electroslag and electro gas welding processes is subjected to special consideration depending upon the specific application and the mechanical properties of the resulting welds and heat-affected zones.

1.4.5. Special welding processes and techniques

Depending upon the extent of the variation from the technique which is generally accepted, special welding techniques employing any of the basic welding processes mentioned in

[2.4.1] through [2.4.4] will also be considered specially. Such special techniques include tandem-arc welding, consumable guide electroslag welding and narrow-gap welding. Additionally, the use of gas tungsten arc welding will be subjected to special consideration, depending upon the application and whether welding is manual or mechanized. Welding processes such as friction stir welding and hybrid laser welding shall be subjected to a special consideration.

SECTION 2 BOILERS, UNFIRED PRESSURE VESSELS, PIPING AND ENGINEERING STRUCTURES

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2.1. General considerations

2.1.1 The piping requirements in this section are applicable to piping other than for installation on vessels which are built in accordance with *INTLREG Rules for building and Classing Steel Rules*. For piping installation on vessels to be built in accordance with *INTLREG Rules for building and Classing Steel Rules, refer Section 4 of this chapter.*

2.1.2 Fabrication

Fabrication of the drums or shells, other pressure parts of boilers, unfired pressure vessels, pipes and pipe connections, and other engineering structures may be fabricated by means of an approved process of fusion welding in accordance with the following requirements, provided they conform to the applicable requirements of Pt 5A, Ch 8, Ch 9 and Ch 10.

2.1.3 Welding approval

Before undertaking the welding of any structure subject to the requirements of these Rules, a manufacturer is to prove to the satisfaction of the Surveyor that the welding consumables and processes proposed to be used have been approved and that the welders and welding operators are duly qualified for the proposed work. Refer Sec [3.3] of this chapter and Refer Ch 3,. Sec 4

2.1.4 Grouping of welded structures

In general, all welding and tests are to be executed as per the requirements of this section, the Rules necessarily vary in accordance with the application in each case and the work is hence divided into the following groups for the purpose of these Rules.

Table 3.3.1 - Grouping of welded structures

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">Service</th><th colspan="3">Limitations</th></tr>
<tr><th>Pressure</th><th>Temperature</th><th>Max. metal thickness (1)</th></tr>
<tr><td rowspan="4">Boilers and group I pressure vessels</td><td>Boilers: All pressure</td><td>Over 3.4 bar (3.5 kgf/cm^2, 50 psi)</td><td>All</td><td>None</td></tr>
<tr><td colspan="4">Unfired Pressure Vessels for:</td></tr>
<tr><td>a) Vapors or Gases</td><td>Over 41.4 bar (42.2 kgf/cm^2, 600 psi)</td><td>Over 371°C (700°F)</td><td>None</td></tr>
<tr><td>b) Liquids</td><td>Over 41.4 bar (42.2 kgf/cm^2, 600 psi)</td><td>Over 204°C (400°F)</td><td>None</td></tr>
<tr><td rowspan="3">Group II pressure vessels</td><td colspan="4">Unfired Pressure Vessels for:</td></tr>
<tr><td>a) Vapors or Gases</td><td>41.4 bar (42.2 kgf/cm^2, 600 psi) and under</td><td>371°C (700°F) and under</td><td>38.1 mm (1.5 in.)</td></tr>
<tr><td>b) Liquids</td><td>41.4 bar (42.2 kgf/cm^2, 600 psi) and under(2)</td><td>204°C (400°F) and under</td><td>38.1 mm (1.5 in.)</td></tr>
<tr><td colspan="5"><u>Notes</u>:
1. To heads made from a single plate, maximum metal thickness is not applicable.
2. Pressure limit is not applicable to hydraulic pressure at atmospheric temperature.</td></tr>
</table>

2.1.4.1 Boilers and pressure vessels

The design temperature, pressure or material thickness determines the group designation of a pressure vessel, as per the table given above.

2.1.4.2 Pipe connections

a. Application – general:
Group I, in general, comprises of all piping intended for working pressures or temperatures in various services, as given below in Table 3.3.2.

Table 3.3.2 - Pipe connections: application

Service	Pressure bar (kgf/cm^2, psi)	Temperature °C (°F)
Vapor and gas	Over 10.3 (10.5, 150)	over 343 (650)
Water	Over 15.5 (15.8, 225)	over 177 (350)
Lubricating oil	Over 15.5 (15.8, 225)	over 204 (400)
Fuel oil	Over 10.3 (10.5, 150)	over 66 (150)
Hydraulic fluid	Over 15.5 (15.8, 225)	over 204 (400)

Group II comprises of all piping proposed for working pressures and temperatures at or below those specified under Group I, cargo-oil and tank-cleaning piping and in addition open-ended lines as drains, overflows, vents and boiler escape pipes are also included.

b. Application – Rules for Building and Classing Steel Vessels:

For piping intended for vessels built with as per the INTLREG Rules, pipe classes are as defined in Pt 5A, Ch 8, Sec 1, Table 8.1.1, and the welding and fabrication requirements are to be in compliance with Sec-4 of this Chapter.

2.1.4.3 Engineering structures

Group I comprises of valve bodies, turbine casings, manifolds and similar constructions which would come under Group I Pressure Vessels with same requirements for workmanship tests, except that where there is no longitudinal seam, no test plates will be required. Refer Pt 5A, Ch 8, Sec 2,[2.3.3].Under group I, gear elements, gear casings and diesel engine entablatures, bed plates, frames and other load support structures are also included.

Group II comprises of turbine casings, valve bodies, manifolds and similar constructions which would come under Group II Pressure Vessels and are to meet same requirements, except that where there is no longitudinal seam, no workmanship tests are required. Under group II, base plates, engine frames and other machinery parts not exposed to internal pressures or direct load support are also included. Refer also Pt 5A, Ch 8, Sec 2, [2.3.8].

2.1.4.4 Weld repairs to ductile (Nodular) iron

Special approval is required for weld repairs to ductile (nodular) iron castings. Where reduced strength and ductility are permitted, welds which demonstrate acceptable tensile strength and soundness in procedure tests, may be approved.

2.2. Plans and specifications

2.2.1. Details

All details of the process and extent of welding proposed for use in the production of the pressure parts of boilers, unfired pressure vessels, piping and engineering structures, together with the types of welds and joints and the proposed method of procedure are to be clearly shown in the plans and specifications submitted for approval.

2.2.2. Base materials

In fusion-welding construction, all base materials which are used are to conform to the specifications approved for the design in each case. In ordinary carbon steels, the carbon content is not to exceed 0.35%, unless otherwise specially approved.

2.3. Workmanship and supervision

2.3.1. Construction

Construction is to be carried out in accordance with the approved plans and in compliance with the Rule requirements. In all cases, the Manufacturer is to be responsible for the quality of the work and as stipulated in the applicable section of the Rules, the Surveyor is to be satisfied with the procedure and workmanship, as well as the materials used are in accordance with the Rule requirements and approved plans. As per the acceptance criteria stipulated in Sec 5, [5.5.2], inspection of welds is to be carried out to the satisfaction of the Surveyor.

2.3.2. Joint tolerance

Plates, pipes or shapes which are to be joined by fusion welding are to be precisely cut to size, and where forming is also to be carried out, this should be carried out by pressure and not by blows. A tapered transition having a length of not less than thrice the offset between the adjacent surfaces of abutting sections is to be provided at joints between sections that vary in thickness by more than one-fourth the thickness of the thinner section or by 3 mm (1/8 in), whichever is less. The transition may be formed by any process that will provide a uniform taper. The weld may be partially or completely in the tapered section or adjacent to it. Alignment of sections at edges to be butt welded are to be such that the maximum offset is not greater than the applicable amount as listed in the following Table 3.3.3, where ‘t ‘is the nominal thickness of the thinner section at the joint.

Table 3.3.3 – Joint Tolerance

Section thickness in mm (in.)	Offset in mm (in.) direction of joints in cylindrical shells	
	Longitudinal	Circumferential
Up to 12.5 (0.5), incl.	1/4 *t*	1/4 *t*
Over 12.5 (0.5) to 19 (0.75), incl.	3.2 (1/8in.)	1/4 *t*
Over 19 (0.75) to 38 (1.5), incl.	3.2 (1/8in.)	4.8 (3/16 in.)
Over 38 (1.5) to 51 (2.0), incl.	3.2 (1/8in.)	1/8 *t*
Over 51 (2.0)	1/16 *t* (9.5 (3/8 in.) max.)	1/8 *t* (19 (3/4 in.) max.)

Note

Any offset within the allowable tolerance above should be faired at a 3 to 1 taper over the width of the finished weld or, if required, by adding additional weld metal, beyond what would be the edge of the weld.

2.3.3. Surface of parts

The surfaces of parts that are to be welded should be freed from scale, grease or rust at least 12.5 mm (0.50 in.) from the welding edge. When it is necessary to deposit metal over a previously welded surface, traces of scale or slag are to be removed to prevent the inclusion of impurities. If the welding is stopped for any reason, special care is to be taken in restarting to secure thorough fusion.

2.3.4. Out of roundness

The barrel or drum or cylinder or shell is to be circular at any section within a limit of 1% of the mean diameter, based on the differences between the maximum and minimum mean diameters at any section, and if necessary, to meet this requirement, is to be rerolled, reheated or reformed. In fabrication of plates of unequal thickness, the measurements are to be corrected for the plate thickness, as applicable, to determine the diameters at the middle line of the plate thickness.

2.4. Joint Details

2.4.1. Shapes and Dimensions

The dimensions and shape of the edges to be joined are to be such as to ensure thorough fusion and complete penetration at the root of the joint.

2.4.2. Butt Joints (Double welded)

In double welded butt joint, the filler metal is deposited from both sides, whether the joint is of the single or double-grooved type. In manual welding, the reverse side is to be prepared by grinding, chipping or otherwise cleaning out, so as to protect sound metal at the base of the weld metal first deposited, prior to applying weld metal from the reverse side, unless approved otherwise. The weld reinforcement on each side of the plate is not to exceed the thickness specified in [2.12.1.1]

2.4.3. Butt Joints (Single welded)

In this type of butt joint, the filler metal is applied from one side only. A single-welded butt joint may be made the equivalent of a double-welded butt joint by providing means for accomplishing complete penetration and meeting the requirements for weld reinforcement as specified in Table 3.4.2. In case of boilers, backing strips used at longitudinal welded joints are to be removed.

2.4.4. Joint Finish

Butt joints are to have full joint penetration with no overlaps, abrupt ridges or grooves and shall also be reasonably free from undercuts. Removal of the reinforcements which are allowed for both single welded and double-welded butt joints may be carried out to provide a smooth finish at the time of completion.

2.4.5. Lap joints

Lap joints are to be made with overlapping of edges not less than four times the thickness of the thinner plate where permitted, except as shown in Figure 3.3.1.

2.4.6. Head to shell attachments

2.4.6.1. Length of flange

Dished heads other than concaved hemispherical to the pressure which are to be attached by butt welding, and flanged heads or flanged furnace connections which are to be fillet-welded are to have a length of flange not below 25 mm (1 in.) for heads or furnace openings not beyond 610 mm (24 in.) in external diameter and not below

38 mm (1.5 in.) for heads or furnace openings over 610 mm (24 in.) in diameter. Refer Fig 3.3.1 for details of unfired pressure vessels.

2.4.6.2. Inserted heads

The dished heads are to have a driving fit before welding, when fitted inside or over a shell.

2.4.6.3. Connections

Acceptable types of fusion-welded connections of heads to shells are detailed in Figure 3.3.1, subject to the tabulated limitations in Pt 5A, Ch 10, Table 10.3.2.

2.4.7. Bending stresses in welds

The Group I or II welded container is to be so designed that the weld will not be subjected to direct bending stresses .Refer Fig 3.3.1(m)]. Corner welds are not to be used unless the plates forming the corner are supported independently of the welds.

2.4.8. Connections

For fusion-welded connections all welding is to be equivalent to that required for the joints of the vessel to which they are attached.

2.4.9. Nozzles

Acceptable types of fusion-welded nozzle connections are shown in Figure 3.3.2 and are to comply with the following conditions.

2.4.9.1. Figure 3.3.2 (a) and (b)

Full penetration groove weld to be provided for necks adjoining the vessel wall.

2.4.9.2. Figure 3.3.2 (c) through (h)

Necks inserted through or into a hole cut in the vessel wall and with no added reinforcing elements are to be attached by a full penetration groove weld or by two partial penetration welds, one on each face of the vessel wall. These may be any desired combination of fillet single-bevel, and Single-J welds.

2.4.9.3. Figure 3.3.2 (l), (m), (n), (o) and (p)

Inserted type necks with additional reinforcement in the form of one or more distinct reinforcing plates are to be attached by welds at the outer edge of the reinforcing plate and at the nozzle-neck periphery. The welds attached from the neck to the vessel wall and to the reinforcement plate are to comprise of one of the combinations given below.

a) Single-bevel or Single-J weld in the shell plate, and full penetration groove weld or a single-bevel or single-J weld in each reinforcement plate. Figure 3.3.2 (n) and (p).
b) A full penetration groove weld in the shell plate, and a fillet, single-bevel, or single-J weld or a full penetration groove weld in each reinforcement plate. Figure 3.3.2 (m) and (o).
c) A full penetration groove welds in each reinforcement plate, and a fillet, single-bevel, or single-J weld in the shell plate. Figure 3.3.2 (l).

2.4.9.4. Figure 3.3.2 (k), (q), (r), (s) and (t)

Nozzles with integral reinforcements in the form of extended necks or saddle type pads are to be attached by a full penetration weld or by means of a fillet weld along the outer edge and a fillet, single bevel, or single-J weld along the inner edge.

2.4.9.5. Figure 3.3.2 (u), (v), (w), and (x)

Fittings with internal threads are to be attached by a full penetration groove weld or by two fillet or partial penetration welds, one on each face of the vessel wall. Figure 3.3.2 (u), (v), (w) and (x). Internally threaded fittings not to exceed 89 mm OD (3 in.NPS) may be attached by a fillet groove weld from the exterior only. Refer Fig 3.3.2(w-3).

The strength of welded connection for all cases is to be in accordance with requirements of Pt 5A, Ch 10, Table 10.3.2.

2.4.10. Limitations

The use of various types of welded construction is subject to the limitations of the group for which it is proposed and also to the limitations tabulated in Pt 5A, Ch 10, Table 10.3.2.

2.5. Forms of welded joints required

2.5.1. Boilers and Group, I pressure vessels

The welded joints are to be in accordance with the following details.

2.5.1.1 Double-welded

All joints are to be of the double-welded butt type, single-or double-grooved, except where a single-welded butt joint is made the equivalent of a double-welded butt joint. Refer 3.4.3 of this section.

2.5.1.2 Nozzles and other connections

Some acceptable types of welded nozzles and other connections to drums, shells and headers are illustrated in Figure 3.3.2.

2.5.1.3 Closing plates

Closing plates of headers for boilers, super heaters as well as flat heads of other pressure vessels may be attached by welding as detailed in Figure 3.3.1(g) or (h) and Pt 5A, Ch 10, Sec 3, Figure 10.3.4.

2.5.2. Group II pressure vessels

Joints are to be in the same as Group I, except as mentioned below.

2.5.2.1. Single-welded

Butt joints which are welded from one side, with or without backing strips, are to be in accordance with the tabulated restrictions in Pt 5A, Ch 10, Sec 3, Table 10.3.2. When backing strips are used, they may be left in place or removed.

2.5.2.2. Full-fillet lap

Double full-fillet lap joints or single full-fillet lap joints, with or without plug welds, when used, are subject to the tabulated limitations in Pt 5A, Ch 10, Sec 3, Table 10.3.2. Refer also Fig 3.3.1.

2.5.3. Group I pipe welded joints

Welded joints are to be as per the following.

2.5.3.1. Pipes over 89 mm OD (3 in. NPS)

The joints for connecting two lengths of pipe or a pipe to a welding fitting, valve or flange are to be of the grooved type. In welding single-welded butt joints, complete penetration at the root is required and is to be demonstrated by the qualification of the procedure used. If complete penetration cannot otherwise be secured, the procedure is to consist of backing. The depth of weld is to be not less than the minimum thickness allowed by the applicable material specifications for the particular size and thickness of the pipe used.

2.5.3.2. Pipes 89 mm OD (3 in. NPS) and below

Joints for connecting two lengths of pipe may be made by sleeves fitted over the joint and attached by fillet welds or by using socket-type joints with a fillet weld. The inner diameter of the sleeve is not to exceed the outer diameter of the pipe by more than 2.0 mm (0.08 in) for sleeve joints. The fit and fillet weld sizes are to be as per an applicable recognized standard (e.g., ANSI B31.1 for fillet weld sizes, ANSI B16.11 for socket-type joints and ASTM F682 for sleeve-type joints). Minimum requirement of the depth of insertion of the pipe into the sleeve or socket fitting is to be 9.5 mm (0.375 in). Between the ends of the pipe for a sleeve joint or between the pipe and socket shoulder for socket- type joints prior to welding, a minimum gap of approximately 2.0 mm (0.08 in) is to be provided. The fittings are to be reasonably centered around the pipe.

2.5.3.3. Flanges

Attachment of the slip-on flanges shall be done to piping by double-fillet welds for applications with a service rating not higher than ANSI 300 Class or any equivalent, provided the throats of the fillet welds are not less than 0.7 times the thickness of the part to which the flange is attached. For boiler external piping, the use of slip-on flanges is additionally restricted to sizes not exceeding 114 mm OD (4 in. NPS) and the throats of fillet welds may not be less than 0.7 times the thickness of the part to which the flange is attached. For higher ratings slip-on flanges which conform to ASME or other recognized standards will be subject to special consideration. Socket-type flanges up to and including ANSI 600 Class or equivalent may be used in piping 89 mm OD (3in. NPS) or less and up to and including the ANSI 1500 Class or equivalent in piping 73 mm OD (2 ½ in. NPS) pipe size or less.

2.5.3.4. Backing

Backing for grooved joints may not be provided in pipes with less than 33 mm OD (1 in. NPS). Backing is recommended for welding pipes of all sizes 33 mm OD (1 in. NPS) and above onboard ships, when welded with single butt joints.

2.5.3.5. Welding

As far as practicable welding in pipe lines is to be carried out in the shop and joints made during the installation onboard ship are to be in positions accessible for proper welding.

2.5.4. **Group II pipe welded joints**

In the construction of piping under this group, the type of welded joints are to be similar to those in Group I except for the following modifications. For [2.5.4.1] [2.5.4.2] and [2.5.4.3] below, full penetration welds are needed

2.5.4.1. Single-groove

Single-groove welded-butt joints may be without backing in all sizes, in case, the weld is ground off flush or chipped on the root side.

2.5.4.2. Backing

Backing may also be dispensed with, without grinding the root of the weld, in such services as overflow pipes and tank-vent.

2.5.4.3. Square-groove welds

Square-groove welds may be used instead of the single-V groove weld for tank vent and overflow pipes, where the thickness of the pipe does not exceed 4.8 mm (3/16 in.).

2.5.4.4. Sleeves

Sleeves which are fitted over the joint and attached by socket-type joints with a fillet weld or fillet welds will be acceptable in all sizes. It is to be ensured that the fit and fillet weld sizes are to be in accordance with recognized standard (e.g., ANSI B16.11 for socket joints, ASTM F682 for sleeve type joints and ANSI B31.1 for fillet weld sizes.) The depth of insertion and gap are to be as per [2.5.3.2]. The fittings are to be reasonably centered around the pipe.

2.5.5. Low-temperature piping systems [Below -18°C (0°F)]

Each welding procedure is to be approved for service temperatures below -18°C (0°F) as per the requirements of Sec-5,[5.3]. All piping systems over 10.3 bar (10.5 kgf/cm^2, 150 psi) are to be considered Group I piping systems. Slip-on flanges, socket-weld joints, single-welded butt joints with backing strips left in place, pipe-joining sleeves and threaded joints are not to be used except where specifically permitted by INTLREG Rules elsewhere.

2.5.6. Engineering structures

The type of welded joints used in Group I or II in. this class of construction is subject to special consideration in relation to the design in each case.

2.6. Preheat

2.6.1. **Boilers, Pressure Vessels, and Group I piping**

When ambient temperatures are below 10°C (50°F), the welded parts of boilers, pressure vessels, and Group I piping are to be preheated prior to welding, so that the parts to be joined by welding will be at a temperature not below 10°C (50°F). Higher preheat is required for thicknesses, material composition and carbon content as indicated in the following paragraphs.

2.6.1.1. General

The thicknesses referred to at the weld for the parts to be joined are nominal. Where the qualification procedure specifies a higher preheat or where different materials having different preheat requirements are to be joined by welding, the higher preheat is to be considered. For materials refer Pt 2/ Ch 2/Sec 2, [2.1], [2.2],[2.3], and[2.4].

2.6.1.2. Preheat temperatures

Welds joining pressure parts or attachments to pressure parts are to be preheated to not less than the temperatures given below:

a) INTLREG Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N, Tube Grades D, F, H, J and Pipe Grades 1, 2, 3, 4, 5, 8, and 9 are to be heated to 79°C (175°F) for material which has both specified maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 25.4 mm (1.0 in).
b) INTLREG Plate Grades H, I, J, Tube Grades K, L, M and Pipe Grades 6 and 7. are to be heated to 79°C (175°F) for material which has either a specified minimum tensile strength in excess of 485 N/mm^2 (49 kgf/mm^2, 70,000 psi) or a thickness at the joint in excess of 16.0 mm (0.625 in).

c) INTLREG Tube Grades N and O and Piping Grades 11 and 12 are to be heated to 121°C (250°F) for material which has a thickness at the joint in excess of 12.5 mm (0.5 in).
d) INTLREG Tube Grade P and Piping Grade 13 are to be heated to 149°C (300°F), regardless of thickness.
e) *Other Materials*. The preheating of other materials requires special consideration.

2.6.2. **Group I pipe connections**

As specified in 3.6, Group I pipe connections defined in [2.1.4.2] are to be preheated.

2.7. General requirements for post-weld heat treatment

2.7.1. General

Prior to the application of the requirements detailed below, satisfactory weld-procedure qualifications of the procedures to be used are to be performed in accordance with all the essential variables of Section 5, together with conditions of post weld heat treatment or lack of post weld heat treatment and other restrictions as listed in the following paragraphs.

2.7.2. Heat treatment determination

Except as otherwise specifically provided for, all welded pressure parts of boilers and all welded pressure vessels or pressure parts are to be given a post weld heat treatment at a temperature not less than that specified in the following paragraphs. Where pressure parts of two different materials are joined by welding, the post weld heat treatment is to be that specified for the material that needs the higher post weld temperature. When non-pressure parts are welded to pressure parts, the post weld heat-treatment temperature of the pressure part is to control.

2.8. Fusion-welded boilers

2.8.1. Post weld treatment

All boilers of plate, pipe and tube materials listed in Chapter 2, Section 2 ,[2.2],[2.3], [2.4] and Chapter 2, Section 15 and Chapter 2, Section 17 are to be given a post-weld heat treatment after all pads, flanges or nozzles have been welded in place. Post weld heat treatment is to be as per Table 3.3.4.

Table 3.3.4: Post weld Heat Treatment

Grades	Minimum holding temperature	Minimum holding time at normal temperature for Weld Thickness (Nominal)	
		Up to 51 mm (2in)	Over 51 mm (2 in.)
All Plates, Tubes and Pipes except Grade N, O and P Tubes and Grade 11, 12 and 13 Pipes	593°C (1100°F)	1 hr/25 mm 15 min minimum	2 hr plus 15 min. for each additional 25 mm (1 in.)
Tube Grades N and O and Pipe Grades 11 and 12	593°C (1100°F)	1 hr/25 mm 15 min. minimum	1 hr/25 mm to 127 mm (5 in.) plus 15 min. for each additional 25 mm (1 in.)

Tube Grade P and Pipe Grade 13	677°C (1250°F)	1 hr/25 mm 15 min. minimum	1 hr/25 mm to 127 mm (5 in.) plus 15 min. for each additional 25 mm (1 in.)
Note: Maximum temperature is to be at least 28°C (50°F) below base material tempering temperature.			

2.8.2. Lower temperatures – Carbon and Carbon Molybdenum steels

It is permitted to heat-treat at lower temperatures for longer periods when it is not practical to post weld heat-treat materials enlisted in [2.8.3] and [2.8.4]at the temperature specified in [2.8.1], as given in table below.

Table 3.3.5 – Heat treatment at lower temperatures

Lower Min. Temp. degrees °C (°F)	**Min. Holding Time at decreased temperature in hr/25 mm (hr/in.)**
566 (1050)	2
538 (1000)	3
510 (950)	5
482 (900)	10

2.8.3. **Heat-treatment Exceptions for Fusion-welded Boilers – INTLREG Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N, Tube Grades D, F, G, H, J and Group I Piping Grades 1, 2, 3, 4, 5, 8, and 9 :**

Post weld heat treatment of these materials and other equivalent pipe, plate and tube material is not required under the conditions given below:

2.8.3.1. Circumferential welds

For circumferential welds in tubes, pipes or headers where the pipes, tubes or headers comply with a nominal wall thickness of 19.1 mm (0.75 in.) or less, at the joint.

2.8.3.2. Fillet welds

For fillet welds, attaching non-pressure parts that have a throat thickness of 12.7 mm (0.50 in.) or less, provided preheat to a minimum temperature of 93°C (200°F) is applied when the thickness of the pressure part exceeds 19.1 mm (0.75 in).

2.8.3.3. Heat-absorbing surfaces

For welds used to attach extended heat-absorbing surfaces to tubes and insulation attachment pins to pressure parts.

2.8.3.4. Tubes

For tubes or pressure retaining hand hole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of 9.5 mm (0.375 in) or less.

2.8.3.5. Studs

For studs which are welded to pressure parts for purposes that are not included in [3.8.3.3] above, provided preheated to a minimum temperature of 93°C (200°F) and when the thickness of the pressure part exceeds 19.1 mm (0.75 in.).

2.8.4. Heat-treatment exceptions for fusion-welded boilers –Plate Grades H, I, J, Tube Grades K, L, M, and Group I Piping Grades 6 and 7

Post weld heat treatment of these materials and other equivalent pipe, plate and tube material is not required under the following conditions.

2.8.4.1. Fillet welds

For fillet welds attaching non-pressure parts having a specified maximum carbon content not more than 0.25% that have a throat thickness of 12.7 mm (0.5 in) or less, provided preheat to a minimum temperature of 93°C (200°F) is applied when the pressure part exceeds 15.90mm (0.625 in).

2.8.4.2. Circumferential welds

For circumferential welds in pipes, tubes or headers where the pipes, tubes or headers conform with both a nominal wall thickness of 16 mm (0.625 in) or less, and a specified maximum carbon content of not more than 0.25%.

2.8.4.3. Heat-absorbing surfaces

For welds which are used to attach extended heat-absorbing surfaces to tubes and insulation attachment pins to pressure parts.

2.8.4.4. Tubes

For tubes or pressure-retaining hand hole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of not more than 9.5 mm (0.375 in).

2.8.4.5. Studs

For studs welded to pressure parts for purposes not included in [2.8.4.3]and which have a specified maximum carbon content of not more than 0.25%, Post weld heat treatment is not mandatory, provided a preheat to a minimum temperature of 93°C (200 °F) is applied when the thickness of the pressure part exceeds 16 mm (0.625 in).

2.8.5. Heat treatment Exceptions for Fusion-welded boilers –Tube Grades N, O and Group I Pipe Grades 11 and 12

Post weld heat treatment of these materials and other equivalent pipe and tube material with 0.15% carbon maximum is not required under the following conditions.

2.8.5.1. Fillet welds

For fillet welds attaching non-pressure parts to pressure parts, provided the fillet weld has a specified throat thickness of 12.5 mm (0.5 in) or less and the pressure part meets the requirements of [2.8.5.2] (a) and (b)

2.8.5.2. Circumferential welds

For circumferential welds where the pipe or tubes comply with all of the following:

a) A maximum outside diameter of 101.6 mm (4 in);
b) A maximum thickness of 16 mm (0.625 in);
c) A minimum preheat of 121°C (250 °F).

2.8.5.3. Heat-absorbing surfaces and studs

For heat-absorbing surfaces and non-load-carrying studs, provided the material is preheated to 121°C (250 °F) minimum and the pressure part meets the requirements of [2.8.5.2] (a) and (b)

2.8.5.4. Tubes

For tubes or pressure retaining hand hole and inspection plugs or fittings that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of 9.5 mm (0.375 in) or less.

2.8.6. Heat treatment exceptions for fusion welded boilers – INTLREG Tube Grade P and Group I Pipe Grade 13

Post weld heat treatment of this material and other equivalent pipe and tube material with 0.15% carbon maximum is not required under the following conditions.

2.8.6.1. Fillet welds

For fillet welds attaching non-pressure parts that have a specified throat thickness of 12.5 mm (0.5 in) or less, provided the pressure part meets the requirements of [2.8.6.2] (a) and (b).

2.8.6.2. Circumferential welds

For circumferential welds where the pipe or tube to conform to all of the following:

a) A maximum outside diameter of 101.6 mm (4 in);
b) A maximum thickness of 16 mm (0.625 in);
c) A minimum preheat of 149°C (300 °F).

2.8.6.3. Heat-absorbing surfaces and studs

Heat-absorbing surfaces and non-load-carrying studs, provided the material is preheated to 149°C (300 °F) and the pressure part meets the requirements of [2.8.6.2](a) and (b).

2.8.6.4. Tubes

For tubes or pressure retaining hand hole and inspection plugs or fittings with a specified maximum chrome content of 6% that are secured by physical means (rolling, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of 9.5 mm (0.375 in) or less.

2.8.7. Other materials

Other materials for boiler plate and tubes Post weld heat treatment will be subject to special consideration.

2.8.8. Other welded connections

Nozzles or other welded attachments for which, post weld heat treatment is required may be locally post weld heat-treated by heating a circumferential band around the entire vessel with the welded connection positioned at the middle of the band. The width of the band is to be at least three times the wall thickness of the vessel wider than the nozzle or other attachment weld, and the band is to be located in such a manner that the entire band will be heated to the temperature and held for the time specified in [2.8.1] for post-weld heat treatment.

2.8.9. Welded joints

In the case of welded joints in pipes, tubes and headers, the width of the heated circumferential band is to be at least thrice the width of the widest part of the welding groove, but in no case less than twice the width of the weld reinforcement.

2.9. Fusion-welded pressure vessels

2.9.1. Post weld heat treatment

2.9.1.1. General

A post weld heat treatment is to be given to all pressure vessels and pressure-vessel parts at a temperature not less than that mentioned in 3.8.1 and 3.8.2 when the nominal thickness, including corrosion allowance of any welded joint in the vessel or vessel part exceeds the limits as stated in [2.9.2] and [2.9.3]. Additionally, post weld heat treatment is required for the following:

a) For all independent cargo tanks where required by Ch 1, [1.1.1].
b) For all carbon or carbon manganese steel pressure vessels and independent cargo pressure vessels not covered by (a) above, when the metal temperature is below -29°C (-20 °F).
c) For all pressure vessels and independent cargo pressure vessels, which are fabricated of carbon or carbon manganese steel and intended to carry anhydrous ammonia.

2.9.1.2. Welded joints

When the welded joint connects parts that are of different thickness, the thickness to be used in applying these requirements is to be the thinner of two adjacent butt-welded plates, including head to shell connections, the thickness of the head or shell plate in nozzle attachment welds, and the thickness of the nozzle neck at the joint in nozzle neck to flange connections, the thickness of the shell in connections to tube sheets, flat heads, covers or similar connections, and the thicker of plate in connections of the type shown in Figure 3.3.1(f).

2.9.2. **Heat-treatment exceptions – INTLREG Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N and Tube Grades D, F, G, H, J**

Post weld heat treatment of these materials is not required under the following conditions:

2.9.2.1. Below 38.1 mm (1.5 in)

For material up to and including 38.1 mm (1.5 in) thickness, provided that material over 31.8 mm (1.25 in.) thickness is preheated to a minimum temperature of 93°C (200°F) during welding.

2.9.2.2. Above 38.1 mm (1.5 in)

For material over 38.1 mm (1.5 in) thickness, all welded connections and attachments are to be post weld heat-treated except that post weld heat treatment is not required for:

a) *Nozzle connections*: Fillet welds with a throat not over 12.7 mm (0.5 in) and groove welds not over 12.7 mm (0.5 in) in size that attach nozzle connections having a finished inside diameter not greater than 50.8 mm (2 in), provided the connections do not form ligaments that require an increase in shell or head thickness, and preheat to a minimum temperature of 93°C (200 °F) is applied.

b) *Non-pressure attachments*: Fillet welds having a throat not over 12.7 mm (0.5 in), or groove welds not over 12.7 mm (0.5 in) in size, used for attaching non-pressure parts to pressure parts, and preheat to a minimum temperature of 93°C (200 °F) is applied when the thickness of the pressure part exceeds 19 mm (0.75 in).

2.9.3. **Heat-treatment exceptions – INTLREG Plate Grades H, I, J and Tube Grades K, L, M**

Post weld heat treatment of these materials is not required under the following conditions.

2.9.3.1. 15.9 mm (0.625 in) and under

For material up to and including 15.9 mm (0.625 in) in thickness having a specified maximum carbon content of not more than 0.25%, provided a welding procedure qualification has been made in equal or greater thickness than the production weld.

2.9.3.2. Over 15.9 mm (0.625 in)

For material over 15.9 mm (0.625 in) thicknesses, all welded connections and attachments are to be post-weld heat-treated, except that post-weld treatment is not required for:

a) *Non-pressure attachments*: Attaching to pressure parts which have a specified maximum carbon content of not more than 0.25% and non-pressure parts with fillet welds that have a throat thickness of 12.7 mm (0.5 in) or less, provided preheat to a minimum temperature of 80°C (175 °F) is applied.

b) *Tube or pipe attachments*: Circumferential welds in pipes or tubes where the pipes or tubes have both a nominal wall thickness of 12.7 mm (0.5 in) or less, and a specified maximum carbon content of not more than 0.25%.

2.9.4. Heat-treatment exceptions – attachments

On pressure vessels which do not require post weld heat treatment as a whole, connections and other attachments after being attached by fusion welding need not be post-weld heat-treated. Refer also [2.11.6] for nozzles or other welded attachments for which post weld heat treatment is not required.

2.9.5. Other materials

Post weld heat treatment of other materials for boiler plate and tubes will be subject to special consideration.

2.9.6. Welded connections

Nozzles or other welded attachments for which post weld heat treatment is required may be heat-treated by heating a circumferential band around the entire vessel in such a manner that the entire band is to be brought up uniformly to the required temperature and held for the specified time. The circumferential band is to extend around the entire vessel and include the nozzle or welded attachment, and is to extend at least six times the plate thickness beyond the welding which connects the nozzle or other attachment to the vessel. The portion of the vessel outside of the circumferential band is to be protected so that the temperature gradient is not harmful.

2.10. Pipe welded joints and engineering structures

2.10.1. Group I pipe welded joints

Group I Pipe welded joints, defined in ,[2.1.4] are to be post weld heat-treated as specified in 3.8 of this section or the American National Standard ANSI B31.1 or any other equivalent standard.

2.10.2. Group II pipe welded joints

Welded joints in Group II piping need not be post weld heat-treated, unless specially required.

2.10.3. Group I engineering structures

According to the applicable requirements of [2.9]of this section, all welded structures under this group are to be post weld heat-treated.

2.10.4. Group II engineering structures

Under this group post weld heat treatment of structures depends on the type and purpose of the construction, and the matter will be subject to specially consideration in connection with the approval of the design.

2.10.5. Low-temperatures piping systems [Below -18°C]

Generally, all piping weldment excluding socket-weld joints and slip-on flanges, where permitted, are to be post weld heat-treated. For specific materials exceptions will be taken into consideration where it can be shown that post weld heat treatment is not required.

2.11. Post weld heat treatment details

2.11.1. Boilers and pressure vessels

As specified in 3.8.1, the weldment is to be heated uniformly and slowly to the temperature and time, and is to be allowed to cool slowly in a still atmosphere to a temperature not exceeding 427°C (800°F). The post weld heat treatment may be carried out either by heating the complete welded structure as a whole or by heating a complete section comprising the parts to be post weld heat-treated. In order to avoid the possibility of error, the post weld-heat-treatment temperature is to be controlled by at least two pyrometric instruments.

2.11.2. Pipe connections

For welded pipe connections requiring post weld heat treatment, the adjacent pipes or fittings are to be heated in a circumferential band at least three (3) times the width of the widest part of the welding groove but not less than twice the width of the weld reinforcement.

2.11.3. Other steels

The post weld heat treatment of other steels which are not specifically covered in Chapter 2 will be specially considered.

2.11.4. Clad pressure vessels

Post weld heat treatment of vessels or parts of vessels constructed of integrally clad or applied corrosion resistant lining material will be specially considered.

2.11.5. Opening connections

Welded connections may be added to a vessel after post-weld heat treatment without re-post weld heat treatment, provided the following conditions are met.

2.11.5.1. Size of weld

The inside and outside attachment welds do not exceed 9.5 mm (0.375 in.) throat dimension.

2.11.5.2. Opening diameter

The diameter of the attachment opening in the vessel shell does not exceed that allowed for an unreinforced opening, or does not exceed 50.8 mm (2 in.), whichever is smaller.

2.11.5.3. Exception

This provision does not apply to those connections so placed as to form ligaments in the shell, the efficiency of which will affect the shell thickness. Such added connections are to be post weld heat-treated.

2.11.6. Seal welding

Seal welding consisting of a fillet weld under 9.5 mm (0.375 in.) without subsequent stress relieving may be applied to secure tightness of connections where the construction is such that no design stress is placed upon the weld even though the structure itself has to be stress-relieved as per these Rules.

2.12. Radiography

2.12.1. General

2.12.1.1. Welded-joint preparation

The preparation of all welded joints to be radiographed is carried out as follows: On inside and outside, all the weld ripples or weld surface irregularities, are to be removed by appropriate mechanical processes to such an extent that the resulting radiographic contrast due to any irregularities cannot mask or be confused with the image of any objectionable defect. Also, it is to be ensured that the weld surface merge smoothly into the plate surface. The finished surface of the reinforcement of all butt-welded joints may be flush with the plate or may have a reasonably uniform crown not exceeding the following thickness.

Table 3.3.6: Welded-joint preparation

Plate thickness, in mm (in.)	**Thickness of reinforcement,** in mm (in.)
≤ 12.7 (0.5)	1.6 (1/16)
> 12.7 (0.5) & ≤ 25.4 (1.0)	2.4 (3/32)
> 25.4 (1.0) & ≤ 50.8 (2.0)	3.2 (1/8)
> 50.8 (2.0)	4.0 (5/32)

2.12.1.2. **Radiographic examination with backing strip**

Radiograph of a single-welded circumferential butt joint with backing strip, is acceptable only if it is not to be removed later and provided the image of the backing strip does not affect the interpretation of the resultant radiographs.

2.12.1.3. **Details of Radiographic Search**
Refer Sec 4,[4.5] for further details of radiographic search of finished joints.

2.12.2. **Boilers**

All longitudinal, circumferential and head joints are to be examined throughout their full length by radiography. Those parts of boilers which have been made of pipe material, such as shells, drums, down comers, risers, headers, cross-pipes and tubes are to be non-destructively examined as necessary by .[2.12.4]

2.12.3. **Other pressure vessels**

2.12.3.1. **Full radiography**

Examination of Double-welded butt joints or their equivalent are to be examined radiographically for their full length under any of the conditions detailed below.

a) **Joint efficiency.** Where the design of the vessel or vessel section is based on the use of the joint efficiency tabulated in Pt 5A, Ch 10, Sec 3, Table 10.3.2. column (a).

b) **Material used.** Complete radiographic examination is essential for each butt-welded joint in vessels built of Steel Plate for Boilers and Pressure Vessels INTLREG Grades, MA, MB, MC, MD, ME, MF, MG, K, L, M and N having a thickness in excess of 31.8 mm (1.25 in) as well as for INTLREG Grades H, I and J having a thickness in excess of 19 mm (0.75 in). Other steels not specifically covered in Chapter 2 will be subject to special consideration.

2.12.3.2. **Spot (Random) radiography**

Those longitudinal and circumferential double-welded butt joints or their equivalent which are not required to be fully radiographed in [2.12.3.1] are to be examined by spot (random) radiography where the pressure vessel or pressure vessel section is based on the usage of the joint efficiency provided in column (b) of Pt 5A, Ch 10, Sec 3, Table 10.3.2. The extent of spot radiography is to compare favorably with accepted practice such as that specified in the ASME Boiler and Pressure Vessel Code or any other equivalent standard and is to be to the satisfaction of the Surveyor.

2.12.4. **Group I pipe connections**

Group I pipe connections are to be radiographically examined as per either of the conditions indicated below, as applicable.

Table 3.3.7: Group I pipe connections

Pipe size	Extent of radiography(1) (2)
Wall Thickness > 9.5 mm (3/8 in)	100%
Diameter > 76.1 mm (3.0 in) O.D.	100%

Notes

1. Where radiographic testing is not practicable, such as for fillet welds, another effective method of nondestructive testing is to be carried out.
2.
3. Where radiographic testing is not required in the above table, alternative nondestructive testing, magnetic particle or penetration methods, may be required by the attending Surveyor when further inspection deems it necessary.

2.12.5. Group II pipe connections

The Surveyor may require spot (random) radiographic or ultrasonic examination of welded joints with an outer diameter greater than 101.6 mm (4.0 in) when further inspection deems it necessary.

2.12.6. Low temperature piping connections [Below -18°C]

For all carbon and alloy steel piping with a service temperature below -18°C and an inside diameter of more than 75 mm (3.0 in) or where the wall thickness exceeds 10 mm or 0.375 in, welds made in accordance with this group are to be subjected to 100% radiographic search or to other approved method of test if the former is not practicable. For pipes of smaller diameter or thickness, welds are to be subjected to spot (random) radiographic examination or to other approved methods of test of at least 10% of the welds, to the satisfaction of the Surveyor.

2.12.7. Group I engineering structures

Group I Engineering Structures are to meet the same radiographic requirements as Group I Pressure Vessels.

2.12.8. Group II engineering structures

Group II Engineering Structures which correspond in service requirements to Group II Pressure Vessels are not required to be subjected to a full or spot (random) radiographic examination of welded joints.

2.12.9. Engine bedplates

Examination of bedplates for main propulsion internal-combustion engines with cylinders 458 mm (18 in.) in diameter and over are to be done radiographically or ultrasonically in way of principal welds.

2.12.10. Miscellaneous

2.12.10.1. Alloy and clad pressure vessels

The radiographic examination of parts of vessels and vessels made of alloy with integrated, clad or applied corrosion-resistant lining materials, will be specially considered.

2.12.10.2. Nozzles, sumps, etc.

Radiography of Butt welds of inserted-type nozzles are to be carried out when used for attachment to a vessel or vessel section that is required to be radiographed or the joint efficiency tabulated in column (a) of Pt 5A, Ch 10, Sec 3, Table 10.3.2. is used. Nozzles and manhole attachment welds which are not of the double welded butt-type need not be radiographed. Joints used in the fabrication of nozzles, sumps, etc., are to be radiographed when intended for installation in a vessel or vessel section that is required to be radiographed or when the joint efficiency tabulated in column (a) of Pt 5A, Ch 10, Sec 3, Table 10.3.2. is used, except that circumferential-welded butt joints of nozzles and sumps not exceeding 254 mm (10 in.) nominal pipe size or 28.6 mm (1.125 in.) wall thickness need not be radiographed.

2.13. Hydrostatic test

2.13.1. Boilers and pressure vessels

Hydrostatic tests are to be conducted in accordance with Pt 5A, Ch 10, Sec 4, 4.6 and Pt 5A, Ch 10, Sec 3, [3.6.6].

2.13.2. Piping

Hydrostatic tests are to be carried out in accordance with the Table 3.3.8. For conditions of hydrostatic testing in other Rules and Guides, refer the requirements within the relevant Rules or Guides.

Table 3.3.8: Hydrostatic Testing of Piping

INTLREG Rule		
Class I	**Class II**	**Class III**
Pt 5A, Ch 8, Sec 2, [2.4]	Pt 5A, Ch 8, Sec 2, [2.4.1]	Pt 5A, Ch 8, Sec 2, [2.4.1]
Pt 5A, Ch 8, Sec 6, [6.4.4].		

2.13.3. Defects

Repairing of Pinholes, cracks or other defects are to be only by chipping, machining or burning out the defects and re welding. After any welding repairs have been carried out , boiler drums and vessels which requires stress relieving are to be stress-relieved.

2.13.4. Retest

After repairs have been made, the drum, vessel or piping is to be hydrostatically tested in accordance with [2.13.1] through .[2.13.2]

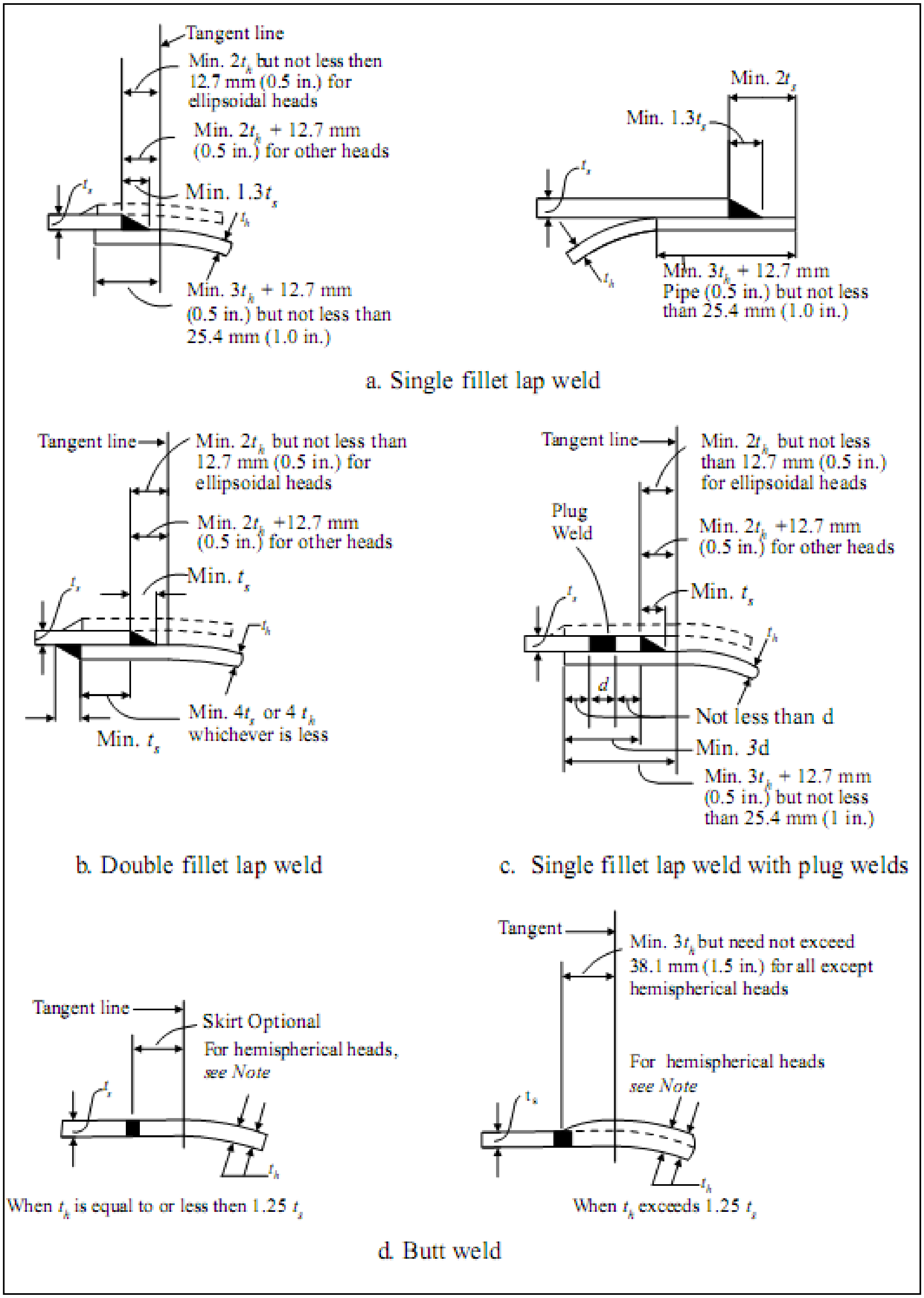


Figure 3.3.1: Head to shell attachments

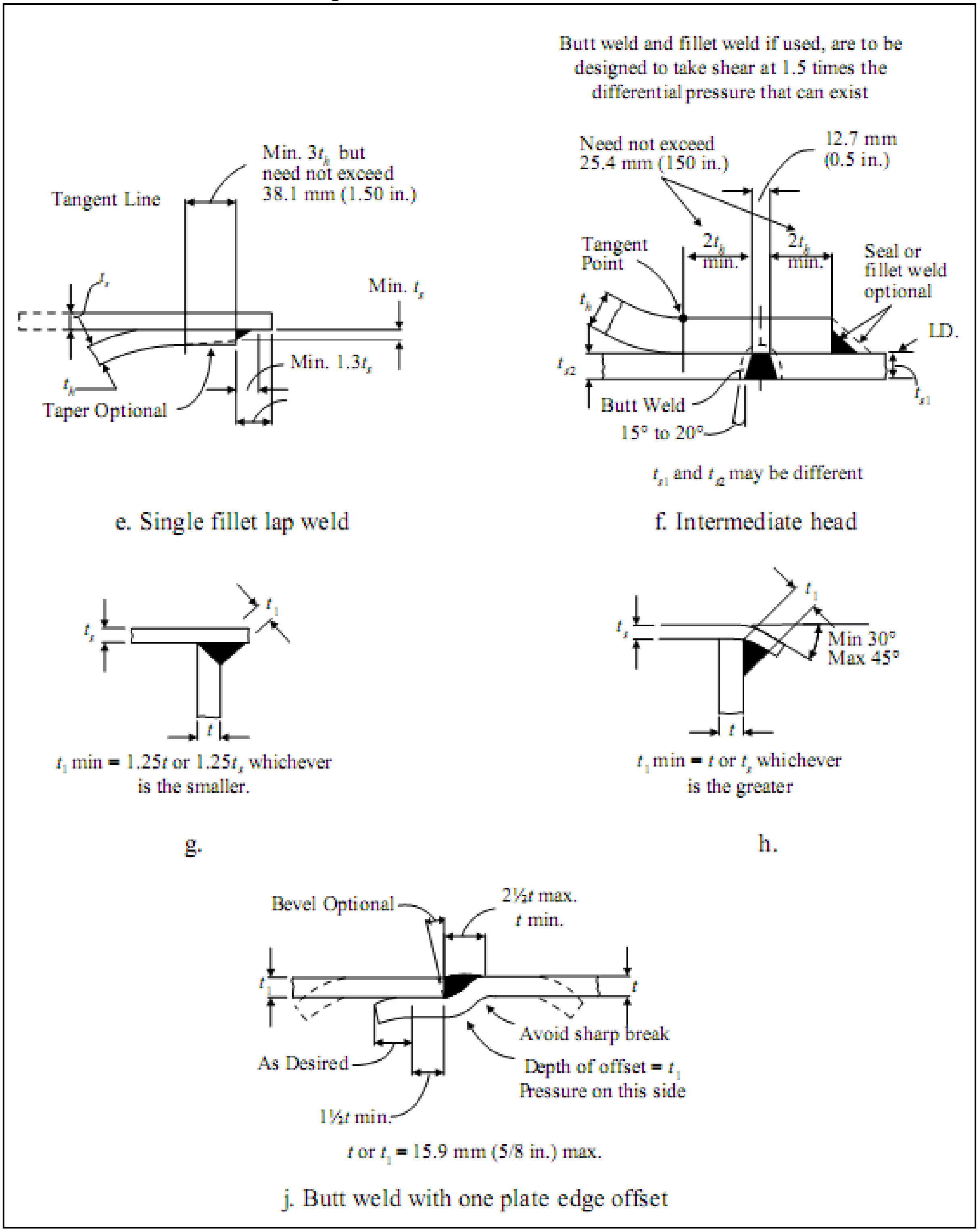
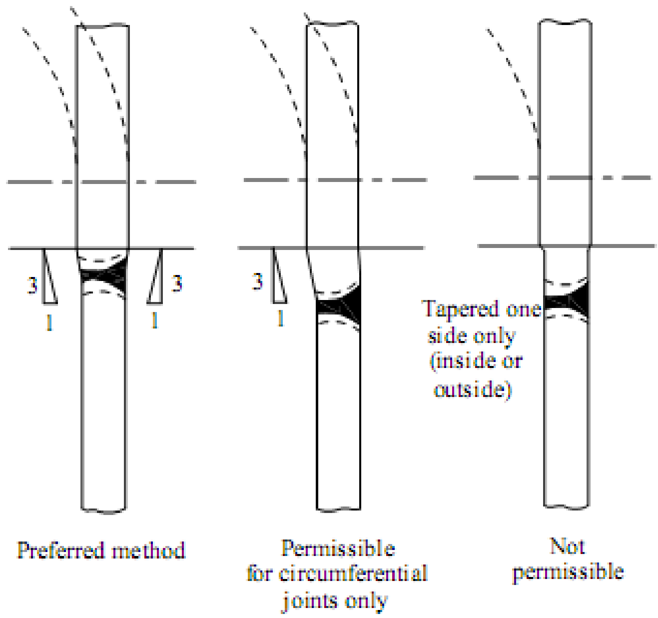


Figure 3.3.1: Head to shell attachments (continued)



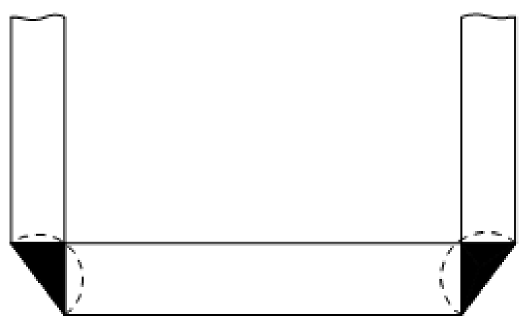


Figure 3.3.1: Head to shell attachments (continued)

Note: Dished heads of full hemispherical shape, concave to pressure, intended for butt-welded attachment, need not have an integral skirt, but where one is provided, the thickness of the skirt is to be at least that required for a seamless shell of the same diameter.

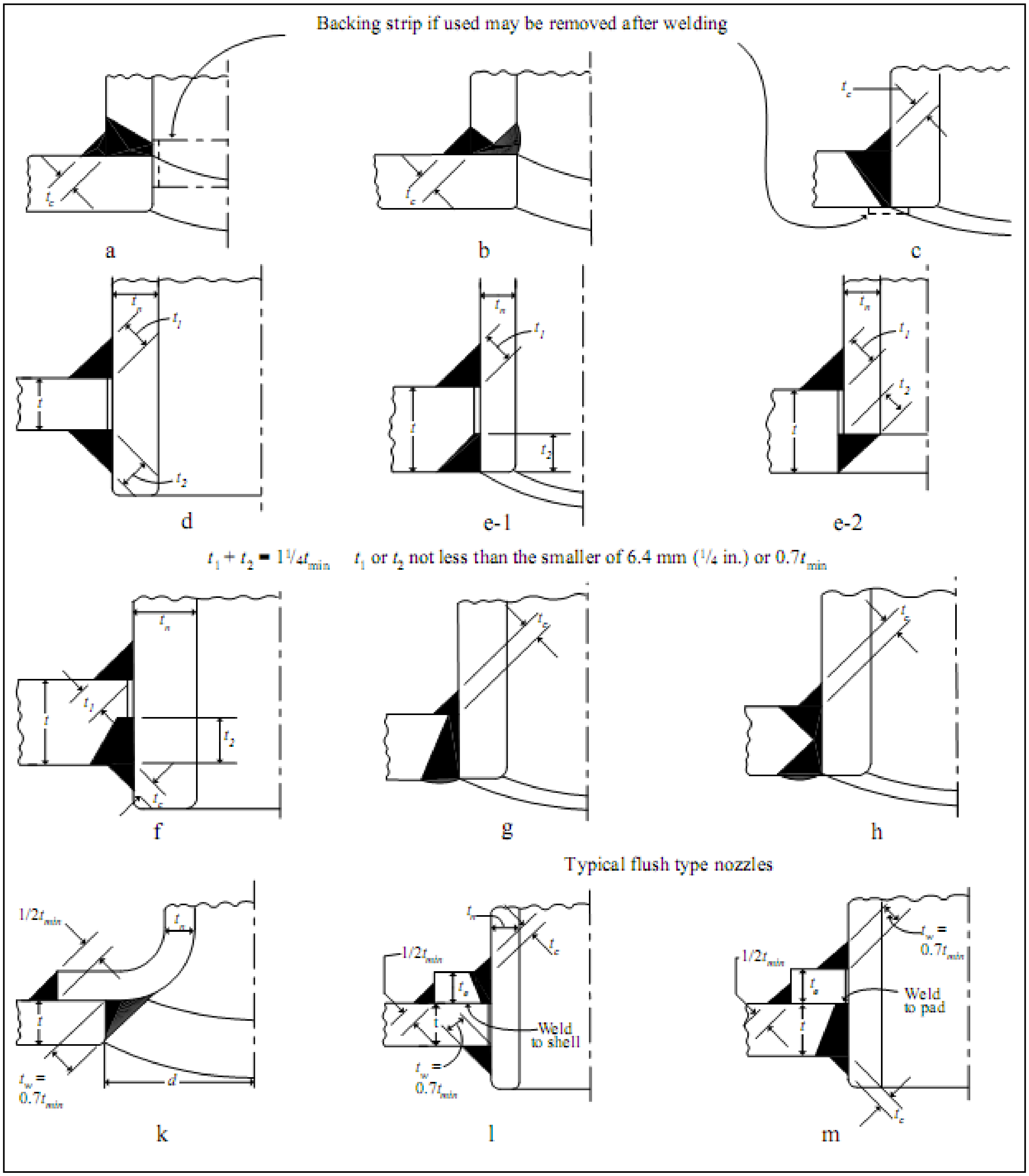


Figure 3.3.2: Types of fusion-welded construction details

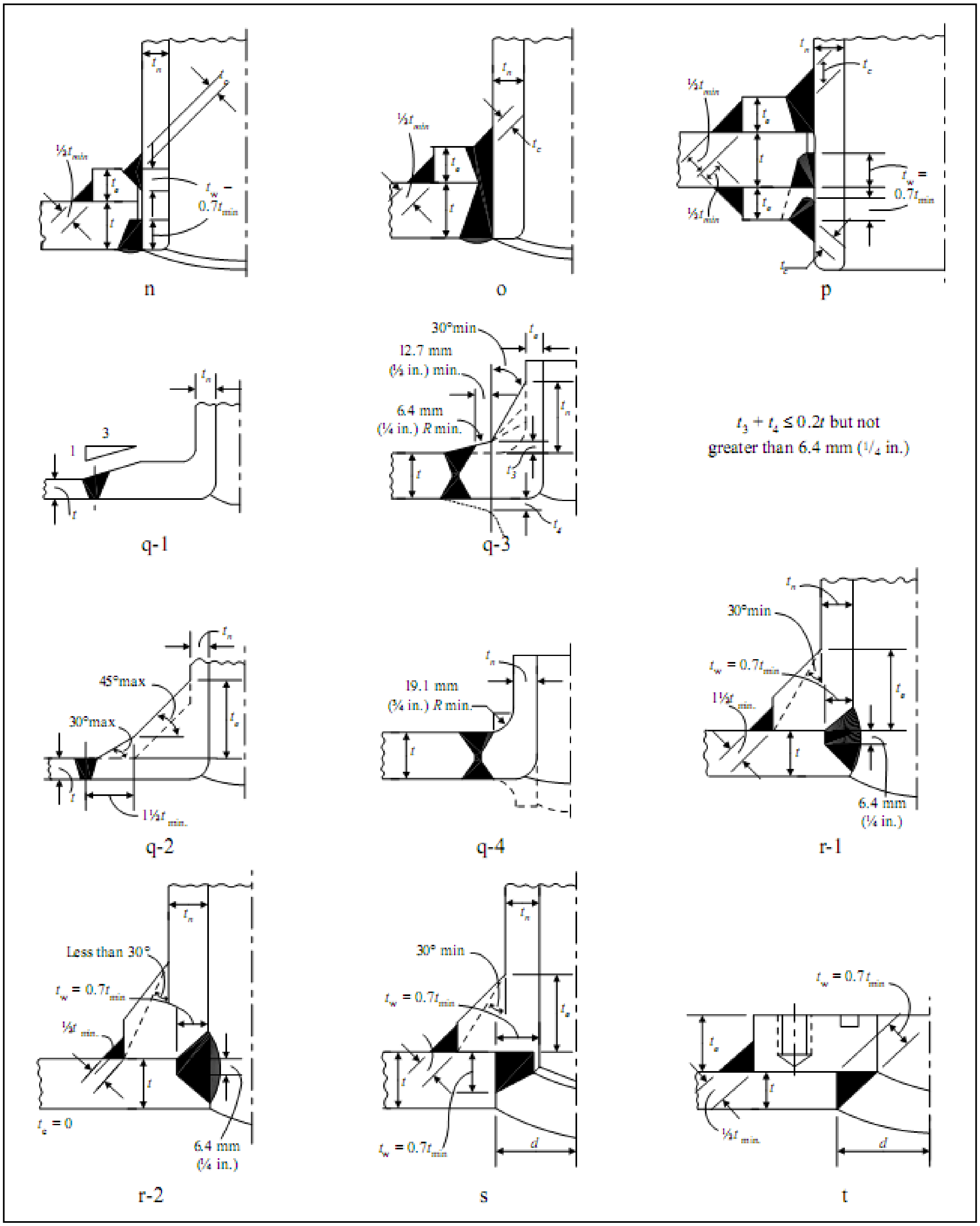


Figure 3.3.2: Types of fusion-welded construction details (continued)

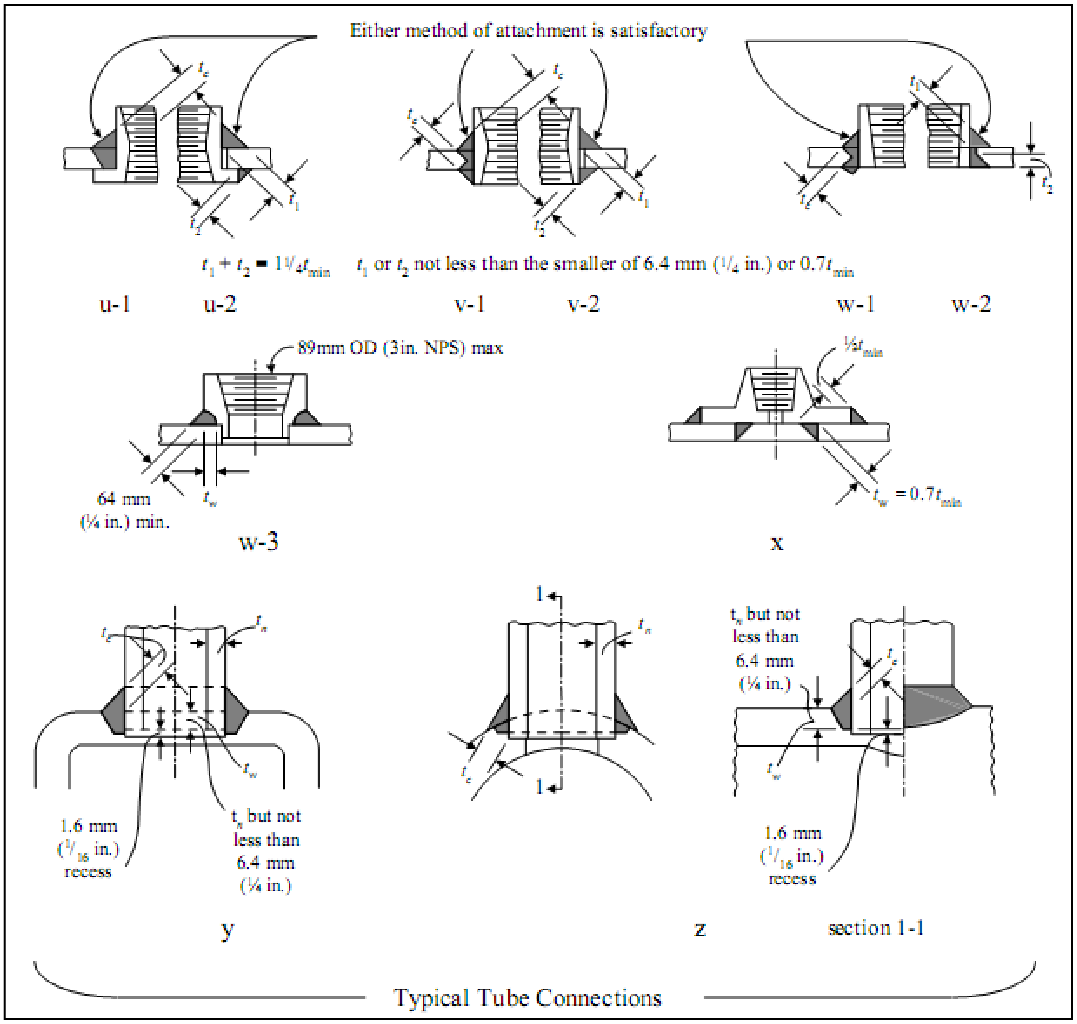


Figure 3.3.2: Types of fusion-welded construction details (continued)

(When used for other than square, round, or oval headers, round off corners)

- t = thickness of vessel shell or head, less corrosion allowance, in mm (in.)
- t_n = thickness of nozzle wall, less corrosion allowance, in mm (in.)
- t_e = thickness of reinforcing element, mm (in.)
- t_w = dimension of partial-penetration attachment welds (fillet, single-bevel, or single-J), measured as shown, mm (in.)
- t_c = the smaller of 6.4 mm (¼in) or 0.7t min (Inside corner welds may be further limited by a lesser length of projection of the nozzle wall beyond the inside face of the vessel wall)
- t_{min} = the smaller of 19.1 mm (¾ in.) or the thickness of either of the parts joined by a fillet, single-bevel, or Single-J weld, mm (in.)

SECTION 3 WELDING FOR PIPES

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3.1. General

3.1.1. Application

This section is applicable only to piping for installation on vessels to be built in accordance with the INTLREG Rules for Building and Classing Steel Vessels

The requirements of this section are intended for welding of steel pipes in systems covered in Pt 5A, Ch 8 and Ch 9 of the Rules for Building and Classing Steel Vessels. Additional provisions, as may be specified for piping systems of specialized carriers in Ch 1, [1.1.1], where applicable, are also to be complied with. Piping intended for all other applications is to comply with Section 3 of this chapter. The compliance with a recognized national or international welding standard is acceptable if it is equally effective.

3.1.2. Class of Pipe

The various pipe classes are defined in Pt 5A, Ch 8, Table 8.1.1. Classes I and II pipes are to conform to all the requirements of this Section. Class III pipes are to conform to at , [4.2],[4.3] and [4.6.1] of this Section.

3.1.3. Materials

For purpose of determining welding requirements, steel pipe materials are grouped as in Table 3.4.1 below:

Table 3.4.1

Material group	**Description**	**Representative** Standards (Refer Note)	
		INTLREG Grade	**ASTM Grade**
C and C / Mn	Carbon; Carbon manganese	1, 2, 3, 4, 5; 8, 9	A53, A106; A135
0.5 Mo 0.5 Mo / 0.5 Cr	Up to 0.5%Molybdenum; 0.5% Molybdenum & 0.5% Chromium	6; 7	A335 P1; A335 P2
1 Cr / 0.5 Mo	1.0 - 1.25% Chromium & 0.5% Molybdenum	11; 12	A335 P11; A335 P12
2.25 Cr / 1 Mo	2.25% Chromium and 1.0% Molybdenum	13	A335 P22

Note:
Other materials complying with recognized National or International standards are also acceptable.

3.1.4. Filler Metals for Welding

The manufacturers of all welding filler metals are to certify that their material conforms to an appropriate and recognized National or International standard. Filler metals tested and certified by INTLREG for meeting such a standard may be used in all cases. Other filler metals may also be accepted provided that:

- They are of the same type as proven in qualifying the welding procedure;
- They are of an acceptable make to the Surveyor; and

- For welding of Class I piping, representative production test pieces are to be taken to prove the mechanical properties of the weld metal.

3.2. Welders and Procedures of Welding

3.2.1. Procedure of Welding

Before proceeding with welding, the concerned fabricator is to prove to the Surveyor that the proposed welding filler metal, welding process, preheat, post weld heat treatment, etc. have been qualified for joining the base metal. Generally, the planned welding procedure is to be supported by a welding procedure qualification record (PQR) conducted in the presence of the Surveyor. The documented PQR, certified by a recognized body may be submitted to the Surveyor for acceptance. The PQR is to be conducted as per the recognized standard, such as the ASME Boiler and Pressure Vessel Code Section IX (or any other equivalent), The PQR may be used to support those welding procedures, whose welding variables (eg. Base metal thickness, welding current etc) are within the ranges defined in the recognized welding standard being used.

3.2.2. Welders and operators for welding

Before commencing welding, the concerned fabricator is to prove to the satisfaction of the Surveyor that the welder or the welding operator is qualified in performing the proposed welding procedure. In general, welders and welding operators are to be qualified in accordance with Sec-4[4.6] in the presence of the Surveyor. Properly documented welder performance qualification records (WPQ) conducted in accordance with recognized welding standard being used (such as the ASME Boiler and Pressure Vessel Code, Section IX) and certified by a recognized body may be presented to the Surveyor for acceptance as evidence of qualification. Once considered qualified, the welding operator is permitted to perform the welding as qualified, as well as other welding, provided that the welding variables (e.g., pipe size, position, with or without backing etc. of such welding are within specified ranges defined by the recognized welding standard being used.

3.3. Types of welded joints

3.3.1. **Full Penetration Butt Joints**

3.3.1.1. General

Full penetration butt joints are to have welds deposited on appropriately prepared single vee, double vee or other suitable types of grooves, with or without backing rings. The edge preparation and fit-up tolerances are to be as indicated in [3.3.1.2] and [3.3.1.3]. Joints welded without backing rings are to ensure complete root penetration and fusion by using qualified welding procedures and a qualified welder demonstrating that successful joints can be achieved. All full penetration butt joints in Classes I and II piping systems are subject to radiographic examination or equivalent to the extent as indicated in 4.6 of this section to guarantee that complete root penetration is achieved and the welds do not include any unacceptable imperfections.

3.3.1.2. Edge preparation

Dimensions of the edge-preparation are to be in accordance with the recognized standards or that used in the welding procedure qualified by the concerned fabricator. Edge preparations shall preferably be carried out by mechanical means. When flame cutting is used, proper care should be taken to remove the oxide scales and any notch due to irregular cutting by matching grinding or chipping back to sound metal.

3.3.1.3. Alignment and fit-up

For pipes to be butt-welded, the alignment of the pipes at the prepared edge is to be within the following maximum offsets:

i. Pipes of all diameters and thickness welded with permanently fitted backing ring: 0.5 mm (0.02 in.).
ii. Pipes welded without fitted backing ring: refer to Table 3.4.2.

Table 3.4.2

Nominal pipe size, d		Pipe wall thickness, t	Alignment tolerance
d ≤ 150 mm (6 in.)	or	t ≤ 6.0 mm (0.24 in.)	lesser of 1.0 mm (0.04 in.) or t/4
150 < d ≤ 300 mm (6 < d ≤ 12 in.)	or	6.0 < t ≤ 9.5 mm (0.24 < t ≤ 0.37 in.)	lesser of 1.5 mm (0.06 in.) or t/4
d > 300 mm (12 in.)	or	t > 9.5 mm (0.37 in.)	lesser of 2.0 mm (0.08 in.) or t/4

For butt welding of pipes of different thicknesses, if the difference in thickness is more than ¼ thickness of the thinner section or 3mm (1/8 in.), whichever is less, a taper transition having a length not less than 3 times the offset between the abutting section is to be provided at the joint.

3.3.2. **Square-Groove Butt Joint**

In Class III piping systems square groove butt joints may be used for low pressure systems which are open to atmosphere, such as tank vent and overflow pipes. Generally, such joints should not be made on pipes having wall thickness greater than 4.8 mm (3/16 in).

3.3.3. **Fillet-Welded Joints**

3.3.3.1. Socket welded joints

Socket welded joints using sockets conforming to recognized standards are to be welded using single fillet weld with leg size not less than 1.1 times the nominal thickness of the pipe. Refer also Pt 5A, Ch 8, Sec 2 [2.3.3.2] for restriction of its use and Pt 5A, Ch 8, Fig 8.2.2 for fit up particulars.

3.3.3.2. Slip-on welded sleeves joints

Sleeves meeting dimensional and fit-up particulars in Pt 5A, Ch 8, Sec 2 [2.3.3.3] and Pt 5A, Ch 8, Fig 8.2.2 may be used for joining pipes with limitations as indicated therein. The fillet weld attaching the sleeve to the pipe is to have a leg size not less than 1.1 times the nominal thickness of the pipe.

3.3.4. **Flange Attachment Welds**

Welding of a weld neck flange is to be carried out to the pipe with a full penetration butt weld conforming to [3.3.1] Attachment of Slip-on welded flange and socket welded flange are to be attached to pipes with double fillet and single fillet welds respectively. The external fillet weld is to have a leg size not less than 1.1 times the nominal thickness of the pipe or thickness of the hub, whichever is less. The size of the external fillet weld need not exceed maximum of 13 mm (0.531 in.) for Class II and Class III flange joints. The internal weld for a slip on welded flange is to have a leg size not less than the smaller of 6.0 mm (¼ in.) or the nominal thickness of the pipe.

3.3.5. Branch Connections

Pipe branches made by welding branch pipe to a hole cut in the run pipe are to be designed in accordance with Pt 5A Ch 8, Sec 2, [2.3.2]. Normally, the attachment weld is to be a full penetration groove weld through the thickness of the run pipe or of the branch pipe, with ample finished fillet weld.

3.3.6. Tack Welding

Tack welds, where used, are to be prepared with filler metal suitable for the base metal. Tack welds intended to be left in place and form part of the finished weld are to be made by qualified pipe welders by employing the same process and filler metal which is equivalent to the welding procedure to be used for the first pass. When preheating is required as per [3.4] below, the same preheating should be applied before tack welding.

3.3.7. Brazing

When brazed pipe joints are tested in tension, the joint strength is not to be less than the tensile strength of the pipe material.

3.4. Preheat

As a standard practice, before welding, dryness is to be assured; this may be achieved with suitable preheating, as necessary. For Classes I and II pipes, where ambient temperatures are below 10°C (50°F), before welding, the welded parts are to be heated to minimum 10°C (50°F). Additionally, preheating is required depending on base metal thickness and chemical composition as indicated in the table given below. The values given in the below table are based on the usage of low hydrogen processes, consideration is to be given to using higher pre-heating temperatures when low hydrogen processes are not used. Alternative preheat requirements based on a recognized standard and welding procedure qualification conducted are given consideration as well.

Table 3.4.3

Material Group	Thickness of the Thicker Joining Base Metal	Minimum Preheat Temperature
C and C/Mn C + Mn/6 ≤ 0.4 C + Mn/6 > 0.4	 ≥ 20 mm (0.79 in.) ≥ 20 mm (0.79 in.)	 50°C (122°F) 100°C (212°F)
0.5 Mo 0.5 Mo/0.5 Cr	> 13 mm (0.51 in.)	100°C (212°F)
1Cr/0.5Mo	< 13 mm (0.51 in.) ≥ 13 mm (0.51 in.)	100°C (212°F) 150°C (302°F)
2.25Cr/1Mo	< 13 mm (0.51 in.) ≥ 13 mm (0.51 in.)	150°C (302°F) 200°C (392°F)

3.5. Post Weld Heat Treatment (PWHT)

3.5.1. Procedure

As per the procedure acceptable to the Surveyor, post-weld heat treatments are to be conducted. They can be carried out in furnaces or locally. If it is conducted locally, the weld is to be heated in a circumferential band around the pipe having a width of minimum three times the wall thickness. For fabricated branch connections, the band is to extend at least two times the run pipe wall thickness beyond the branch weld. Appropriate temperature and time recording equipment is to be provided.

The welded joint is to be gradually and uniformly heated to a temperature within the range given in the table in Sec [3.5..2] and soaked at this temperature for a period of 1 hour per 25 mm (1 in.) of thickness, with a minimum of ½ hour. Then, it is to be cooled uniformly and slowly in the furnace or under insulation to a temperature not more than 400°C and later cooled in a still atmosphere.

3.5.2. **Requirement**

Depending on base metal thickness and compositions as provided in the following table, post-weld heat treatment is to be conducted on welded joints. Based on a recognized standard, consideration will be given to alternate post-weld heat treatment requirements, provided that such requirements are also applied to the welding procedure qualification.

Table 3.4.4

Material group	Thickness of the thicker joining base metal	Post-weld heat treatment soaking temperature(1)
C and C /Mn	≥ 15 mm (0.59 in.)(2)	550–620°C (1022–1148°F)
0.5Mo 0.5Mo / 0.5Cr	≥ 15 mm (0.59 in.)	580–640°C (1076–1184°F)
1 Cr / 0.5Mo	> 8 mm (0.32 in.)	620–680°C (1148–1256°F)
2.25Cr / 1Mo	All(3)	650–720°C (1202–1328°F)

Notes:
1. Maximum temperature is to be minimum 20°C (65°F) below the tempering temperature of the base metal.
2. PWHT may be omitted for Class III pipes of thickness ≤ 30 mm (1.2 in.) subject to special consideration of base metal, preheat, welding process, and welding procedure qualification.
3. PWHT may not be required for pipes with thickness ≤ 8 mm (0.31 in.) and nominal size ≤ 100 mm (4 in.) and with a service temperature of 450°C (842°F) and above.

3.6. Non-destructive examination

3.6.1. Visual examination

All the welded joints are to be visually examined wherever possible including the root side. All visible defects, such as cracks, undercuts, excessive weld reinforcement, lack of fusion on surface, incomplete penetration where the inner side is accessible, deficient size for fillet welds, etc. are to be repaired, as provided for in [3.7] of this section.

3.6.2. Butt weld joints

3.6.2.1. Radiographic examination

a) ***Extent of examination***: Radiographic examination of Butt joints are to be carried out, as per Table 3.4.5 below.

Table: 3.4.5

Pipe class	**Nominal Size,** d **or** **wall thickness**, t	Extent
I	*d* > 65 mm (2.5 in.) or *t* > 9.5 mm (3/8 in.)	100%
II	*d* > 90 mm (3.5 in.)	10%
III	All	None

Radiographic examination is to be performed with techniques and by qualified operators meeting a recognized standard and acceptable to the Surveyor. Radiographic films are to be of acceptable image quality according to a recognized standard and are to be submitted, along with interpretation of the results, to the Surveyor for review.

b) **Criteria for Acceptance.** Welds shown by radiography to have any of the following types of imperfections are to be judged unacceptable and are to be repaired, as provided in [3.7]of this section.

i. Any type of crack, or zones where fusion or penetration is not complete.

ii. Any elongated slag inclusion which has length greater than

6.0 mm (¼ in.)	for ≤ 19.0mm (¾ in),
t / 3	for 19.0mm (¾ in) < t ≤ 57.0 (2¼ in)
19.0mm (¾ in)	for t > 57.0 (2¼ in)

where t is the thickness of the thinner portion of the weld.

iii. Rounded indications in excess of an acceptance standard, such as ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1.

c) ***Re-examination*.** If the results of radiograph tests have objectionable imperfections, the weld is to be repaired and subsequently re-examined by radiography. For Class II pipe joints subjected to 10% radiographic examination only, if unacceptable imperfections were disclosed to such an extent that quality of welds is in doubt, more joints are to be examined at the discretion of the Surveyor.

3.6.2.2. Ultrasonic examination

In place of radiographic examination, ultrasonic examination may be used as per requirement detailed in.[3.6.2.1] In accordance with procedures, such examination technique is to be conducted by qualified operators meeting a recognized standard and acceptable to the Surveyor.

3.6.3. Fillet weld joints

Examination of all fillet welds attaching pipes to flanges, sockets, slip-on sleeves, pipe branches, etc. for Class 1 piping are to be carried out by the magnetic particle method or other appropriate nondestructive methods. All surfaces shall be examined and found to have any of the following indications, are to be repaired.

- Crack or relevant linear indication (having a length greater than three times the width);
- Relevant rounded indication (circular or elliptical shape with a length equal to or less than three times its width) greater than 5 mm (($^3/_{16}$ in); or
- Four or more relevant rounded indications in a line separated by 2.0 mm ($^1/_{16}$ in.) or less, edge to edge.

3.7. Weld repair

As per 4.6 of this section, any weld joint imperfection disclosed by examination and considered unacceptable is to be removed by mechanical means or thermal gouging processes. Thereafter the joint is to be welded using the proper qualified welding procedure by a qualified welder. As indicated in [3.4] and [3.5] of this section, Preheat and post-weld heat treatment is to be performed, as applicable. After completion of repair, the repaired weld is to be re-examined by the appropriate technique that disclosed the defect in the original weld.

3.8. Pipe forming and bending

3.8.1. Cold forming

Cold Forming is to be subjected to a stress relieving heat treatment equivalent to that mentioned in ,[3.5.2] where pipe is cold bent to a mean bending radius of less than or equal to four times the outside diameter of the pipe, except for C and C/Mn steels with critical tensile strength of 410 MPa (42 kgf/mm^2, 60,000 psi) or less.

3.8.2. Hot forming

Hot forming is to be carried out in the temperature range of 850 – 1000°C for all material groups and the temperature may drop down to 750°C during the forming process. When hot forming is carried out within this temperature range, no stress relieving heat treatment is required for C, C/Mn, 0.5Mo, 0.5Mo/0.5Cr material groups, while stress relieving heat treatment equivalent to that specified in ,[3.5.2] is required for 1-1.25Cr/0.5Mo and 2.25Cr/1Mo material groups.

When hot forming is carried out outside this temperature range, the post-forming heat treatment is to be performed as indicated in Table 3.4.6.

Table 3.4.6

Material group	Heat treatment and temperature
C and C/Mn	Normalizing 880 – 940°C (1616 – 1724 °F)
0.5 Mo 0.5 Mo/0.5 Cr	Normalizing 900 – 940 °C (1652 – 1724 °F)
1Cr/0.5Mo	Normalizing 900 – 960 °C (1652 – 1760 °F) Tempering 640 – 720 °C (1184 – 1328 °F)
2.25Cr/1Mo	Normalizing 900 – 960°C (1652 – 1760 °F) Tempering 650 – 780°C (1202 – 1436 °F)

3.9. Additional requirements for low temperature piping [Below -10°C (14°F)]

3.9.1. Application

These requirements are applicable for piping operating at below -10°C (14°F) that forms part of the cargo piping of specialized carriers.

3.9.2. Welding procedure

Welding procedures proposed for piping intended to operate below -10°C (14°F) are, in addition to the provisions of,[3.2.1] to be qualified with Charpy V-notch tests as provided for in Ch 1, [1.1.1].

3.9.3. Pipe joints

All welded pipe joints are to be in conformation to ,[3.3.1] [3.3.3] and- [3.3.5] and are subject to the restrictions mentioned in the table below..Refer also Ch 1, [1.1.1].

Table 3.4.7

Type of joint	Temperature / pressure limitation	Size limitation
Full penetration butt joint	None	None
Full penetration butt joint with backing ring retained	10 bar (145 psi) max	None
Socket welded joint	Socket fitting rating	NS 50 mm (2 in.) max
Slip-on welded joint	≤ -55°C (-67°F), open-ended systems	NS 40 mm (1.5 in.) max
Weld neck flange	Flange rating	None
Socket welded flange	Flange rating	NS 50 mm (2 in.) max
Slip-on welded flange	Flange rating	NS 100 mm (4 in.) max

3.9.4. Post Weld Heat Treatment (PWHT)

All butt-welded joints are to be post-weld heat-treated. Exemption from post-weld heat treatment can be considered for butt-welded and fillet-welded joints based on consideration of material, weld sizes, thickness, design pressure and temperature.

3.9.5. Non-destructive Examination

As mentioned in.[3.6.2.1] (a) for Class I pipes butt-welded joints are to be radiographically examined. Butt-welded joints of smaller thickness or diameter are to have at least 10% of the joints radiographed.

SECTION 4 WELD TESTS

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4.1. General

The steps to be taken in obtaining approval of electrodes and welding procedures by INTLREG for qualifying welders and for demonstrating satisfactory workmanship are given below.

4.1.1. Weld groups

By index letters and numbers, the various groups of welds are designated, by which they are referred to in subsequent paragraphs, as given below:

Hull Construction	H	All hull structures
Boilers, etc. Group I	B1	
Unfired Pressure Vessels Group II	B2	
Piping Group, I	P1	As defined in Sec 2,[2.1.4]
Piping Group II	P2	
Engineering Structures Group I	E1	
Engineering Structures Group II	E2	

4.1.2. Tests

In order to approve, details of tests, preparation of test samples and test results required in each application are given in [5.2] to [5.5], and Fig-3.5.1 to Fig-3.5.13. Where the position of welding is referred to, the same is to be defined in the American Welding Society definitions.

4.2. Filler metals

4.2.1. General

In order to manufacture, filler metals are to be of type appropriate to produce sound welds that have strength and toughness comparable to the materials being welded.

4.2.2. Approval basis

Filler metals will be approved and listed after conducting tests at manufacturer's plant or alternatively at a location outside the manufacturer's plant under the supervision of the manufacturer. After satisfactory completion of tests, a certificate will be issued for general approval, indicating, where applicable, the INTLREG Grade, operating characteristics and limits of application. In the presence of the Surveyor, test assemblies are to be prepared and all tests are to be performed to the Surveyor's satisfaction. Procedure and testing are to comply with either of the following standards.

4.2.2.1. INTLREG Standards

Approval of filler metals for welding vessels and other engineering structures will be granted upon compliance with the Chapter-3,. Sect-5

4.2.2.2. Standards of other agencies

Filler metals will be considered for approval based on the tests conducted to standards established by the American Welding Society or other recognized agencies.

4.2.2.3. Special approval

On the basis of filler metal manufacturer's guaranteed requirements, INTLREG will consider approval under circumstances where exact specifications have not been established. For special applications with reliance upon procedure tests at a user's plant, qualified approvals will also be considered, with and without classifying as to grade.

4.3. Approval of welding procedures

4.3.1. Approved filler metals

The type of approved filler metals used on INTLREG-classed weldments will depend on the specific application for which the filler metal is intended. In order to decide shipyard or fabricator's capability in the application of the proposed filler metal to the base material, procedure tests may be required at the discretion of the attending Surveyor. Depending on the intended application, the extent of such tests may differ, but generally are to follow those tests defined in [5.3.4] below.

4.3.2. Surveyor's acceptance

In a shipyard or fabricator's plant where welding procedure is established to the Surveyor's satisfaction, the Surveyor may, at his discretion, accept the welding procedure, a filler metal, or both, that they have been effectively used for similar work under similar conditions.

4.3.3. New procedures and methods

When new or unusual methods, base metals or filler metals are proposed, by each shipyard or fabricator they may be required to prepare weld tests using procedures and materials similar to those intended for production welding. All tests are to be made and carried out to the Surveyor's satisfaction.

4.3.4. Tests

The number of specimens is to be as indicated in Figure 3.5.1. The minimum test results required are stated with the following figures.

- **Test No. 1** (For butt welds) **Reduced-section Tension Test** (Figure 3.5.3 or Figure 3.5.4). One test assembly for each position involved; two reduced-section tension test specimens taken from each test assembly as shown in Figure 3.5.1.
- **Test No. 2** (For butt welds) **Guided Bend Test** (Figure 3.5.5 and Figure 3.5.6). One test assembly for each position involved. For material 19 mm (0.75 in.) thick and under, two face-bend and two root bend specimens taken from each test assembly as shown in Figure 3.5.1, except that at the option of the fabricator, four side bends may be substituted for material thickness over 9.5 mm (⅜ in.). For material over 19 mm (0.75 in.) thick, four side-bend specimens taken from each test assembly as shown in Figure 3.5.1. The bending jig and test requirements are indicated in Figure 3.5.7.
- **Test No. 3 Fillet-weld Test** (Figure 3.5.8). One specimen made in each position involved.

4.3.5. Special tests

For certain applications, such as higher-strength steels, one-side welding, electroslag welding, etc. all weld-metal tension, Charpy V-notch impact, macro-etch or other relevant tests may be required and the results submitted for consideration. Figure 3.5.13 specifies the location of Charpy V-notch impact tests when heat affected zone tests are required. A Charpy V-notch test is to consist of three specimens per location.

4.3.6. Repair and cladding of stern tube and tail shafts

Weld repairs and cladding on stern tube shafts and tail shafts are to be carried on in an approved facility.

4.4. Workmanship Tests

4.4.1 Hull construction

For Fillet-weld Tests (Test No. 3) for the positions involved, the Surveyor may, when it is deemed necessary, require welders to prepare specimens. Details of the specimen are illustrated in Figure 3.5.8.

4.4.2 Boilers and Group I Pressure vessels

4.4.2.1. Required tests

The below mentioned tests are to be carried out using equivalent material of the same thickness as the boiler or pressure vessel. The results required are specified with the applicable figures and in [5.5.2] of this section.

- **Test No. 1** Reduced-section Tension Test (Figure 3.5.3)
- **Test No. 2** Guided Bend Test, (Figure 3.5.5 or Figure 3.5.6)
- **Test No. 3** Radiographic Search of Welds on Finished Joint

4.4.2.2. Test exceptions

Test Nos. 1 and 2 are not required for cylindrical pressure parts of Boilers and Group I Pressure Vessels constructed of INTLREG Steel Plate for Boilers and Pressure Vessels Grades A through G inclusive and Grades K through N inclusive whose welded joints are completely examined by radiography.

4.4.2.3. Attached test plates

Structures made in accordance with the requirements of Group B1 of materials other than those specified in [4.4.2.2] are to have test plates attached as shown in Figure 3.5.2, to permit the longitudinal joint of the shell and test plates to be welded continuously. In order to provide two specimens for each of Tests Nos. 1 and 2 as detailed above, the test plate is to be of sufficient length. One specimen is to be tested; the other specimen is for the purpose of retesting, if found necessary.

4.4.2.4. Separate test plates

Test plates need not be provided for Circumferential joints of a boiler or pressure vessel unless there is no longitudinal welded joint, in which case test plates are required to be welded individually.

4.4.2.5. Number of test plates

Where several drums or vessels of the same design and grade of material are welded in succession., a set of test plates for each linear 61 m (200 ft) of longitudinal joints, or 61 m (200 ft) of circumferential joints where there are no longitudinal joints, will be acceptable, provided that the joints are welded by the same operators maintaining the same welding method/ procedure. If the plate thicknesses fall within a range of 6.4 mm (0.25 in.) and the shell diameters do not vary by more than 150 mm (6 in .), then shells having no longitudinal joints may be considered as being of the same design.

4.4.2.6. Test-plate heat treatment and retests

Treatment for Stress relieving, etc., shall be done to the welded test plates in the same manner as the work which they represent. If any of the tests fail, one retest is to be made for each failure; and if the retest also fail, the welding represented is to be chipped or gouged out and re-welded and new test plates provided.

4.4.3 Other pressure vessels

In this Group, workmanship test plates are not required for structures. When required in Sec 4 [4.4]of this chapter, Test No. 3 is to be carried out.

4.4.4 Group I pipe connections

According to the requirements of this group, in carbon and carbon-molybdenum steel piping for all diameters where the thickness exceeds 9.5 mm (0.375 in.) and other alloy-steel piping 76 mm (3 in.) in diameter and over regardless of thickness, welds made in accordance with this group are to be subjected to either 100% Radiographic Search - Test No. 3, or to other approved method of test, where the former is not applicable.

4.4.5 Group II pipe connections

No workmanship tests are required.

4.4.6 Group I engineering structures

As per the specifications made in [4.4.2] of this section, Group I Engineering Structures are to meet the same requirements, except that where there is no longitudinal joint, no test plates will be required.

4.4.7 Group II engineering structures

Testing of the welds in structures in this group which correspond in service requirements to Group B2 are to be carried out in the same manner as Group B2, except that where there is no longitudinal joint, no tests will be required.

4.5. Radiographic or Ultrasonic Inspection

4.5.1.Hull construction

Radiographic or ultrasonic inspection should be carried out in consultation with INTLREG Surveyor.

4.5.2. Boilers Pressure Vessels, Machinery and Piping

4.5.2.1. General

Whenever a radiographic examination is required as detailed in [5.4.2], [5.4.3],[5.4.4] and [5.4.6] of this section, the radiographs are to be obtained by means of an approved technique and are to compare favorably with accepted standards.

4.5.2.2. Acceptability of welds-full radiography

Generally, fully radiographed sections of weld to have any of the following types of imperfections are to be considered unacceptable and are to be repaired.

i) *Incomplete Fusion or Penetration*. Any type of crack or zone of incomplete fusion or penetration.

ii) *Elongated Slag Inclusions or Cavities.* Any elongated slag inclusion or cavity which has a length greater than the following, where *t* is the thickness of the thinner plate being welded

- 6.4 mm (0.25 in.) for *t* up to 19.1 mm (0.75 in.)
- $\frac{1}{3}t$ for *t* from 19.1 mm (0.75 in.) to 57.2 mm (2.25 in.)
- 19.1 mm (0.75 in.) for *t* over 57.2 mm (2.25 in.)

iii) *Slag Inclusion in Line.* Any group of slag inclusions in line that have an aggregate length greater than t in a length of $12t$, except when the distance between the successive imperfections exceeds $6L$ where L is the length of the longest imperfection in the group

iv) *Porosity Standards.* Porosity in excess of that permitted by accepted porosity standards such as given in American Society Of Mechanical Engineers(ASME) Boiler and Pressure Vessel Code or any Recognized International Standards.

4.5.2.3. Acceptability of welds-spot (random) radiography

Spot Radiographic inspection of the production welds is to compare favorably with accepted standards and methods, such as given in the ASME Boiler and Pressure Vessel Code.

4.5.2.4. Survey report data

The Surveyors report shall include a statement on the extend and the results of the radiographic examination for each case. The manufacturer shall document the inspection procedure and technique on file and it is to compare favorably with accepted practice such as that specified in the ASME Boiler and Pressure Vessel Code.

4.5.2.5. Pipe-joint exception

In lieu of the radiographic inspection of pipe joints, an approved method of test may be used, where the latter cannot be applied.

4.6. Welders

4.6.1. General requirements

The welders shall be qualified for the type of work which they are called upon to perform, either through requiring any or all of the tests outlined in the following paragraphs or through due consideration of the system of employment, training, apprenticeship, plant testing, inspection, etc., employed and shall be to the satisfaction of the Surveyor.

4.6.2. Qualification tests

For qualification in the various positions for different materials and thicknesses, the tests are tabulated in Table 3.5.1. In accordance with Figure 3.5.9 to Figure 3.5.12 respectively, the tests are referred to by Nos. Q1 to Q4 inclusive for which samples are to be prepared and physically tested if the welder is qualified by this method. On the other hand, upon the request of the employer, the welder may be qualified by use of radiography, except for gas metal arc welding with the short circuit transfer technique for which bend tests are required. In accordance with the material thickness and welding position, as stated in Table 3.5.1, test assemblies for either physical testing or radiographic examination are to be prepared.

Alternatively, the welders may be qualified in accordance with a recognized standard. Application of such recognized standard is to be submitted for acceptance by the Surveyor.

4.6.3. Tests Nos. Q1, Q2, Q3, and Q4

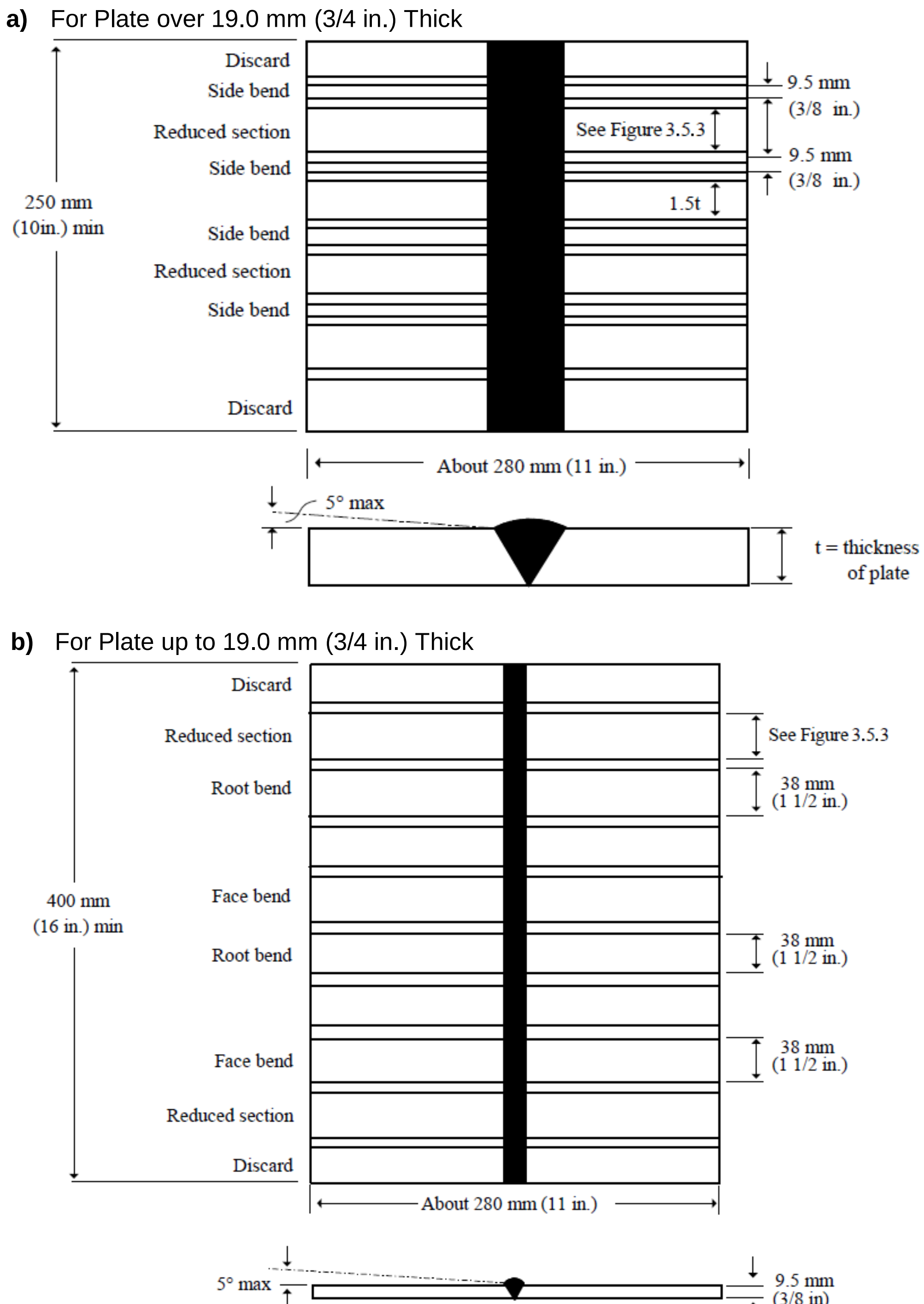
Test specimen for qualification Tests Nos. Q1, Q2, Q3 and Q4 are to be bent in a bending jig having the profile illustrated in Figure 3.5.7.

Table 3.5.1 Welder qualification tests

Construction material	Position in Which Welding Is To Be Done on Job		
	Flat, Horizontal, Vertical and Overhead	**Flat and Vertical**	**Flat position only**
Plate Material of 19.1 mm ($^3/_4$ in.) or less in thickness(1)	Test No. Q1 in vertical (3G) and overhead (4G) positions	Test No. Q1 in vertical (3G) position	Test No. Q1 in flat (1G) position
Plate material of any thickness	Test No. Q2 in vertical (3G) and horizontal (2G) positions	Test No. Q2 in vertical (3G) position (2)	Test No. Q2 in flat (1G) position
Piping or tubing of any thickness (2)	Test No. Q3 in inclined fixed (6G) position	Test No. Q3 in horizontal fixed (5G) position (4)	Test No. Q3 in horizontal rolled (1G) position (4)
Piping or tubing of any thickness (5)	Test No. Q3R in horizontal and vertical positions		
T, K and Y joints (3)	Test Q3 in inclined fixed position with restriction ring (6GR)		
Tack welders for hull construction (6)	Test No. Q4 in vertical and overhead positions	Test No. Q4 in vertical position	

Notes:

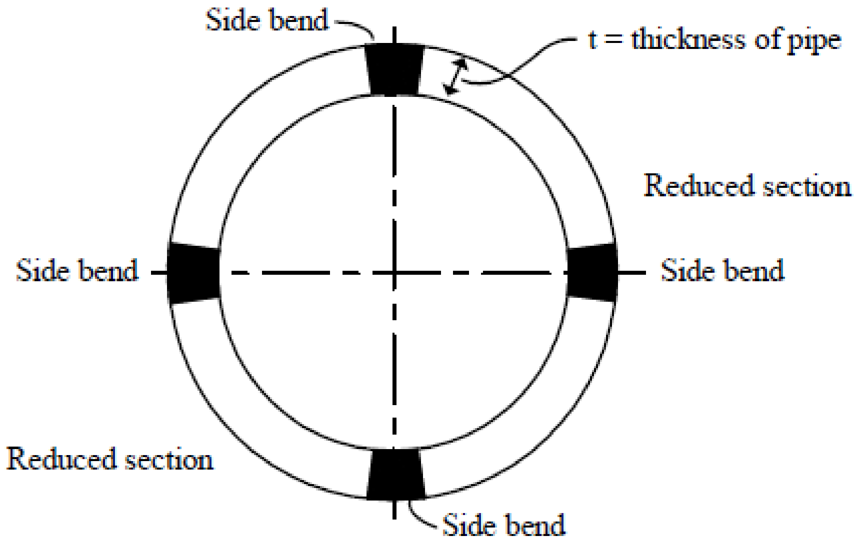
1. Where the maximum plate thickness to be welded is less than 9.5 mm ($^3/_8$ in.), the test plate thickness is to be 5.0 mm ($^3/_{16}$ in.).
2. Welders qualified under the requirements of Test No. Q3 will be considered as qualified to make welds governed by Test Nos.Q1 and Q2, in accordance with test thickness; test thickness over 5.0 mm ($^3/_{16}$ in.) but less than 19.0 mm ($^3/_4$ in.) qualifies for range of 1.5 mm ($^1/_{16}$ in.) to 2*t*; test thickness 19.0 mm ($^3/_4$ in.) and greater qualifies for range of 5.0 mm ($^3/_{16}$ in.) to unlimited thickness. Welders qualified to weld on plate in the vertical position may be permitted to weld on pipe in the horizontal rolled position.
3. For qualification of T, K and Y joints, Test No. Q3 in the inclined fixed position with restriction ring (6GR) is required
4. Test No. Q3 in the horizontal fixed (5G) position also qualifies for overhead (4G) welding. Test No. Q3 in the 2G position qualifies for welding in the 1G, 1F, 2G and 2F positions.
5. Test No. Q3R may be used when special qualification for welding in areas of restricted access is required.
6. Sec-4, [4.3.6] of this chapter, applicable for pipe welding



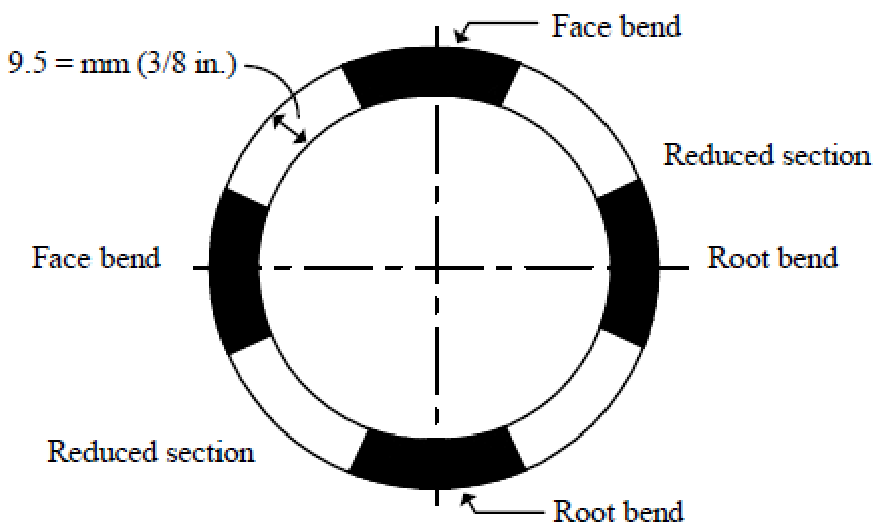
Note: Edge preparation, welding procedure and post weld heat treatment, if any, are to be the same as those for the work represented.

Figure 3.5.1: Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2

a) For Plate over 19.0 mm (3/4 in.) Thick

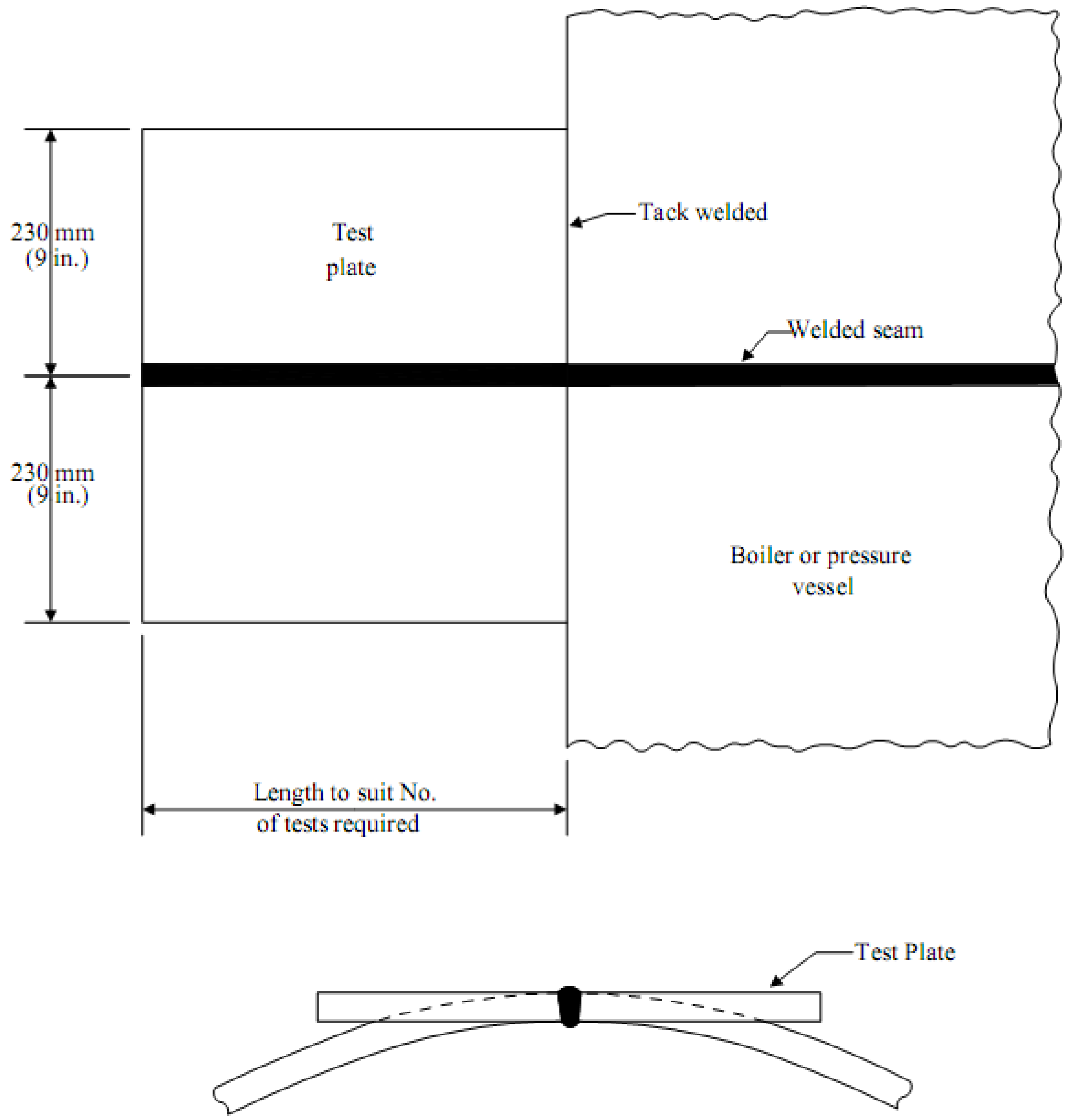


b) For Plate up to 19.0 mm (3/4 in.) Thick



Note: Edge preparation, welding procedure and post weld heat treatment, if any, are to be the same as those for the work represented.

Figure 3.5.1 (Continued) Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2



Note: Tack weld test plates together and support test assembly so that warping due to welding does not cause deflection of more than 5 degrees. Should straightening of any test assembly within this limit be necessary to facilitate making test specimens, the test assembly is to be straight-ended after cooling and before any post weld heat treatment.

Figure 3.5.2: Typical Arrangement of Test Plates for Workmanship Tests in Group B1

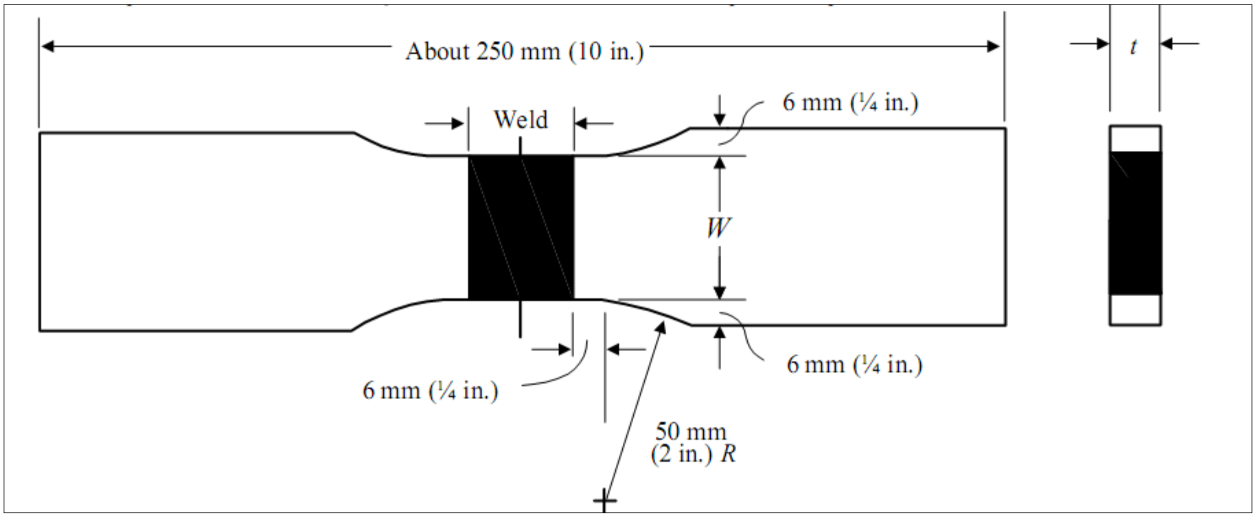


Figure 3.5.3: Test No. 1 - Reduced-section Tension Test for Plate
Required for all Procedure Qualification and for Workmanship in Group B1 and E1

Notes:

1. Both faces of weld are to be machined flush with base metal.
2. For procedure qualification *t* = 9.5 mm (⅜ in.) for construction materials up to 19.0 mm (3/4 in.). For construction material over 19.0mm (3/4 in.) *t* = thickness of material.
3. For workmanship tests *t* = thickness of construction material.
4. *W* = approximately 38 mm (1.5 in.) where *t* is 25.4 mm (1 in.) or less. *W* = 25.4 mm (1 in.) where *t* is more than 25.4 mm (1 in.).
5. When the capacity of the available testing machine does not permit testing of the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

Requirements:

1. The tensile strength of each specimen, when it breaks in the weld, is not to be less than the minimum specified tensile strength of the base material.
2. The tensile strength of each specimen, when it breaks in the base metal and the weld shows no signs of failure, is not to be less than 95% of the minimum specified tensile strength of the base material.

Retest Procedure:

1. When the tensile test fails to meet the requirements, two retests may be performed with specimens cut from the same tested piece. The results of both test specimens shall meet the test requirements.

2. If one or both of these fail, the weld test is to be rejected.

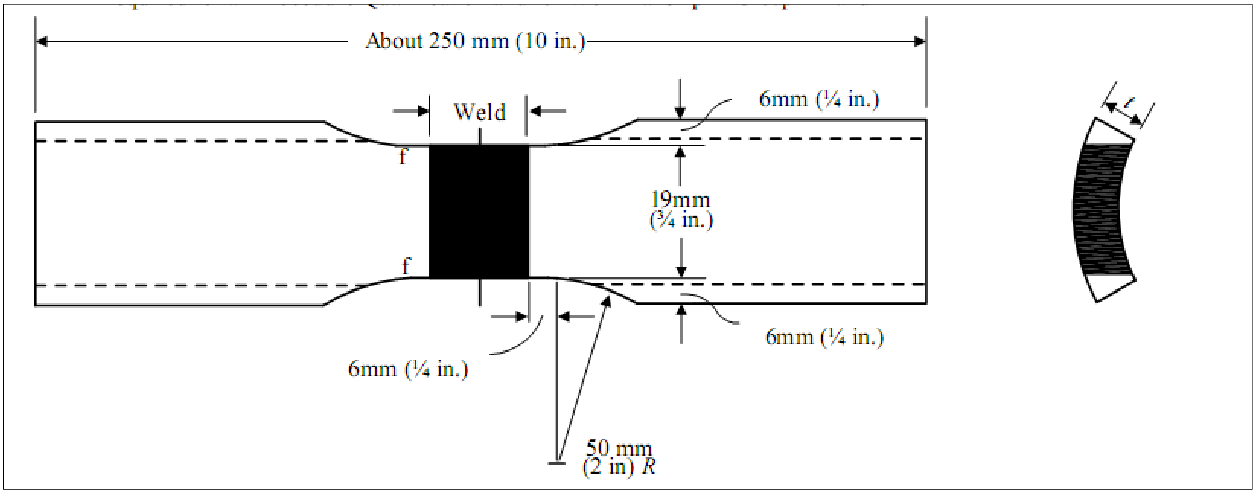


Figure 3.5.4 Test No. 1 - Reduced-section Tension Test for Pipe
Required for all Procedure Qualification and for Workmanship in Group B1 and E1

Notes:

1. Both faces of weld are to be machined flush with base metal. The minimum amount needed to obtain plane parallel faces over 19 mm (3/4 in.) wide reduced section may be machined at the option of the testing facility.
2. For procedure qualification *t* = 9.5 mm (3/4 in.) for construction materials up to 19.0 mm (3/4 in.). For construction material over 19.0mm (3/4 in.) *t* = thickness of material.
3. For workmanship tests *t* = thickness in material.
4. When the capacity of the available testing machine does not permit testing of the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

Requirements:

1. The tensile strength of each specimen, when it breaks in the weld, is not to be less than the minimum specified tensile strength of the base material.
2. The tensile strength of each specimen, when it breaks in the base metal and the weld shows no signs of failure, is not to be less than 95% of the minimum specified tensile strength of the base material.

Retest Procedure:

1. Two retests may be performed with specimens from the same tested piece, when the test fails to meet the requirements. The results of both test specimens shall meet the test requirements.
2. If one or both of these fail, the weld test is to be rejected.

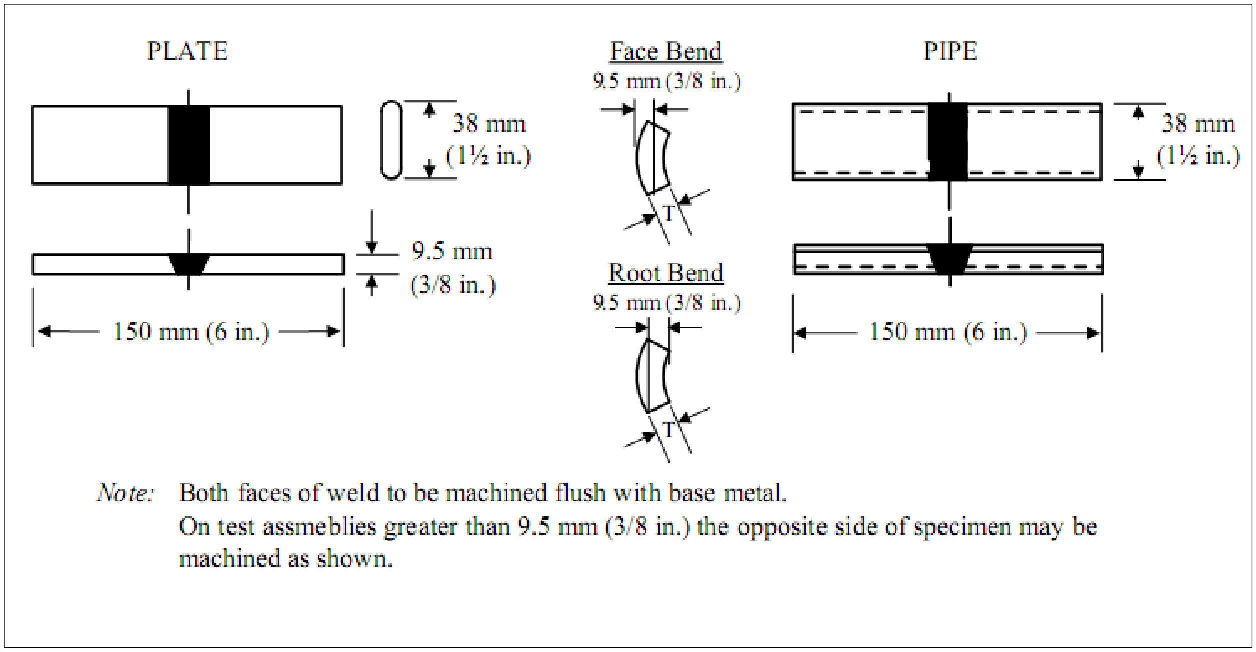


Figure 3.5.5: Test No. 2 – Guided Bend Test for Root Bend and Face Bend (Plate or Pipe)

Required for Procedure Qualification, Workmanship Tests in Groups B1, B2, and E1

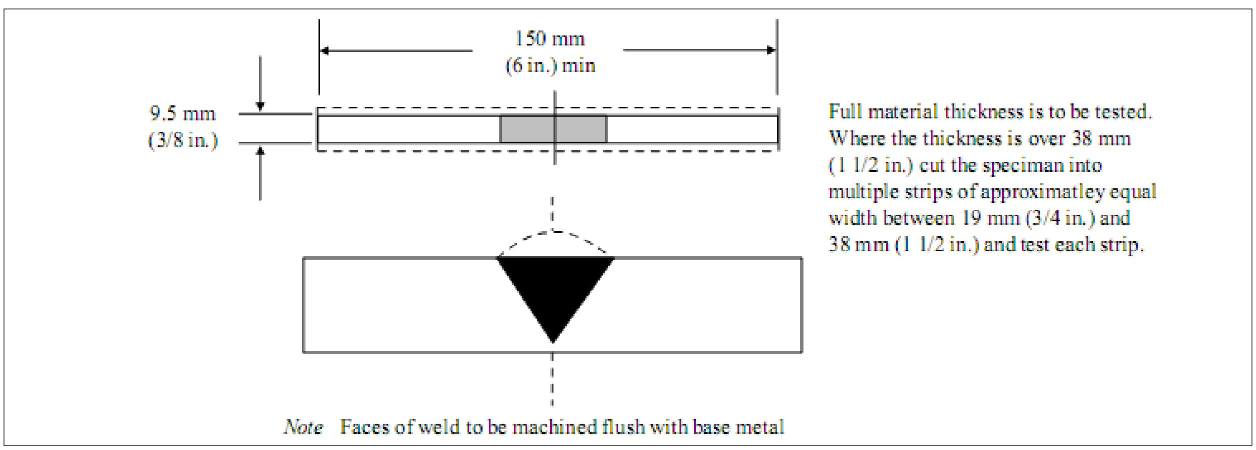


Figure 3.5.6: Test No.2 – Guided Bend Test for Side Bend (Plate or Pipe)

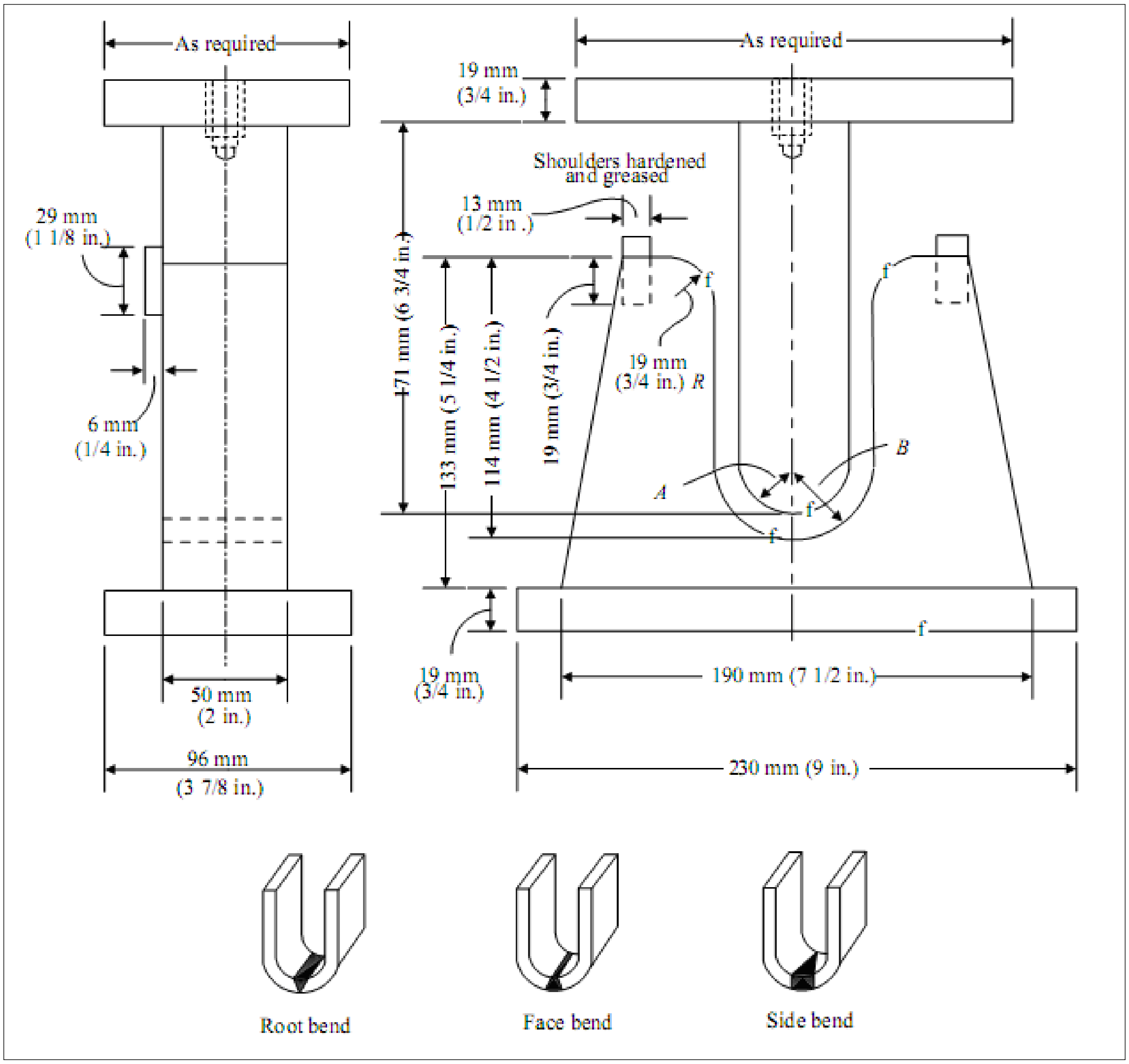


Figure 3.5.7 Guided Bend Test Jig

Note: The specimen is to be bent in this jig or in an equivalent guided bend roller jig around a mandrel with the following maximum dimensions proportional to the specimen thickness (*t*).

	A	B
Ordinary strength steel	2 t	3*t* + 1.6 mm (1/16 in.)
Higher strength steel	2.5 t	3.5*t* + 1.6 mm (1/16 in.)
High strength quenched and tempered steel > 620 N/mm^2 (90 ksi) YS	3.3 t	4.3*t* + 1.6 mm (1/16 in.)

Requirements:

1. After bending, the specimen is not to show any cracking or other open defect exceeding 3.2 mm (⅛ in.) on the convex side in any directions except at the corners.
2. After bending, the sum of the greatest dimensions of all discontinuities exceeding 0.8 mm (1/32 in.) on the convex side is not to exceed 9.5 mm (3/8 in.)
3. After bending, the maximum corner crack is not to exceed 6.4 mm (1/4 in.), except when that corner crack results from visible slag inclusion or other fusion type discontinuity, then 3.2 mm (1/8 in.) maximum shall apply.

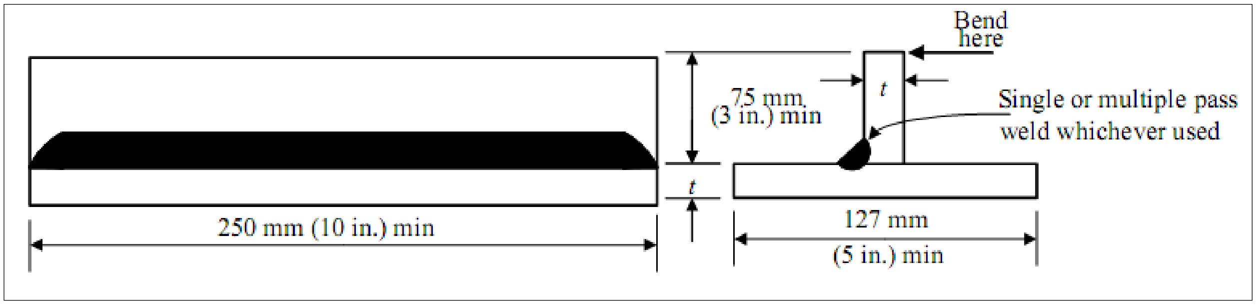


Figure 3.5.8: Test No. 3 – Fillet-weld Test

Notes:

1. For procedure qualification t = 9.5 mm (3/8 in.) for construction materials up to 19.0 mm (3/4 in.).
2. For construction material over 19.0mm (3/4 in.) t = thickness of material.
3. Base and standing web is to be straight and in intimate contact and securely tacked at ends before fillet-weld is made, to ensure maximum restraint.
4. The test plate may be flame cut into short sections to facilitate breaking open.

Requirements:

The fillet is to be of the required contour and size, free from undercutting and overlapping. When broken, as indicated, the fractured surface is to be free from cracks. Visible porosity, incomplete fusion at the root corners and inclusions may be acceptable, provided the total length of these discontinuities is not more than 10% of the total length of the weld.

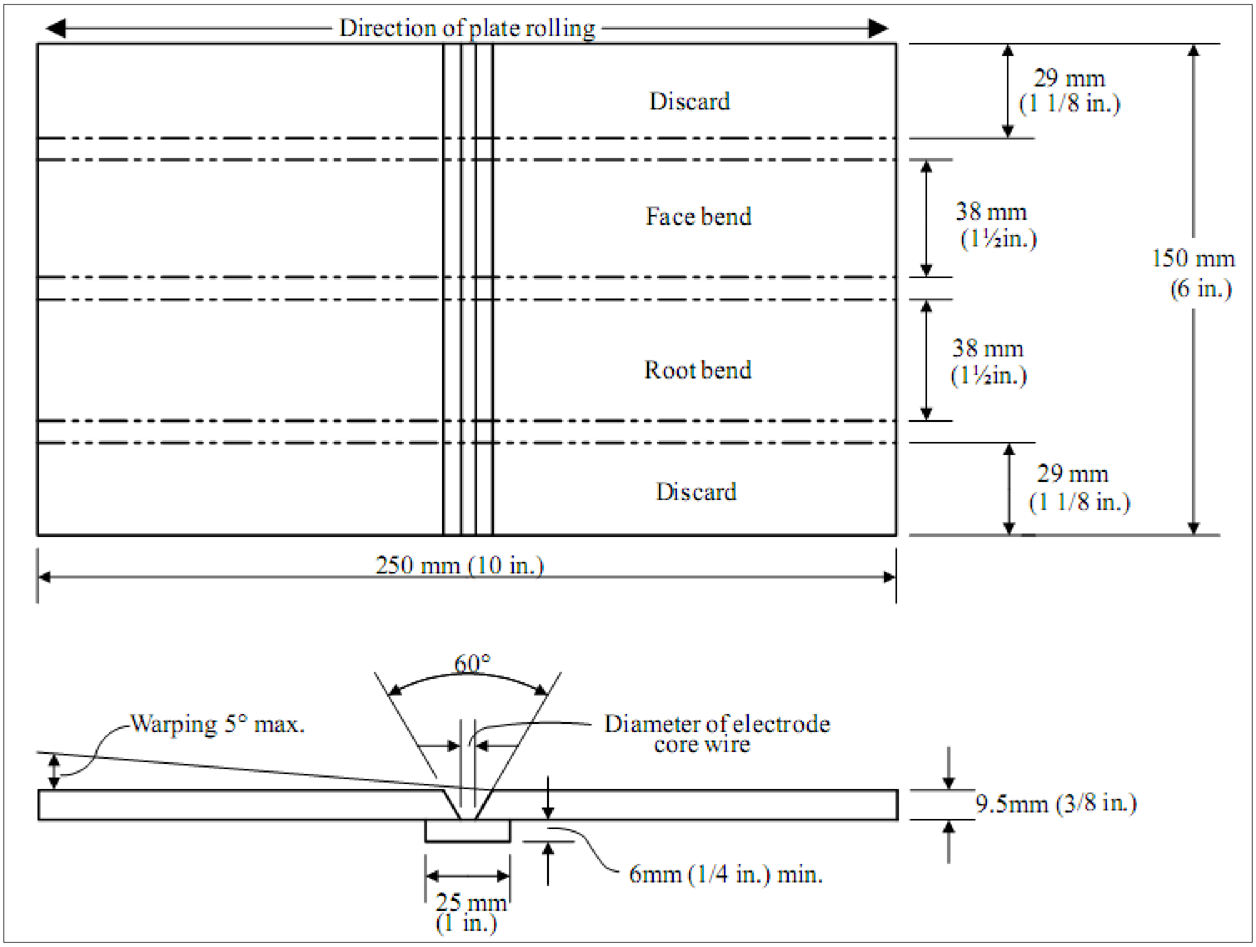


Figure 3.5.9 - Welder Qualification Test No. Q1
For Plate Material 19.0 mm (3/4 in.) or less

Notes:

1. Weld is to be made with the maximum size of electrodes that will be used in production.
2. Thickness of test assembly is to be reduced to 5 mm (3/16 in.) for qualifying construction material less than 9.5 mm (3/8 in.) per Note-1 of Table 3.5.1.
3. Machine reinforcement and backing strap flush. Do not remove any undercutting.
4. Machining is to be done transverse to weld.
5. All specimens are to be machined or sawed from plate.
6. Backing strap is to be contiguous with plates.
7. Joints welded in the vertical position are to be welded upwards.
8. Welding is to be done from one side only.
9. Break edges of specimens to a radius of t/6 maximum.
10. Bend specimens in Guided Bend Test Jig (Figure 3.5.7)
11. One (1) Face Bend and one (1) Root Bend required.

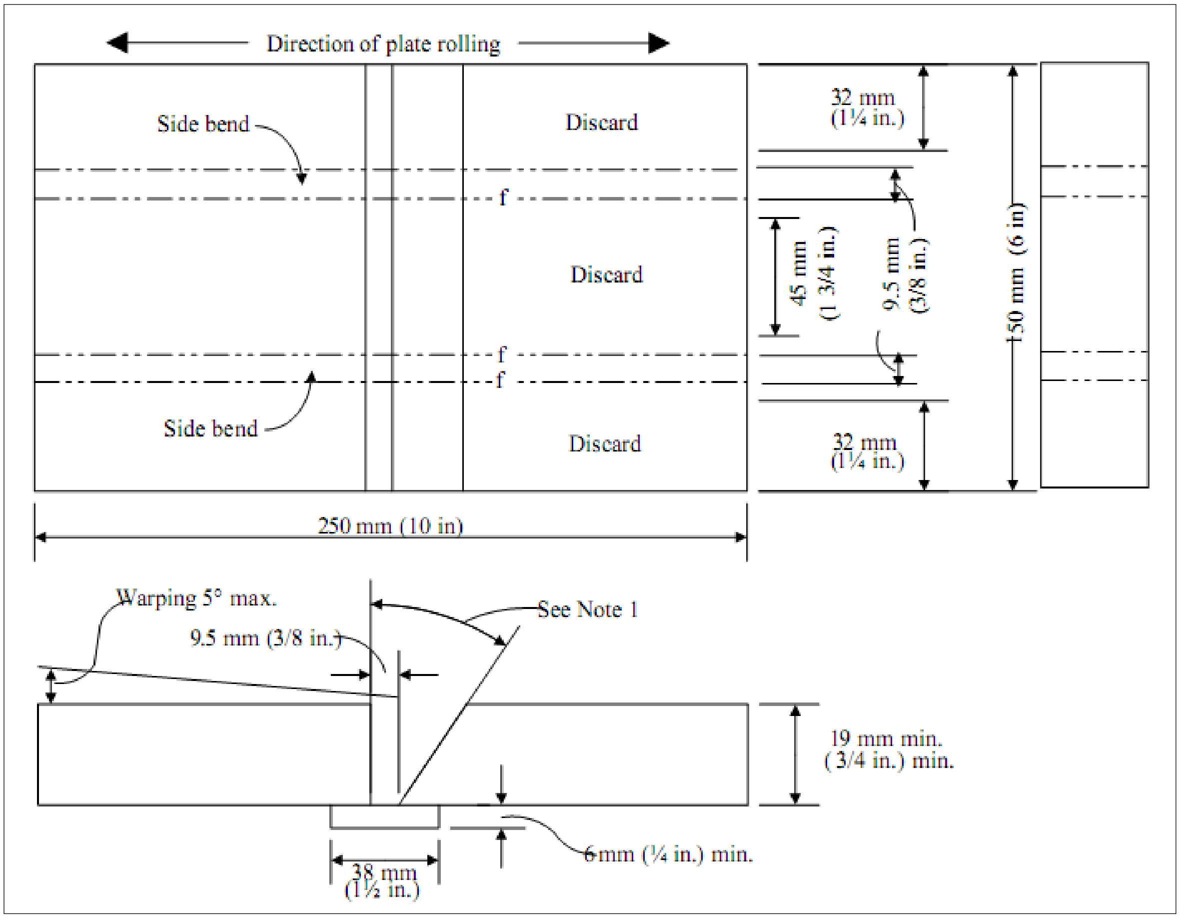
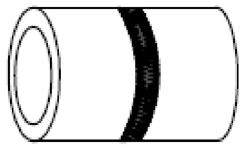


Figure 3.5.10 Welder qualification test No. Q2
For materials of any thickness.

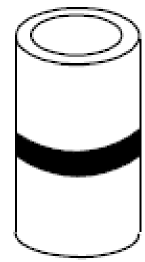
Notes:

1. When welding in the flat and vertical positions of welding, the groove angle is to be 25 degrees; when welding in the horizontal position, the groove angle is to be 35 degrees and the unbeveled plate is to be located on the top side of the joint.
2. Backing strap is to be contiguous with plates.
3. Each pass of the weld is to be made with the same size of electrodes that will be used in production.
4. Joints welded in the vertical position are to be welded upwards.
5. Welding is to be done from one side only.
6. Machine reinforcement and backing strap flush. Do not remove any undercutting.
7. All specimens are to be machined or sawed from plate.
8. Machining is to be done transverse to weld.
9. Break edges of specimens to a radius of t/6 maximum.
10. Bend Specimen in Guided Bend Test Jig (Figure 3.5.7).
11. Two (2) Side Bends required for plate. Four (4) Side Bends required for pipe.

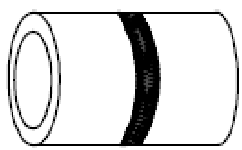
Positions of Test Pipe or Tubing (also Refer Table 3.5.1)



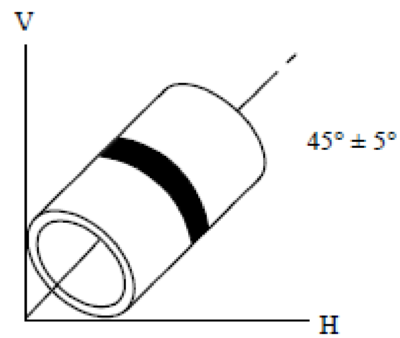
(a) Horizontal rolled (1G)
(Refer Note-9 in Fig-3.5.11-C)



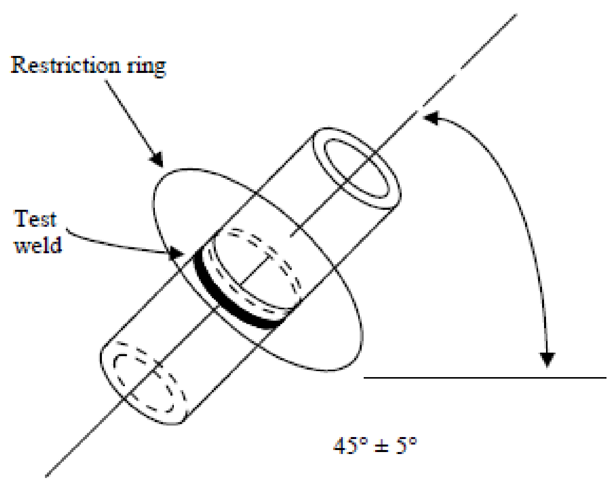
(b) Vertical fixed (2G)
(Refer Note-9 in Fig-3.5.11-C)



(c) Horizontal fixed multiple welding test position (5G)
(Refer Note-9 in Fig-3.5.11-C)



(d) Inclined fixed multiple welding test position (6G)
(Refer Note-9 in Fig-3.5.11-C)

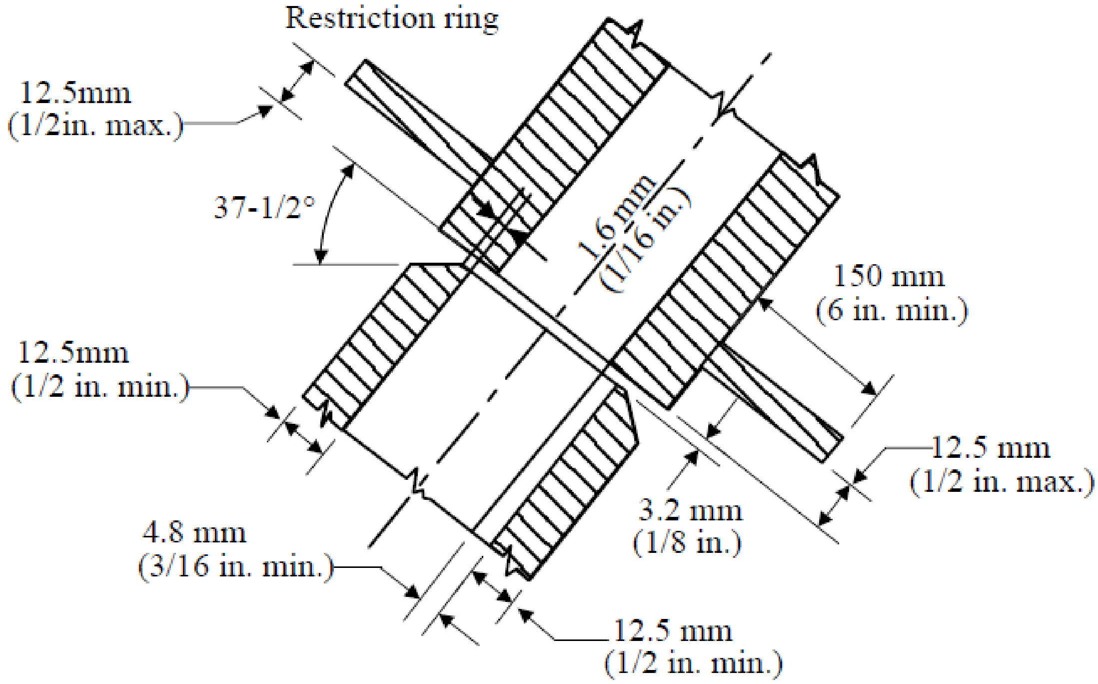


(e) Inclined fixed multiple welding test position with restriction ring (6GR)
(Refer Note-9 in Figure-3.5.11-C)

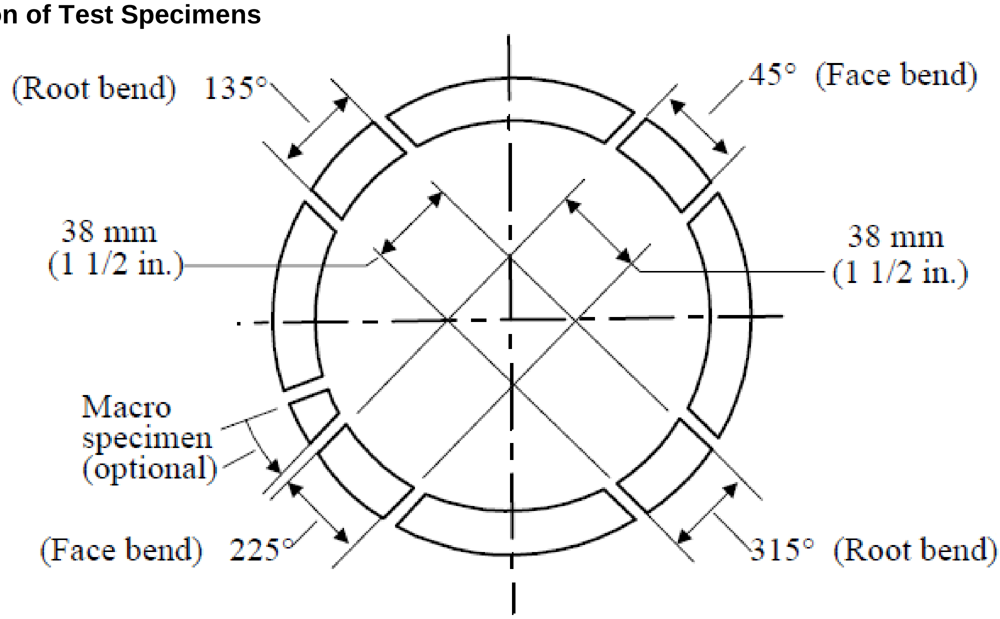
For Joint Details Refer Figure 3.5.11-B

Figure 3.5.11-A: Welder Qualification Test No. Q3

Positions of Test Pipe or Tubing



Location of Test Specimens



(Refer Note-10 in Fig-3.5.11-C)

Figure 3.5.11-B: Welder Qualification Test No. Q3 – 6GR

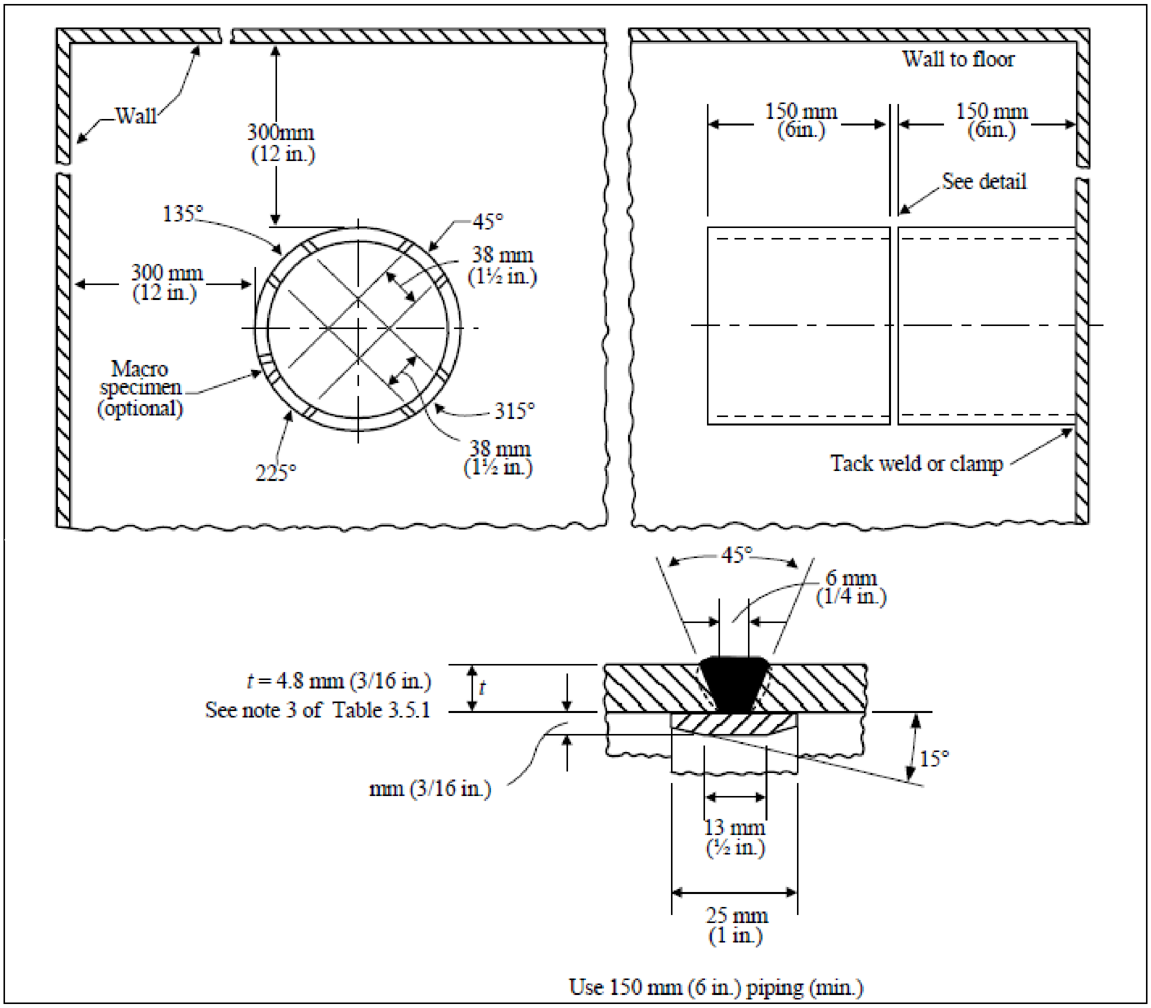


Figure 3.5.11-C: Welder Qualification Test No. Q3R (also Refer Table 3.5.1)

Notes:

1. Welds are to be made with electrode sizes representative of production.
2. Machine reinforcement and backing strap flush. Do not remove any undercutting.
3. All specimens are to be machined or sawed from piping.
4. Break edges of bend specimens to a radius of *t*/6 maximum.
5. Mark top and front of piping to insure proper location of specimens.
6. Remove face-bend specimens from 45 and 225 degree points, and root-bend specimens from 135 and 315 degree points as indicated. If piping of greater wall thickness than 9.5 mm (3/8 in.) is used in this test four (4) side bend tests are to be conducted in lieu of root and face bends.
7. Welding is to be done from one side only.
8. Bend specimens in Guided Bend Test Jig (Figure 3.5.7).
9. Position designations.

Tack Welders for Hull Construction (Refer Sec-4, [4.3.6] of this chapter - applicable for pipe welding.)

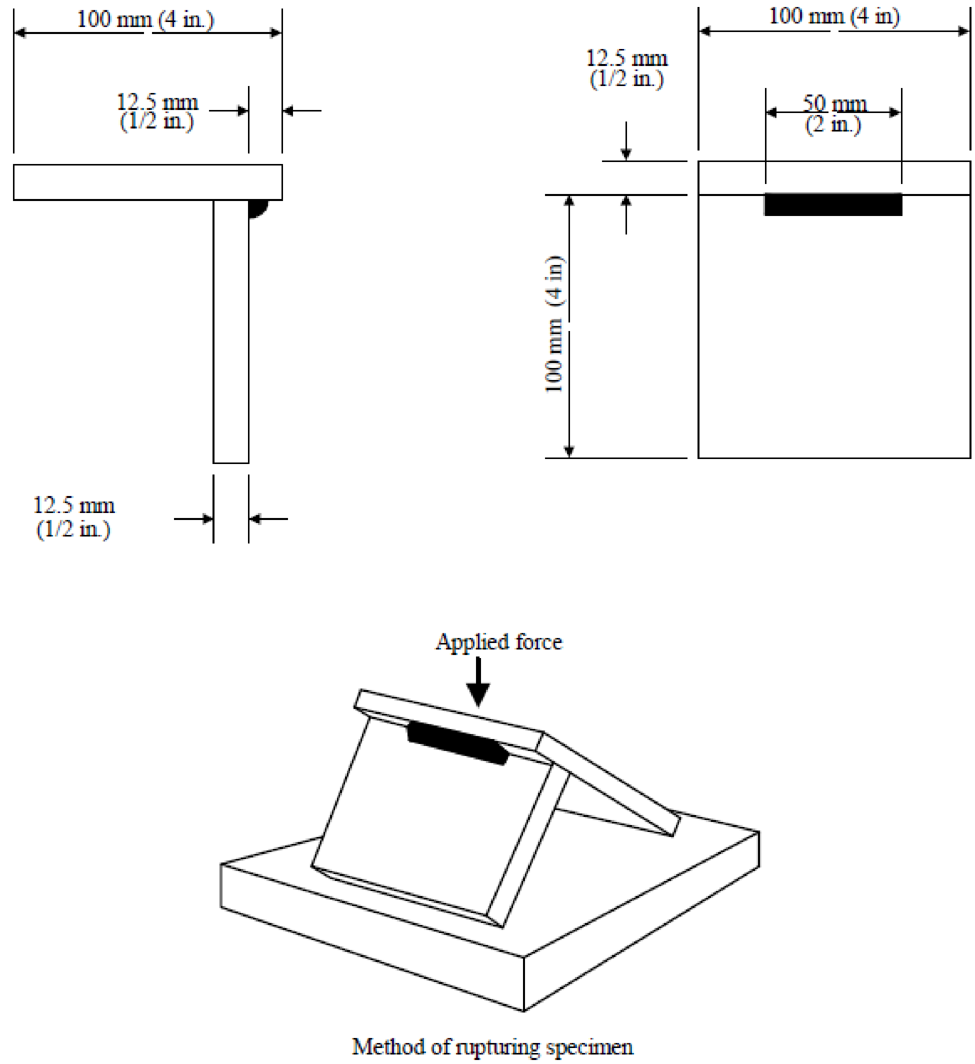


Figure 3.5.12 Welder Qualification Test No. Q4

Notes:

1. 3.2 mm ($^1/_8$ in.) diameter electrodes are to be used to make a 6.4 mm ($^1/_4$ in.) maximum size tack weld.

2. Welding in the vertical position is to be welded upwards.

3. The tack weld is to be free of overlap, cracks and excessive undercut and present a reasonably uniform appearance. There is to be no visible surface porosity.

4. The fractured surface of the tack weld is to be free of incomplete fusion or porosity larger than 2.4 mm ($^3/_{32}$ in.)

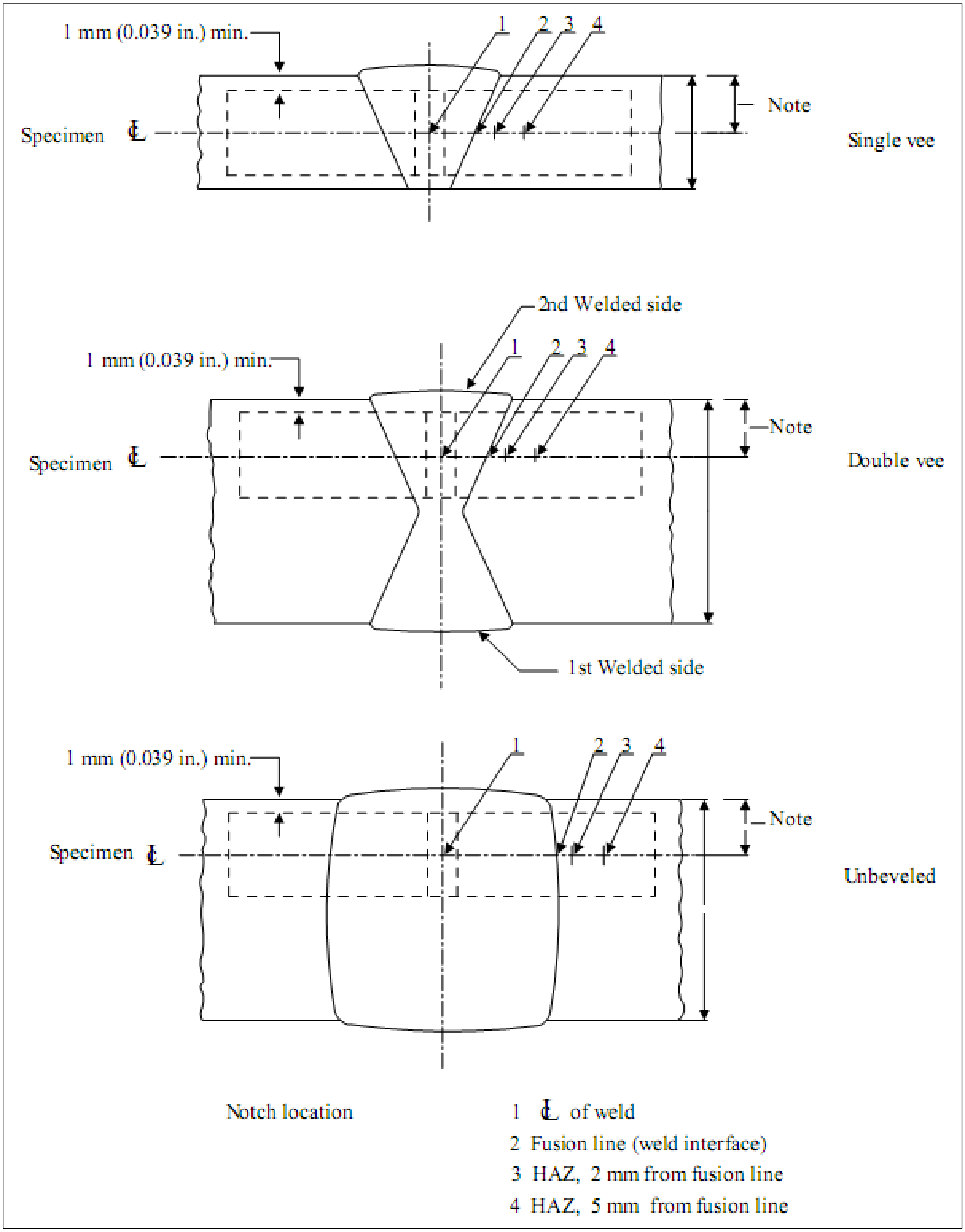


Figure 3.5.13: Orientation and Location of Charpy V-notch Specimens for Weld and Heat Affected Zone Properties

The largest size Charpy specimens possible for the material thickness are to be machined with the center of the specimen located as near as practicable to a point midway between the surface and the center of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen should be approximately 1 mm (0.039 in.) or greater. For double-vee butt welds, specimens are to be machined closer to the surface of the second welded side.

HAZ CVN [Heat Affected Zone -Charpy V-notch] and Weld metal testing of Non-INTLREG steels is to comply with weld metal limitations indicated in Sec 2, [2.1.4.3].

Table 3.5.2 Minimum Average Weld Metal and HAZ CVN Impact Values for INTLREG Grade Steels

Manual and Semi automatic Welding Processes, F, H, and OH Positions,Energy Absorbed J (ft-lb)	Automatic Welding Processes in all Positions and Manual and Semiautomatic Welding Processes in Vertical Position, Energy Absorbed J (ft-lb)	CVN Test Temperature °C (°F)	Hull Steel Grade
34 (25)	27 (20)	20 (68)	A > 50 mm
34 (25)	27 (20)	20 (68)	B > 25 mm
34 (25)	34 (25)	20 (68)	AH32/36 ≤ 12.5 mm (1/2 in.)
34 (25)	34 (25)	0 (32)	AH32/36 > 12.5 mm (1/2 in.)
47(35)	34 (25)	0 (32)	D, DH32/36
47(35)	34 (25)	-20 (-4)	E, EH32/36
47(35)	34 (25)	-40 (-40)	FH32/36
47(35)	41 (30)	20 (68)	AH40
47(35)	41 (30)	0 (32)	DH40
47(35)	41 (30)	-20 (-4)	EH40
47(35)	41 (30)	-40 (-40)	FH40
64 (48)	64 (48)	20 (68)	AH47
64 (48)	64 (48)	0 (32)	DH47
64 (48)	64 (48)	-20 (-4)	EH47
64 (48)	64 (48)	-40 (-40)	FH47
27 (20)	27 (20)	0 (32)	AQ43
27 (20)	27 (20)	-20 (-4)	DQ43
27 (20)	27 (20)	-40 (-40)	EQ43
27 (20)	27 (20)	-60 (-76)	FQ43
31 (23)	31 (23)	0 (32)	AQ47
31 (23)	31 (23)	-20 (-4)	DQ47
31 (23)	31 (23)	-40 (-40)	EQ47
31 (23)	31 (23)	-60 (-76)	FQ47
33 (24)	33 (24)	0 (32)	AQ51
33 (24)	33 (24)	-20 (-4)	DQ51
33 (24)	33 (24)	-40 (-40)	EQ51
33 (24)	33 (24)	-60 (-76)	FQ51
37 (27)	37 (27)	0 (32)	AQ56
37 (27)	37 (27)	-20 (-4)	DQ56
37 (27)	37 (27)	-40 (-40)	EQ56
37 (27)	37 (27)	-60 (-76)	FQ56
41 (30)	41 (30)	0 (32)	AQ63
41 (30)	41 (30)	-20 (-4)	DQ63
41 (30)	41 (30)	-40 (-40)	EQ63
41 (30)	41 (30)	-60 (-76)	FQ63
46 (34)	46 (34)	0 (32)	AQ70
46 (34)	46 (34)	-20 (-4)	DQ70
46 (34)	46 (34)	-40 (-40)	EQ70
46 (34)	46 (34)	-60 (-76)	FQ70
ABBREVIATIONS:	F: Flat; V: Vertical; H: Horizontal; OH: Overhead		

SECTION 5 FILLER METALS

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5.1. General

5.1.1 Scope

5.1.1.1 Condition of Approval

The approval of welding filler metals shall be in accordance with the scope and conditions of classification contained in Part 1 of the INTLREG Rules, to the extent that they are appropriate. Approval will be for each plant of each manufacturer carrying out its own quality control inspection and certification.

5.1.1.2 Approval procedure

INTLREG will approve welding filler metals which are intended for hull construction subject to compliance with the requirements and test schedules as outlined herein. The requirements are based on the following:

a. Guarantee by the manufacturer of the minimum properties;
b. Inspection of the manufacturing facility by an INTLREG Surveyor;
c. Testing of selected samples.

In the presence of an INTLREG Surveyor, the test assemblies are to be prepared and tested. The manufacturer's plant and method of filler metal production are to be capable of ensuring reasonable uniformity in production to the satisfaction of the Surveyor. INTLREG is to be notified regarding any alterations proposed in the production of filler metals.

5.1.1.3 Aluminum Filler Metals

Approval of aluminum filler metals is subject to special consideration by INTLREG.

5.1.2 Grading

5.1.2.1. INTLREG Grades

Based on the steel for which they are intended, filler metals are divided into three groups.

a) Ordinary-Strength Steel — No suffix.
(Ch 1, Sec 2, Table 1.2.2 through Table 1.2.5)

b) Higher-Strength Steel — Suffix Y and Y400
(Ch 1, Sec 3, Table 1.3.1 through Table 1.3.4)

c) Quenched and Tempered Steel — Suffix YQ420 through YQ690
(Ch 1, Sec 4, Tables 1.4.1 and 1.4.2)

On the basis of strength and/or toughness, each group is further divided into multiple levels, the latter being represented by the toughness digit 1 through 5. Exact combination of digit/suffix and corresponding tensile and impact requirements are indicated in Table 3.6.3 and Table 3.6.4.

5.1.2.2. Other standards

At the discretion of the manufacturer, filler metals may be approved to a recognized standard. However, the tests and procedures required for such approval are to be in compliance with the standard specifications. Additionally, for the purpose of continued approval, inspection and testing are to be carried out annually.

5.1.2.3. Special properties

Approval of welding filler metals may be issued to the manufacturer's guaranteed minimum properties over and above or in addition to the requirements for the applicable standard. Notations indicating guaranteed minimum properties will be added, as appropriate, upon verification by test.

5.1.3 Manufacturer's guarantee

For each filler metal, each plant of the manufacturer is to file an application indicating the following:

a) Specification and Grade/Classification;
b) Electrode (wire) size and welding position;
c) Flux or shielding gas;
d) Current/Polarity;
e) Recommended volts and amperage;
f) Guaranteed all-weld-metal chemical and mechanical properties;
g) Guaranteed hydrogen content (for H15, H10, H5, Y or Y400 designation).

5.1.4 Plant Inspection

5.1.4.1. Initial inspection

An INTLREG Surveyor shall inspect each plant manufacturing welding filler metals which are submitted for INTLREG approval before marketing the product. The inspection is required in order to confirm that the production method, facilities, quality assurance procedures, etc., in that plant are adequate for maintaining uniform and acceptable quality in production.

Moreover, the Surveyor is to be satisfied with the condition of the testing machines and that a record of periodical calibration is to be maintained up to date.

Plant inspection may be carried out for the facilities, production methods, and quality control procedures for the new product, where a plant approved by INTLREG proposes to start production of a new product.

5.1.4.2. Annual Inspection

Inspection of each plant manufacturing INTLREG-approved welding filler metals is to be carried out by an INTLREG Surveyor annually. The extent of the inspection is as indicated in [5.1.4.1] Special consideration for equivalent arrangements may be accepted subject to special agreement with INTLREG.

5.1.5 Test requirements

5.1.5.1. General

After completion of the plant inspection as required in [5.1.4] representative filler metal samples will be selected by the Surveyor for welding and testing in his presence. The preparation of the test assemblies and test samples are to be in accordance with the following:

5.1.5.2. Test plate material

a. Deposited metal test and diffusible hydrogen test

Except as indicated below, all test assemblies can be prepared using any grade of ordinary-strength or higher-strength hull structural steel.

Fine grain structural steel well matched with the properties of the weld metal is to be used for the deposited metal test assemblies of YQ Grades. Alternatively, other steel may be used, provided the groove is buttered with the filler metal. In case, deposited metal testing is carried out with a process not suitable for buttering, another process and a filler metal of equivalent chemical composition may be used for buttering.

b. Butt weld test and fillet weld test

As applicable, one of the grades of steel as listed below, or equivalent IACS grade or other classification society grade, for the individual grade of filler metals is to be used for butt weld test assembly and fillet weld test assembly, .

Table 3.6.1: Material Grade

Grade 1	A
Grade 2	A, B, D
Grade 3	A, B, D, E
Grade 1Y	AH32, AH36
Grade 2Y	AH32, AH36, DH32, DH36
Grade 3Y	AH32, AH36, DH32, DH36, EH32, EH36
Grade 4Y	AH32, AH36, DH32, DH36, EH32, EH36, FH32, FH36
Grade 2Y400	AH36, AH40, DH36, DH40
Grade 3Y400	AH36, AH40, DH36, DH40, EH36, EH40
Grades 4Y400, 5Y400	AH36, AH40, DH36, DH40, EH36, EH40, FH36, FH40
Grade 3 YQXXX	AQZZ, DQZZ
Grade 4 YQXXX	AQZZ, DQZZ, EQZZ
Grade 5 YQXXX	AQZZ, DQZZ, EQZZ, FQZZ

Note:

1. XXX/ZZ = 420/43, 460/47, 500/51, 550/56, 620/63 and 690/70
2. For Y grade filler metals, the tensile strength of the base metal is to be at least 490 N/mm^2 (50 kgf/mm^2, 71 ksi)

c. Ordinary and higher-strength filler metals (Dual approvals)

Using either ordinary or H32/36 higher- strength hull structural steel, required deposit metal test assemblies may be prepared. The required butt weld test assemblies are to be completed using steel with a tension strength of 490 N/mm^2 (50 Kgf/mm^2, 71 ksi) or greater. The test results are to conform to the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade.

A special consideration will be given to Dual approval of Y400 grade filler metals.

d. Electro slag or Electro gas welding for higher-strength steel

The test plate should contain niobium close to its maximum acceptable limit of 0.05% for unrestricted approval. Where such a plate is not used, the filler metal approval may be restricted to plates other than niobium treated.

5.1.6 Welding conditions

As recommended by the manufacturer, the welding conditions used, such as amperage, voltage, travel speed, etc., are to be held within the range for normal good welding practice. AC is to be used for the welding of the test assemblies, where a filler metal is specified to be suitable for both alternating current (AC) and direct current (DC), unless specified otherwise by the applicable standard of.[5.1.2.2.]

5.1.7 Chemical analysis

The manufacturer must supply the chemical analysis of the deposited weld metal and the content of all significant alloying elements (e.g., those identified in an AWS filler metal specification) is to be included. Results of the chemical analysis shall not exceed the limit values specified in the standard or by the manufacturer, the narrower tolerances being applicable in each case.

5.1.8 Deposited metal tension test

5.1.8.1. Specimen type and preparation

As indicated in Figure 3.6.13 the deposited metal tension test specimens are to be machined to the dimensions, care being taken that the longitudinal axis coincides with the center of the weld and the mid-thickness of the plate.

5.1.8.2. Hydrogen removal

Before testing, the tension test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for removal of hydrogen.

5.1.8.3. Test requirements

The values of tensile strength, yield stress and elongation are to be documented. The results are to be in accordance with the requirements of Table 3.6.3.

5.1.9 Butt weld tension test

5.1.9.1. Specimen type and preparation

The butt weld tension test specimens are to be machined to the dimensions indicated in Figure 3.6.2. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

5.1.9.2. Test requirements

The results are to conform to the tensile strength requirement of Table 3.6.3. The position of the fracture is to be reported.

5.1.10 Impact test

5.1.10.1 Specimen type and preparation

For the impact test, specimens are to be of the Charpy V-notch type and machined to dimensions indicated in Figure 3.6.3. The test specimens are to be cut with their longitudinal axis perpendicular to the weld and are to be taken from the middle of the plate thickness for multi-pass welds, from the middle of the second (2nd) run for two-run technique welds and from 2 mm (5/64 in.) maximum below one surface for electroslag or electro gas welds. Unless otherwise specified in [5.3.10] and [5.4.9] of this section, the notch is to be positioned in the center of the weld. The notch is to be cut perpendicular to the surface of the plate. Where the test temperature is other than the ambient, the test temperature of the test pieces at the moment of braking is to be controlled to within +/- 2°C (+/- 3.6°C) of the required temperature.

5.1.10.2 Test requirements

In accordance with the applicable grade and welding technique, average value of three specimens is to conform to the required average value indicated in tabulated in Table 3.6.4. Only one individual value may be below the required average value, provided it is not less than 70% of the required average.

5.1.10.3 Retest

Three additional specimens may be taken for retest from the same assembly and the results added to those previously obtained to form a new average when the results fail to meet the above requirements but conditions (b) and (c) below are complied with. The retest is satisfactory, if for the six specimens, all of the following conditions are met.

a) The new average is not less than the required average.
b) No more than two individual values are below the required average.
c) No more than one individual value is below 70% of the required average.

If the test is unsatisfactory, at the discretion of the Surveyor, further tests may be conducted on a new assembly. In such cases, all essential tests, including those previously found satisfactory, are to be carried out.

5.1.11 Butt weld bend test

5.1.11.1. Specimen type and preparation

The butt welds face and root bend test specimens are to be 30 mm (1.2 in.) in width. The upper and lower surfaces of the weld are to be filed, ground, or machined flush with the surface of the plate. The corners of the specimens may be rounded to a radius not greater than 2 mm (5/64 in.).

5.1.11.2. Test requirements

The test specimens are to be bent through an angle of 120 degrees around a pin or mandrel having the diameter detailed below:

Ordinary Strength	Three times the thickness of the specimen
Y and Y400	Three times the thickness of the specimen
YQ420, YQ460 & YQ500	Four times the thickness of the specimen
YQ550, YQ620 & YQ690	Five times the thickness of the specimen.

At the time of testing, for a face bend, the face of the weld is to be in tension and for a root bend, the root of the weld is to be in tension. The samples are to withstand bending without developing any crack or discontinuity greater than 3.2 mm (1/8 in.) in length on the tension surface of the specimen. For electro slag or electro gas welded test assemblies, side bend tests are to be used in lieu of root and face bend tests.

5.1.11.3. Alternative test for YQ-grades

In accordance with Figure 3.6.4 For YQ-Grade, a bending elongation test may be accepted. For this alternative, the bending elongation on gauge length $L_o = L_S + t$ (L_s = width of weld, t = specimen thickness) is to meet the minimum elongation requirements in Table 3.6.3.

5.1.12 Diffusible hydrogen test

5.1.12.1. Optional or required test

For any INTLREG grade welding consumables not required to go through diffusible hydrogen testing as specified below, at the discretion of the manufacturer, they may be submitted for testing. In order to indicate compliance with the hydrogen test requirements as specified in [5.1.12.4],a suffix indicating the hydrogen amount will be added to those welding consumables.

A hydrogen test is to be carried out for higher-strength, shielded metal arc welding electrodes and flux cored wires, and YQ grade shielded metal arc welding electrodes, submerged arc welding wire-flux combinations, and flux-cored wires. Test results are to meet the requirements for the following notations, except that Y-grade electrodes with diffusible hydrogen content greater than H10 and Y-grade flux-cored wires with diffusible hydrogen content greater than H15 will be specially identified, as indicated in [5.1.12.4], [5.2.6.2], and [5.4.7.1. (c)].

Y-Grade shielded metal arc electrodes	H10
Y-Grade flux-cored wires	H15
YQ 420/460/500 Grades	H10
YQ 550/620/690 Grades	H5

5.1.12.2. Test methods

Diffusible hydrogen content of the weld metal is to be ascertained in accordance with the test methods prescribed in ISO 3690 or AWS A4.3, or any other method such as the gas chromatographic method that correlates with ISO 3690 with respect to cooling rate and delay times during preparation of the weld samples and hydrogen volume determinations.

As described in BS-6693 Appendix C, the Thermal Conductivity Deduction (TCD) method, is also acceptable provided that the equipment is calibrated against another standard such as AWS A4.3 or ISO 3690.

5.1.12.3. Alternative test method

Instead of the test methods as indicated i [5.1.12.2], consideration may be given to a recognized alternate procedure for Grades other than YQ. The glycerin method as below will be acceptable.

Four test samples are to be prepared measuring approximately 12 × 25mm (1/2 × 1 in.) in cross section by 125 mm (5 in.) in length. The test specimens can be hull structural steel of any grade and are to be weighed to the nearest 0.1 gm prior to welding. On the wider surface of each test specimen, a single bead of welding is to be deposited about 100 mm (4 in.) in length with a 4 mm (5/32 in.) electrode, using about 150 mm (6 in.) of the electrode. The welding is to be carried out with as short an arc as possible and with a current of almost 150 amperes.

Before welding, the electrodes can go through the normal drying process recommended by the manufacturer. Once the welding of each specimen is completed, the slag is to be removed within thirty seconds and the specimen quenched in water having a temperature of approximately 20°C (68°F). After another 30 seconds, the specimens is to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerin. The glycerin used for this purpose is to be kept at a temperature of 45°C (113°F). All four test specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.

For a period of 48 hours, the specimens are to be kept submerged in the glycerin. After that, in order to determine the actual amount of weld deposited, the specimens is to be cleaned using water or any other suitable solvent, dried, and weighed to the nearest 0.1 gram. The amount of gas evolved is to be measured to the nearest 0.01 ml and corrected for temperature and pressure to 0°C (32°F) and 760 mm (30 in.) Hg.

5.1.12.4. Test requirements

The individual and average diffusible hydrogen content of the four specimens is to be reported and the average value in milliliters (ml) per 100 grams is not to go beyond the following Table 3.6.2:

Table 3.6.2

Suffix	AWS A4.3 or ISO 3690	Glycerin Method
H15	15	10
H10	10	5
H5	5	-

All higher-tensile strength steel grade shielded metal arc electrodes with an average value above the H10 requirement and flux cored wires with an average value above the H15 requirement are to be identified with “non-low hydrogen electrode, requires special approval for use with higher-strength steel”.

5.1.13 Special tests

5.1.13.1. Nondestructive testing

Prior to testing the welded assemblies may be subjected to radiographic or ultrasonic examination to ascertain any discontinuities in the weld.

5.1.13.2. Additional tests

INTLREG may specify any additional tests as may be necessary.

5.1.14 Licensee approvals

When a filler metal is manufactured in more than one plant of the same company or by a licensee company, a complete set of approval tests is to be performed on the samples selected from products of the main plant. In the other plants, a reduced test program equivalent to annual check tests plus diffusible hydrogen test may be permitted, provided the main plant and licensee can certify that the materials used, the fabrication process and final products by the licensee are identical to those in the main plant. Affidavits from both the main plant and licensee are to be submitted attesting this fact. However, if there is any doubt, a complete test series may be required.

Note: Wire-flux combinations for submerged arc welding. If a unique flux is combined with different wires coming from several factories belonging to the same firm, it is acceptable, after initial approval, to perform only one test series if the various wires conform to the same technical specification.

5.1.15 Annual Check Tests

5.2.15.1. An inspection shall be done annually to check the facilities and associated quality control systems, where approved filler metals are manufactured. Test data are to conform to the applicable requirements for the respective welding process. The annual check tests 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 and average of one annual test per year. Special consideration for equivalent arrangements may be accepted subject to special agreement with INTLREG.

5.2.15.2. Upgrading and Uprating

Upon the request of the manufacturer, upgrading and uprating of welding filler metals will be considered. Generally, in addition to the normal annual check tests, tests from butt weld assemblies and where applicable, a diffusible hydrogen test will be necessary. The data is to conform to the applicable requirements.

a) Upgrading

Upgrading refers to notch toughness and, accordingly, Charpy V-notch impact tests are required from butt weld and deposited metal test assemblies. The impact tests are to be conducted at the upgraded temperature.

b) Uprating

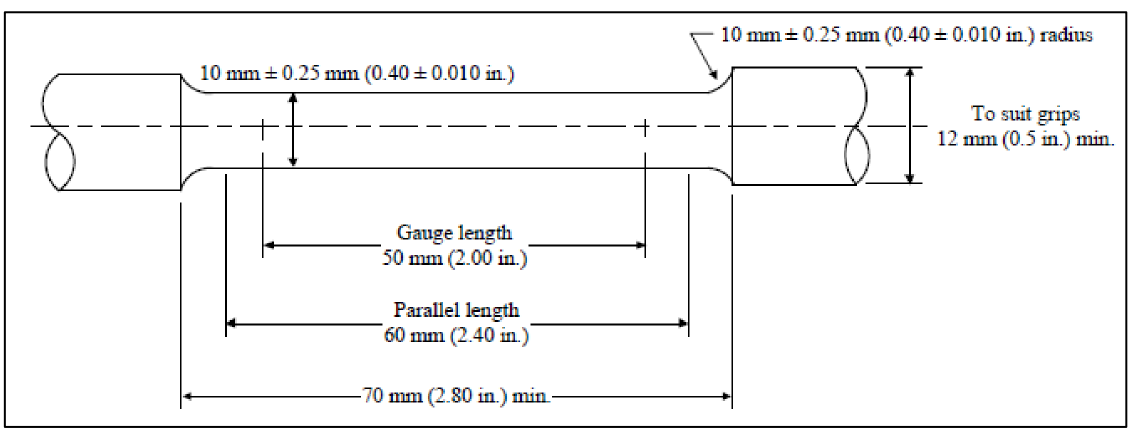
Uprating refers to the extension of approval to also cover the welding of higher-strength steels (dual approvals). For this purpose, butt-weld tests are to be carried out as required in [5.1.5.2. (c)]. Fillet testing is to be conducted as per [5.2.5] for uprating to YQ grades of SMAW electrodes.

5.1.16 Quality assurance program

Whenever a periodical audit is carried out satisfactorily and an INTLREG-approved Quality Assurance Program is maintained, the presence of the Surveyor at the annual check test may be waived, provided that the results of the annual check tests are examined by the surveyor and found to be in accordance with the applicable requirements.

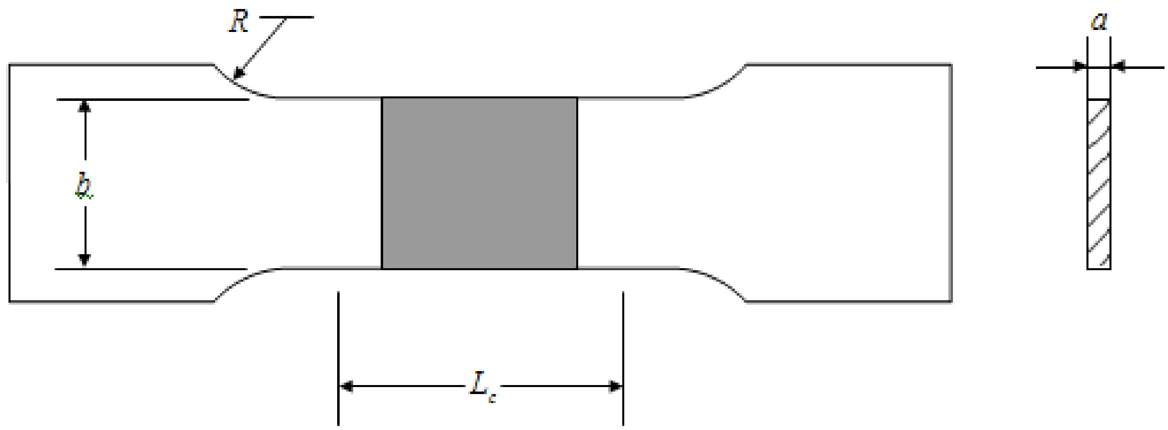
5.1.17 Retests

If the result of a tension or bend test does not comply with the requirements, two test samples of the same type are to be prepared and tested from the original test assembly, if possible. From the same batch, a new assembly may be prepared using welding consumables. Same procedure (particularly number of runs) shall be used in order to make the new assembly as the original assembly. Testing of the new assembly is to include CVN [Charpy V-notch] testing. Refer [5.1.10.3] for impact retests.



Note: The reduced section may have a gradual taper from the ends toward the center, with the ends nor more than 1% larger in diameter than the center (controlling dimension)

Figure 3.6.1: Deposited Metal Tension Test Specimen



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 mm for t ≤ 2 mm
b	=	25 mm for t > 2 mm
L_c	=	width of weld + 60 mm
R	>	25 mm

Figure 3.6.2: Butt Weld Tension Test Specimen

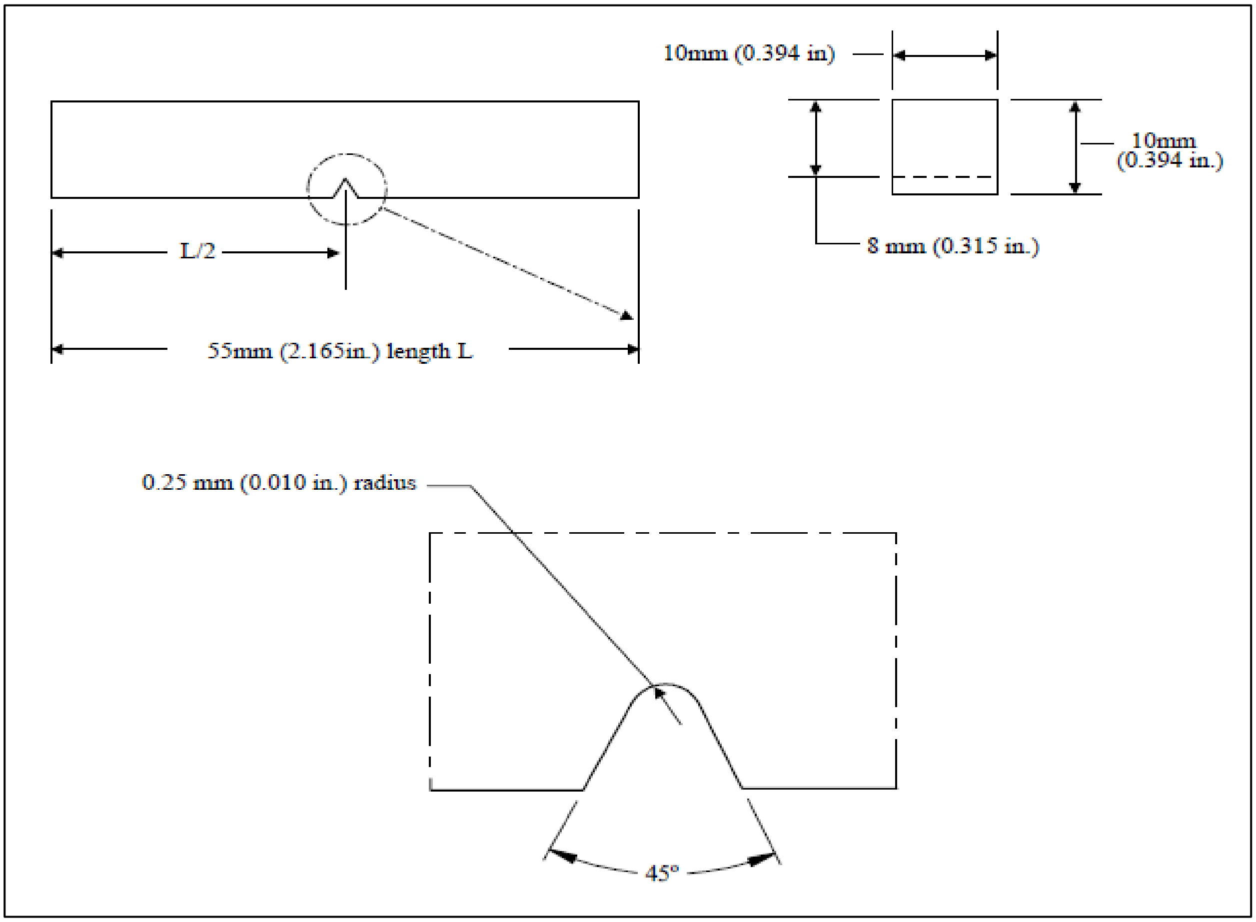


Figure 3.6.3: Charpy V-Notch Impact Test Specimen

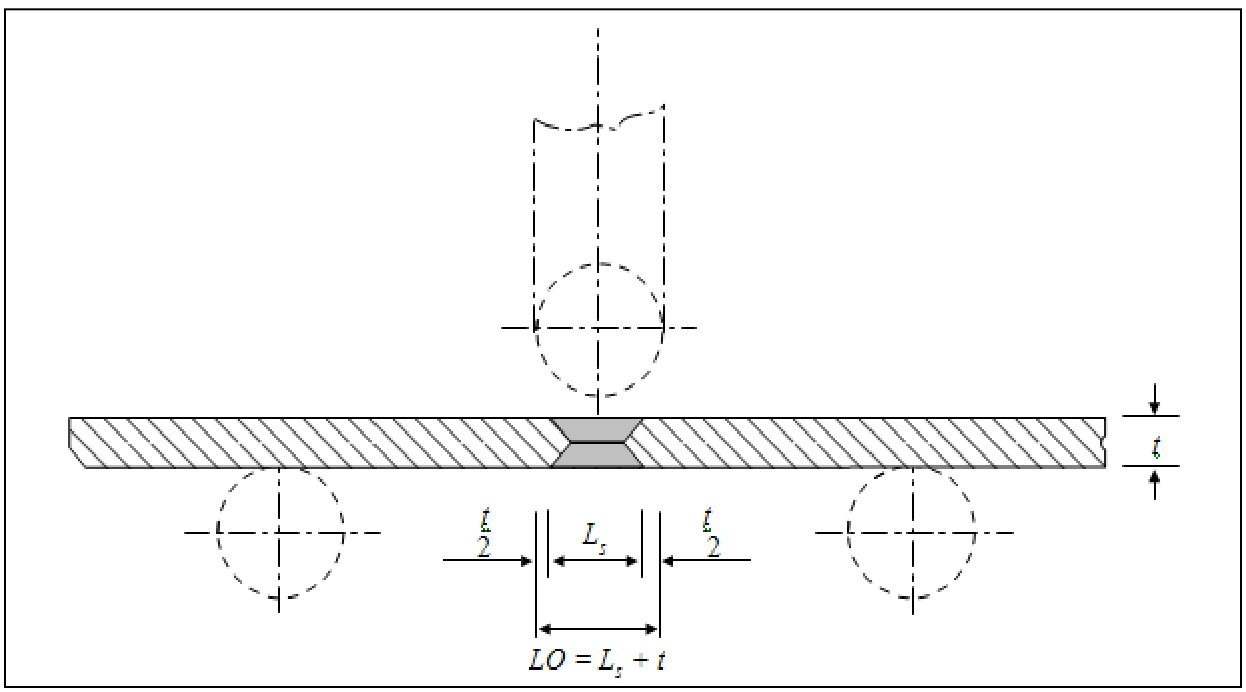


Figure 3.6.4: Bending Elongation Test

Table 3.6.3: Tension test requirements

The tensile requirements are based on the type of test specimen (longitudinal or transverse) specified elsewhere in these Requirements for the particular combination of weld process and the type of required test.

To find the required tension test properties, first locate in the "process" column the welding process for which the filler metal is intended (e.g., wire-flux). Then locate in that line under "applicable test" column the test in question (e.g., DM/M). The required properties are found below the box in which the particular test is located (longitudinal specimen for the example chosen).

Process	Applicable Tests	
MW	DM	BW
WF	DM/M, DM/TM, BW/T, BW/TM	BW/M, BW/T, BW/TM
WG/SA	DM	BW
WG/A	DM/M, DM/TM, BW/T, BW/TM	BW/M, BW/T, BW/TM
ESEG	BW	BW

Required Properties

Grade [3]	Longitudinal specimen			Transv. specimen
	Tensile Strength N/mm^2(kgf/mm^2, ksi)	**Yield Point**, min. N/mm^2 (kgf/mm^2, ksi)	**Elongation** min. %	**Tensile Strength**, min. N/mm^2 (kgf/mm^2, ksi)
1, 2 & 3	400/560 (41/57, 58/82)	305 (31, 44)	22	400 (41, 58)
1Y[1], 2Y, 3Y & 4Y	490/660 (50/67, 71/95)	375 (38, 54)	22	490 (50, 71)
2Y400, 3Y400, 4Y400 & 5Y400	510/690 (52/70, 74/100)	400 (41, 58)	22	510 (52, 74)
XYQ420 [4]	530/680 (54/69, 77/98)	420 (43,61)	20	530 (54, 77)
XYQ460 [4]	570/720 (58/73, 83/104)	460 (47, 67)	20	570 (58, 83)
XYQ500 [4]	610/770 (62/78, 88/112)	500 (51, 73)	18	610 (62, 88)
XYQ550 [4]	670/830 (68/85, 97/120)	550 (56, 80)	18	670 (68, 97)
XYQ620 [4]	720/890 (73/91, 104/129)	620 (63, 90)	18	720 (73, 104)
XYQ690 [4]	770/940 (78/96, 112/136)	690 (70, 100)	17	770 (78, 112)

Abbreviations:

WF: Wire-flux combination
WG: Wire-gas combination
ESEG: Electro-slag or electro-gas
MW: Covered electrode for manual welding
M: Multi-run
SA: Semi-automatic
DM: Deposited metal test
TM: Two run & Multi-run[2]
T: Two run[2]
A: Automatic
BW: Butt weld

Notes:

1 Grade 1Y not applicable to MW and WG/SA.

2 Two run not applicable to YQ Grades.

3 X = 3, 4 or 5. Refer Table 3.6.4.

4 Specifications for high strength quenched and tempered steels, for which these XYQ grades of welding consumables are intended, may be found in Ch 1, Sec 4.

Table 3.6.4: Impact test requirements

There are two levels of energy requirements depending upon the particular combination of weld process, types of required test and, where applicable, welding position.

To find the required energy, first locate under “process” column the welding process for which the filler metal is intended (e.g., wire- gas, semi-automatic). Then locate in that line under “applicable test” column the test/position in question (e.g., BW/F). The required energy is found in the box under the particular test/position combination for respective grade (47J for the example chosen if it is Grade 2Y or 3Y).

Process	Applicable tests	
MW	DM, BW/F/H/OH	BW/V
WF	—	DM, BW
WG/SA	DM, BW/F/H/OH	BW/V
WG/A	—	DM, BW

Required Temperature / Energy

Temp °C (°F)	**Grade**	**Av. absorbed energy** J (kgf-m, ft-lbf)	**Av. absorbed energy** J (kgf-m, ft-lbf)
20 (68)	1	47 (4.8, 35)	34 (3.5, 25)
0 (32)	2	47 (4.8, 35)	34 (3.5, 25)
-20 (-4)	3	47 (4.8, 35)	34 (3.5, 25)
20 (68)	1Y[1]	Refer Note 1	34 (3.5, 25)
0 (32)	2Y	47 (4.8, 35)	34 (3.5, 25)
-20 (-4)	3Y	47 (4.8, 35)	34 (3.5, 25)
-40 (-40)	4Y	47 (4.8, 35)	34 (3.5, 25)
0 (32)	2Y400	47 (4.8, 35)	41 (4.2, 30)
-20 (-4)	3Y400	47 (4.8, 35)	41 (4.2, 30)
-40 (-40)	4Y400	47 (4.8, 35)	41 (4.2, 30)
-60 (-76)	5Y400	47 (4.8, 35)	41 (4.2, 30)
-20 (-4) X=3 -40 (-40) X=4 -60 (-76) X=5	XYQ420[2]	47 (4.8, 35)	47 (4.8, 35)
	XYQ460[2]	47 (4.8, 35)	47 4.8, 35)
	XYQ500[2]	50 (5.1, 37)	50 (5.1, 37)
	XYQ550[2]	55 (5.6, 41)	55 (5.6, 41)
	XYQ620[2]	62 (6.3, 46)	62 (6.3, 46)
	XYQ690[2]	69 (7.0, 51)	69 (7.0, 51)

Alternate Temperature and Energy

-10 (14)	3	61 (6.2, 45)	44 (4.5, 33)
10 (50)	1Y	—	40 (4.1, 30)
0 (32)	1Y	27 (2.8, 20)	—
-10 (14)	2Y	—	27 (2.8, 20)
-20 (-4)	2Y	27 (2.8, 20)	—
-10 (14)	3Y	68 (6.9, 50)	52 (5.3, 38)
-30 (-22)	3Y	—	27 (2.8, 20)
-40 (-40)	3Y	27 (2.8, 20)	—

Abbreviations:
F: Flat; V: Vertical; H:Horizontal; OH: Overhead (Refer also Table 3.6.3

Notes:

1. Grade 1Y not applicable to MW and WG/SA.
2. Specifications for high strength quenched and tempered steels, for which these XYQ grades of welding consumables are intended,

5.2. Electrodes for shielded metal arc welding

5.2.1. General

In accordance with [5.2.3] the annual check test shall consist of two deposited metal test assemblies welded and tested.

5.2.2. Chemical analysis

The manufacturer must supply the chemical analysis of the deposited weld metal.

5.2.3. Deposited metal test assemblies

5.2.3.1. Test assembly

As illustrated in Figure 3.6.5, welding of the two deposited metal test assemblies are to be carried out in the flat position, one using 4 mm (5/32 in.) electrodes or the smallest size manufactured, whichever is greater, and the other using the largest size manufactured. One test assembly is sufficient, if an electrode is produced in one size only or if the largest size produced is 4 mm (5/32 in.) or less. According to normal practice, the weld metal is to be deposited in single or multiple layers, and the direction of deposition of each layer is to different from each end of the plate, each run of weld metal being not less than 2 mm (5/64 in.) and not more than 4 mm (5/32 in.) thick. In the middle of each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. As permitted in [5.1.8.2]of this section, after welding, the test assemblies are to be subject to hydrogen removal and not to be subject to any heat treatment.

5.2.3.2. Test specimens

As indicated in Figure 3.6.5, one tension and one set of three impact specimens are to be arranged from each deposited metal test assembly, and the results are to be in compliance with the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade and welding technique.

5.2.4. Butt Weld Test Assemblies

5.2.4.1. Test Assemblies

As indicated in Figure 3.6.6, welding of one butt weld test assembly is to be done in each position (flat, vertical-up, vertical-down, overhead and horizontal) for which the electrode is recommended by the manufacturer except that those electrodes which meet the requirements for flat and vertical positions. It will be considered as it complies with the requirements for the horizontal position. Where the approval of the electrode is only in the flat position, one additional test assembly is to be welded in that position.

5.2.4.2. Welding Procedure

Generally, the following welding procedure is to be adopted in making the test assemblies:

a) **Flat:** First run using 4 mm (5/32 in.) electrodes; according to the normal welding practice with the electrodes, remaining runs excluding last two layers with 5 mm (3/16 in.) or above; the runs of the last two layers with the largest size electrodes manufactured. When a second flat assembly is required, the runs of the last three layers are to be welded with the largest size electrode manufactured.

b) **Horizontal:** First pass with 4 mm (5/32 in.) or 5 mm (3/16 in.) diameter electrode. Subsequent passes with 5 mm (3/16 in.) diameter electrode.

c) **Vertical-up and overhead:** The first run with 3.25 mm (1/8 in.) electrodes; remaining runs with the largest diameter recommended by the manufacturer for the position concerned.

d) **Vertical down:** The electrode diameter used is to be as recommended by the manufacturer.

For all assemblies, after removing the root run to clean metal, the back weld is to be made with 4 mm (5/32 in.) electrodes in the welding position suitable to each test sample. The test assemblies may be turned over to carry out the back weld for electrodes suitable only for flat position welding.

Normal welding practice is to be followed, and of between each run, the assembly is to be left in still air until it has cooled down to less than 250°C (482°F) but not below 100°C (212°F). It is to be ensured that the temperature is taken in the center of the weld, on the surface of the seam. After welding, the test assemblies are not to be subjected to any heat treatment.

5.2.4.3. Test Specimens

As indicated in Figure 3.6.6 from each butt weld test assembly, one tension, one face bend, one root bend is to be prepared together with one set of three impact specimens from the flat and vertical test assemblies. For the applicable grade, position and welding technique, the results of tension and impact tests are to comply with the requirements of Table 3.6.3 and Table 3.6.4. The results of bend tests are to meet the requirements of [5.1.11.2] of this section.

5.2.5. Fillet weld test assemblies

5.2.5.1. General

In addition to deposited metal testing, fillet weld testing is required for gravity fillet welding electrodes (including combination gravity/manual electrodes). Butt weld testing is not required. Fillet weld testing is required in addition to deposited metal and butt weld testing for gravity welding electrodes (including combination gravity/manual electrodes) which are intended for both fillet and butt welding. In welding fillet weld test assemblies, gravity welding equipment is to be used. In accordance with [5.2.5.2] through , [5.2.5.4] such fillet weld tests are to be carried out and tested using gravity welding equipment and the longest size electrode manufactured.

Other than gravity electrodes, the following applies to SMAW electrodes:

An electrode other than YQ Grades is considered approved for fillet welding in position for which the butt weld test of 6.2.4 was satisfactory. The electrodes meeting the flat butt weld requirements will be considered as complying with the requirements for horizontal fillet (HF) welds. Where an electrode is already submitted for approval for fillet welds only, the butt weld tests specified in 6.2.4 may be omitted and fillet weld tests are to be carried out and tested in accordance with .. [5.2.5.2] through [5.2.5.4]

5.2.5.2. Test Assemblies

As illustrated in Figure 3.6.7, one fillet weld test assembly is to be welded in each position for which the electrode is suggested by the manufacturer.

5.2.5.3. Welding procedure

In order to allow for the tests required in, [5.2.5.4] the length L of the fillet test assemblies is to be sufficient to allow for at least the deposition of the entire length of the electrode being tested. One side is to be welded by using the maximum size electrode manufactured and the second side using the minimum size of electrode manufactured which is recommended for fillet welds. In general, the electrode size and the welding current employed at the time of the testing will determine the fillet size. By using the welding equipment and technique as recommended by the manufacturer, the fillet weld is to be done with the longest size electrode. For each electrode size and welding position, the current used while conducting the test, and the manufacturer's recommended current range are to be reported.

5.2.5.4. Test specimens

a. Macrographs and hardness tests

As detailed in Figure 3.6.7, each fillet weld test assembly is to be sectioned in order to form three macro-sections. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity, undercut and slag inclusions. On each section hardness readings are to be made. The number and location of hardness readings are to approximate those indicated in Figure 3.6.8. The hardness of the weld is to be determined and is to comply with the following listed equivalent values.

Load	**Grade 1, 2, 3**	**Grades Y, Y400 and YQ**
Diamond Pyramid (Vickers) Hardness- 10 kg (98 N)	To be reported for information	150 min.
Rockwell B-100 kg (980 N)		80 min.

b. The hardness of the heat affected zone (HAZ) and base metal are to be determined and reported for information only.

c. Breaking test

One of the remaining sections of the fillet weld is to have the weld, on the side welded first, gouged or machined. This is to facilitate breaking the fillet weld on the other side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the side welded second is to be gouged or machined and the section fractured using the above procedure. The fractured surfaces are to be verified and there shall not be any evidence of incomplete penetration or internal cracking and they are to be reasonably free from porosity.

5.2.6. Low hydrogen approval

5.2.6.1. Ordinary-Strength Filler Metals

At the discretion of the manufacturer, electrodes which have satisfied the requirements of Grades 2 and 3 are subjected to a hydrogen test, as mentioned in [5.1.12.2] of this section. A Suffix indicating the hydrogen amount will be added to the grade number of those electrodes which indicates compliance with the hydrogen test requirements as specified in [5.1.12.4] of this section.

5.2.6.2. Higher-Strength Filler Metals

According to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400, 4Y400, or 5Y400 electrodes which are submitted for approval are to be subjected to a hydrogen test and are to meet the requirement as per specifications made in 6.1.12.4 of this section for the H10 suffix. Such suffix however, will not be added to the grade. Electrodes meeting H5 requirements will be so identified. Electrodes meeting the higher-strength requirements, except for hydrogen test, will require special approval for use on higher strength steel for each user and will be so identified in the list of approved electrodes.

5.2.6.3. YQ grade filler metals

According to YQ Grades, electrodes which are submitted for approval are to be subjected to a hydrogen test, as mentioned in [5.1.12.1] of this section. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

5.2.7. Annual check tests

5.2.7.1. General

In accordance with [5.2.3] of this section, the annual check test shall consist of two deposited metal test assemblies welded and tested.

5.2.7.2. Upgrading and uprating

At the request of the manufacturer's, upgrading of electrodes will be taken into consideration. In addition to the two deposited metal tests as indicated in [5.2.7.1] a butt weld test assembly is to be welded as specified in [5.2.4] of this section. For each position initially tested, and sets of three impact specimens from each test assembly are to be tested at the upgraded temperature.

Uprating refers to the extension of approval in order to cover the welding of higher-strength steels (dual approvals) as well. As mentioned in [5.1.5.2 (c)]and [5.2.4] of this section, butt weld tests are to be carried out for this purpose. Additionally, the diffusible hydrogen test required by the grade or suffix referred to in [5.2.6.1] and [5.2.6.2] above is to be carried out.

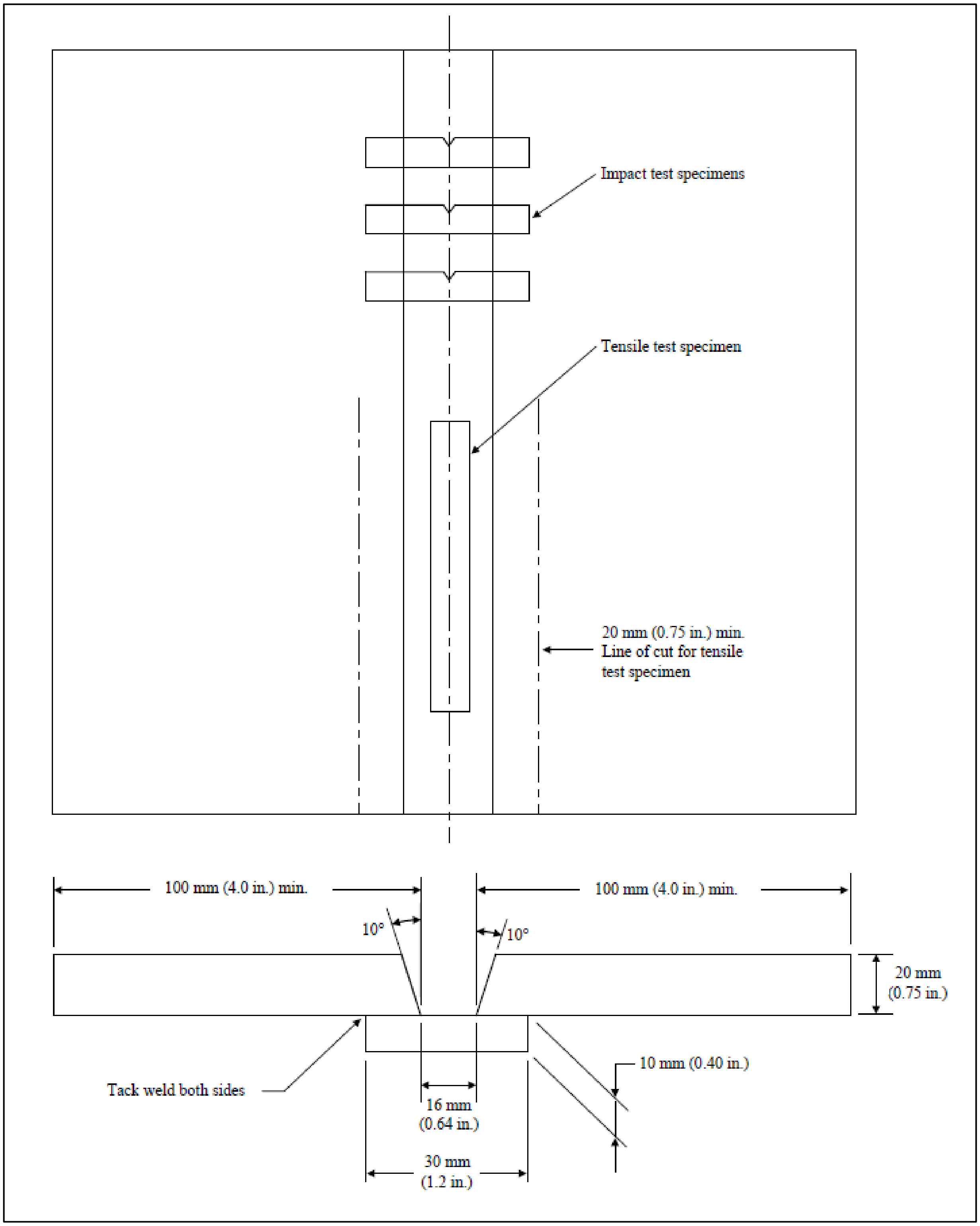


Figure 3.6.5: Deposited-Metal Test Assembly for Manual and Gas-Metal Arc Welding

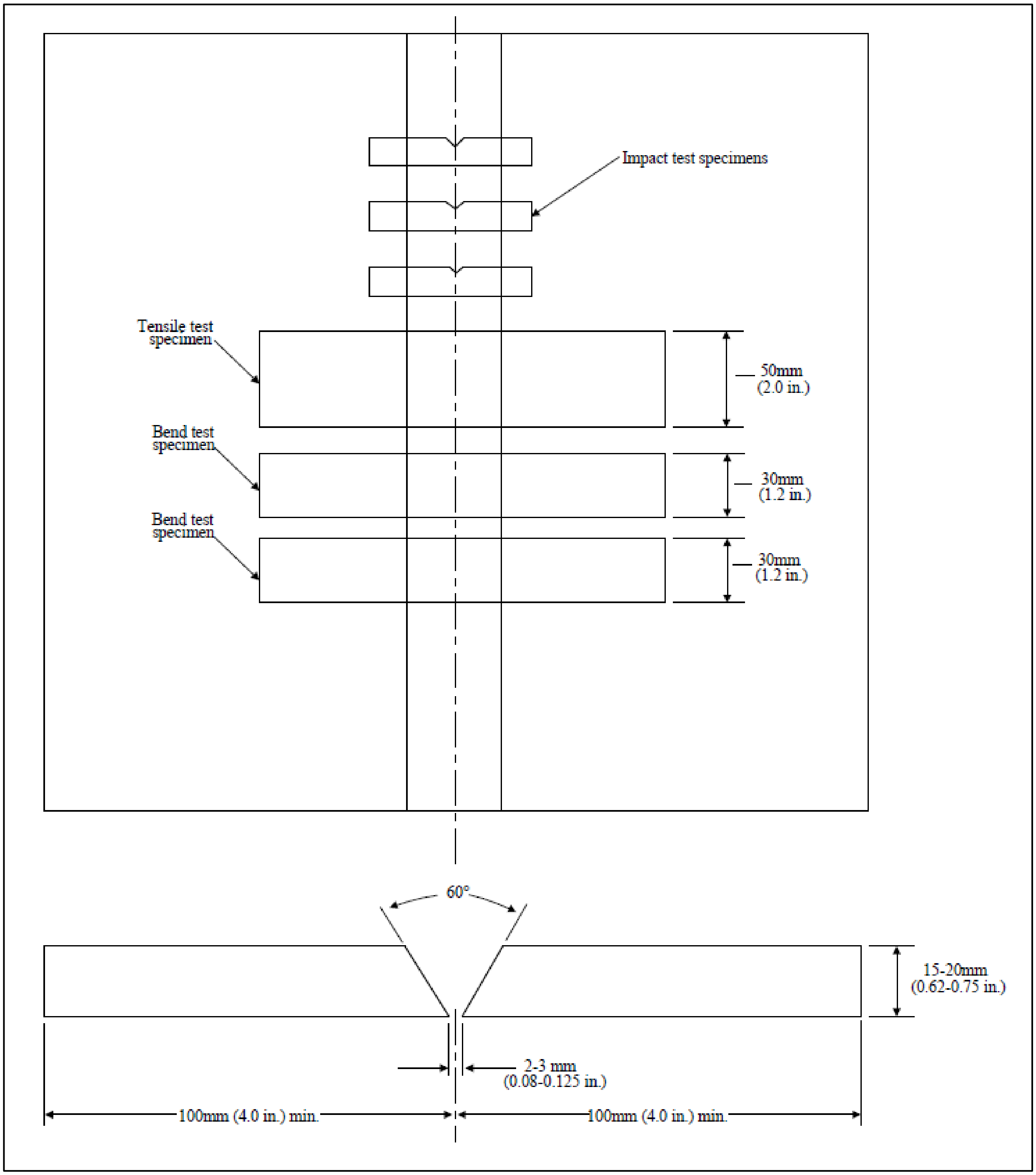


Figure 3.6.6: Butt-Weld Test Assembly for Manual and Gas-Metal Arc Welding

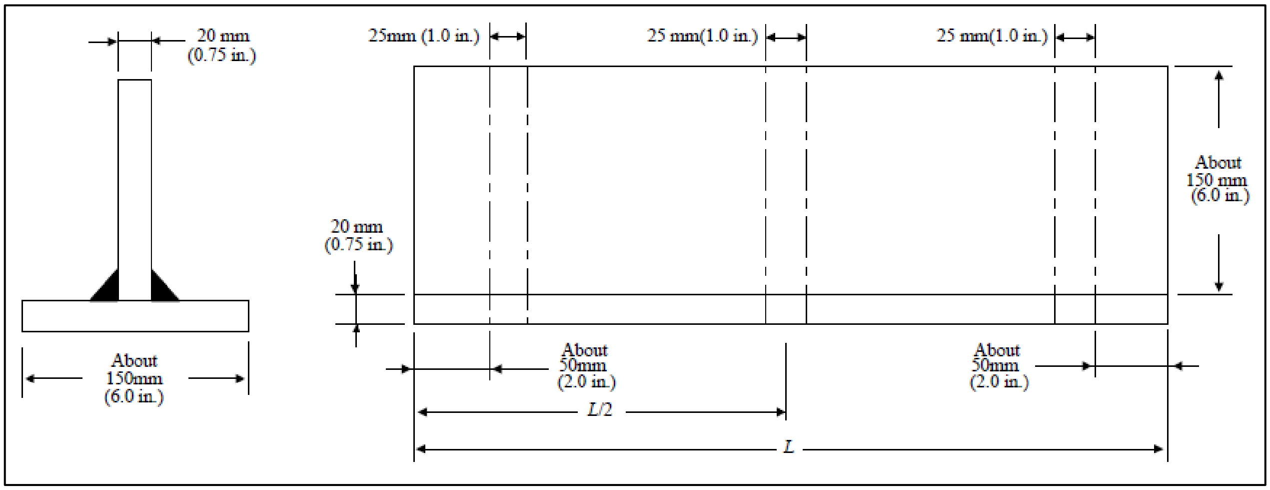


Figure 3.6.7: Fillet-Weld Test Assembly

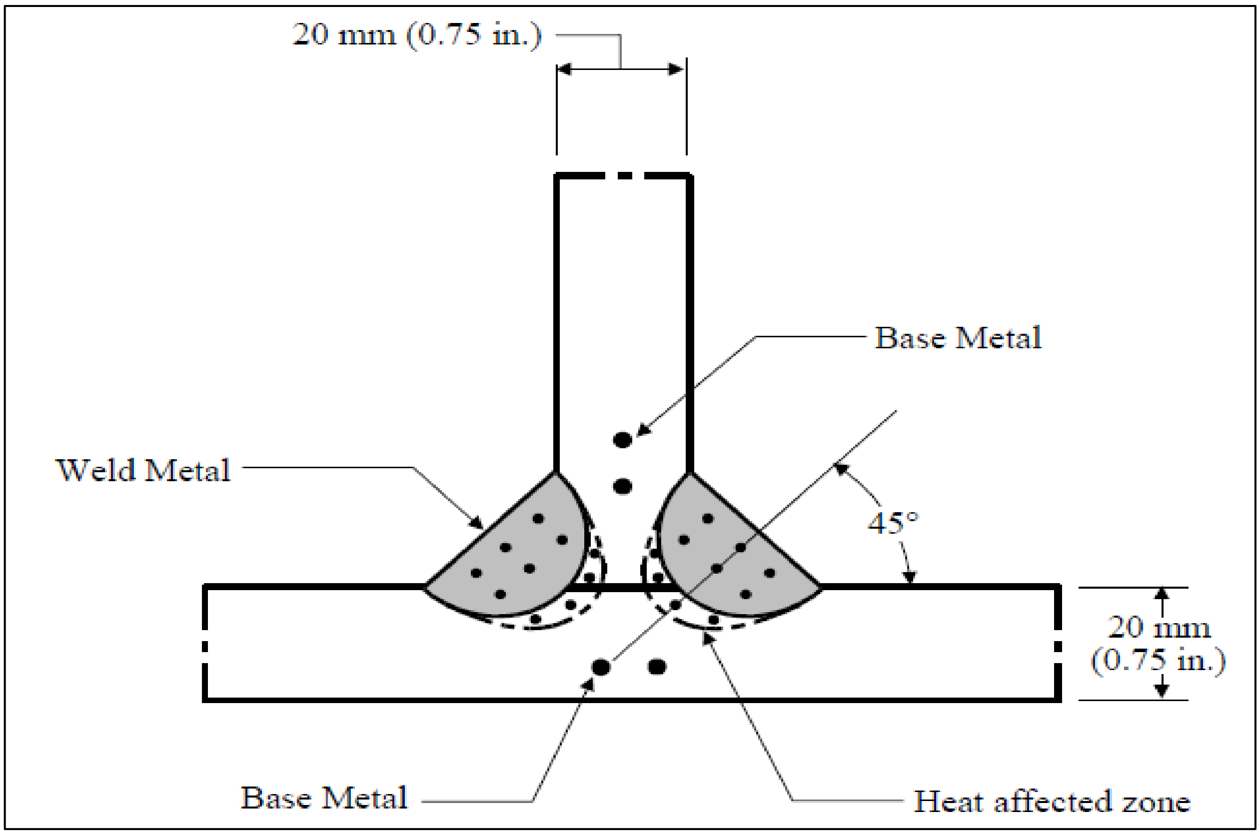


Figure 3.6.8: Fillet Weld Hardness Test Locations

5.3. Wire-flux combinations for submerged arc welding

5.3.1. General

This test program is intended for the approval of automatic or semi-automatic, single-electrode submerged arc welding. Provisions are made for the testing of weld metal deposited by multi-run and two-run (one pass each side) techniques. A multi-run technique is considered for YQ Grades automatic welding. Application for high heat input process, such as automatic welding two-run technique, may be considered under [5.1.2.3] and approval by a technical office. Both series of tests are to be done where a manufacturer states that a particular wire- flux combination is appropriate for welding with both techniques. In order to indicate two-run technique, multi-run technique, or both techniques, respectively, the suffix T, M, or TM will be added to the grade.

5.3.2. Chemical analysis

The manufacturer to provide the chemical analysis of the deposited weld metal.

5.3.3. Deposited Metal Test Assemblies for Multi-run Technique

5.3.3.1. Test assembly

One deposited metal test assembly, as illustrated in Figure 3.6.9, is to be welded in the flat position using the wire size recommended by the manufacturer. The direction of deposition of each run is to alternate from each end of the plate and the flux and welding slag are to be removed after completion of each run. The thickness of each layer is not to be less than the size of the wire, or 4 mm (5/32 in.), whichever is the greater. Between each run the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. The welding conditions (amperage, voltage, and travel speed) are to be in accordance with the recommendations of the manufacturer and are to comply with normal good welding practice for multi-run welding. Except hydrogen removal, as permitted in [5.1.8.2], the welded test assembly is not to be subjected to any heat treatment.

5.3.3.2. Test specimens

From the deposited metal test assembly, as illustrated in Figure 3.6.9, two tension and one set of three impact specimens are to be prepared and the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade and welding technique.

5.3.4. Butt Weld Test Assemblies for Multi-run Technique

5.3.4.1. Test Assembly

As indicated in Figure 3.6.10, one butt weld test assembly is to be welded in the flat position using the wire size as recommended by the manufacturer. For deposited metal test assembly, the welding conditions are to be essentially similar as those specified in .[5.3.3.1] After the removal of the root run to clean metal, the back weld is to be applied in the flat position. After the completion of welding, the test assembly is not to be subjected to any further heat treatment.

5.3.4.2. Test Specimens

From the butt weld test assembly, as indicated in Figure 3.6.10, two tension, two face bend and two root bend together with one set of three impact specimens are to be prepared and the results of tension and impact tests are to comply with the requirements as tabulated in Table 3.6.3 and Table 3.6.4 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of [5.1.11.2].

5.3.5. Butt Weld Assemblies for Two-run Technique

5.3.5.1. Test assemblies

Welding of the two butt weld test assemblies, as indicated in Figure 3.6.11, are to be welded in the flat position. The maximum size of wire, grades of steel plate, and the edge preparation to be used are also to be in accordance with Figure 3.6.11. Small deviations in the edge preparation may be permitted at the request of the manufacturer. The root gap is not to exceed 1.0 mm (0.04 in.). Welding of each test assembly is to be welded in two runs, one from each side, using welding conditions (amperage, voltage, and travel speed) which are in compliance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C (212°F) or less, the temperature being taken in the center of the weld, on the surface of the seam. After completion of the welding, the test assemblies are not to be subjected to any treatment.

5.3.5.2. Test specimens

As shown in Figure 3.6.11 and Figure 3.6.12, two tension, one face bend, one root bend, and one set of three impact specimens are to be made from each butt weld assembly, and the results of tension and impact tests are to comply with the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade and welding technique. The results of bend tests are to comply with the requirements of [5.1.11.2].

In order to confirm proper fusion and interpenetration of the welds, the edges of all test specimens and also the discards are to be checked.

5.3.5.3. Longitudinal all-weld-metal tension test

Where the combination is to be approved for two-run technique only, one longitudinal all-weld-metal tension sample is to be cut from the thicker butt weld test assembly as shown in Figure 3.6.11. The specimen to be machined to the dimensions indicated in Figure 3.6.9. Sufficient care must be taken to ensure that the longitudinal axis which coincides with the center of the weld and is approximately 7 mm (0.28 in.) below the plate surface on the side from which the second run is made. Prior to testing, the test specimen may be subjected to a temperature not exceeding 250°C (482°F) for up to 16 hours for hydrogen removal. The results of the tests are to conform to the requirements of Table 3.6.3.

5.3.6. Fillet weld tests

Where a wire-flux combination is submitted for fillet welds only, then the butt weld tests may be omitted, and fillet weld tests are to be carried out and tested according to the applicable parts of [5.4.6.2] to [5.4.6.4].

5.3.7. Low hydrogen approval

5.3.7.1. YQ grade wires – flux combination

All wire-flux combination of this grade are to be submitted to the diffusible hydrogen test, as required by [5.1.12.1]. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

5.3.8. Annual check tests

5.3.8.1. General

For each approved technique the annual check tests shall comprise of the following:

a. *Multi-run technique*: One deposited metal test assembly is to be welded in accordance with [5.3.3.1]. In accordance with [5.3.3.2], one tension and one set of three impact specimens are to be made and tested.

b. *Two-run technique*: In accordance with [5.3.5.1], welding of one butt weld test assembly of 20 mm (0.75 in.) thickness is to be done. One transverse tension, one face bend, one root bend, and one set of three impact specimens are to be made and tested in compliance with [5.3.5.2] and [5.3.5.3]. Where approval to wire-flux combination is given solely for the two-run technique, one longitudinal tension test specimen is also to be prepared.

5.3.8.2. Upgrading and uprating

At the manufacturer's request, upgrading of wire-flux combinations will be taken into consideration. For multi-run technique, in addition to the deposited metal test as indicated in [5.3.8.1] welding of one butt weld test assembly is to be prepared, as indicated in [6.3.4], and one set of three impact specimens is to be tested at the upgraded temperature. For the two-run technique, butt weld testing is to be carried out as specified in [5.3.8.1], except the test assembly is to be fabricated using the maximum thickness approved.

Uprating refers to the extension of approval to cover welding of higher-strength steels (dual approvals) also. For this purpose, butt weld tests are to be carried out as required in [5.3.4], [5.3.5] and [5.1.5.2. (c)] of this section, as applicable.

5.3.9. Multiple electrodes

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

5.3.10. Electroslag Welding

5.3.10.1. General

Where approval is requested for wire-flux combinations other than YQ Grades, (with or without consumable nozzles) for use in electroslag welding, two test assemblies of 20–25 mm (0.75–1.0 in.) and 35–40 mm (1.38–1.58 in.) or more in thickness are to be prepared with a minimum root opening of 16 mm (0.63 in.), or with another joint design sufficient to allow the selection of the following test specimens. The chemical composition of the plates including the content of grain refining elements is to be reported.

- 2 Longitudinal tension specimens from the axis to the weld;
- 2 Transverse tension specimens;
- 2 side bend specimens;
- 3 Charpy-V specimens notched at the center of the weld;
- 3 Charpy-V specimens with their notches in the weld metal at 2 mm (5/64 in.) from the fusion line;
- 2 macro-sections.

In accordance with the applicable grade and welding technique, the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4.

5.3.10.2. Annual tests

Preparation for one butt test assembly of 20–25 mm (0.75–1.0 in.) or more in thickness is to be completed. One longitudinal tension, one transverse tension, two side bend and two sets of three Charpy V-notch specimens are to be made and tested. The notch of the impact specimens is to be positioned at the center of the weld and 2 mm (0.08 in.) from the fusion line in the weld. Examination of one macro-section is also to be carried out.

In accordance with the applicable grade and welding technique, the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4.

5.3.10.3. Upgrading and uprating

Upon the request of the Manufacturer, upgrading and uprating will be taken into consideration. Full tests as indicated in [5.3.10.1] will be needed.

In accordance with the applicable grade and welding technique, the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4.

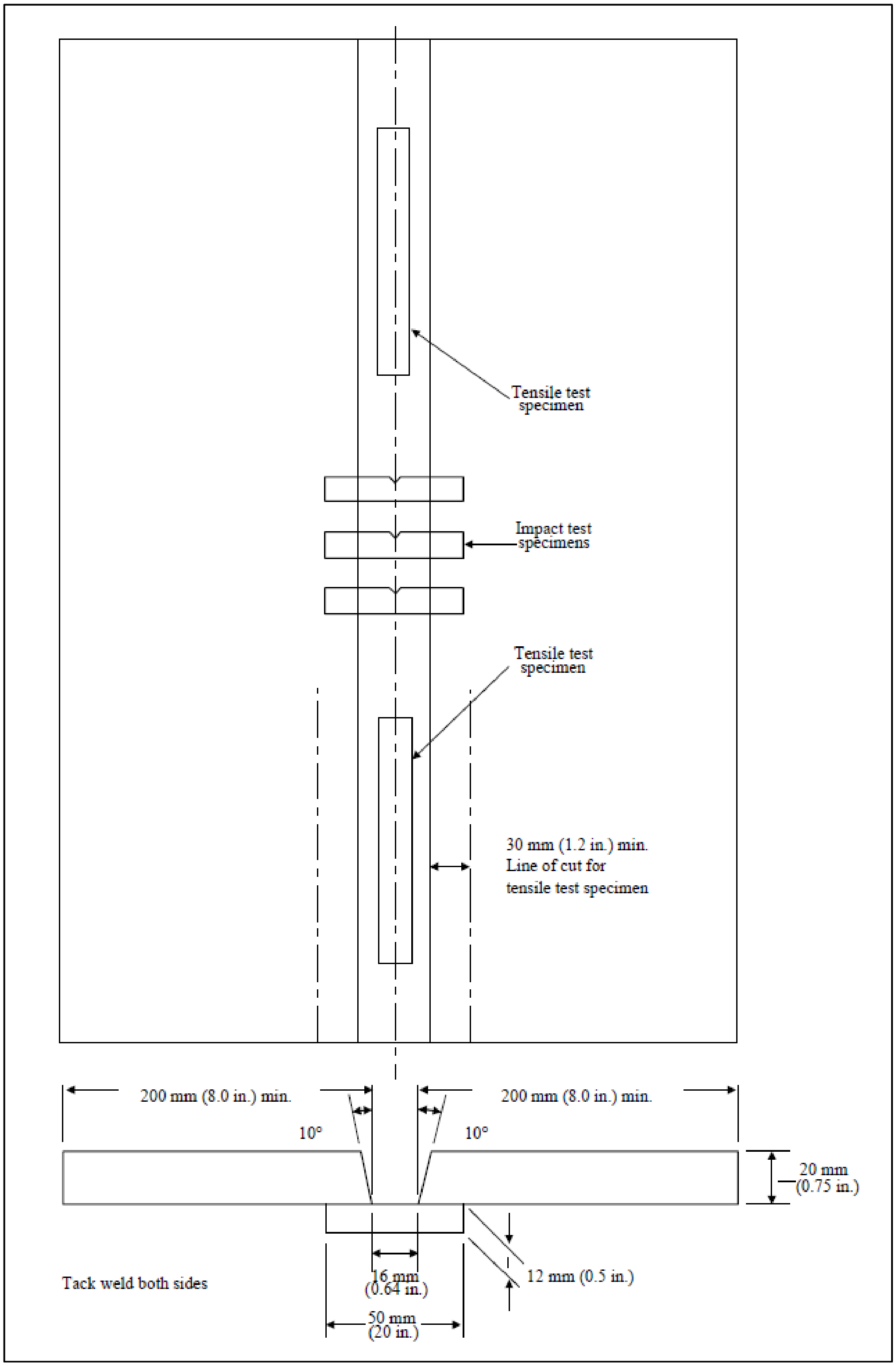


Figure 3.6.9: Deposited-Metal Test Assembly for Submerged Arc Welding – Multi-run Technique and Automatic Gas-Metal Arc Welding

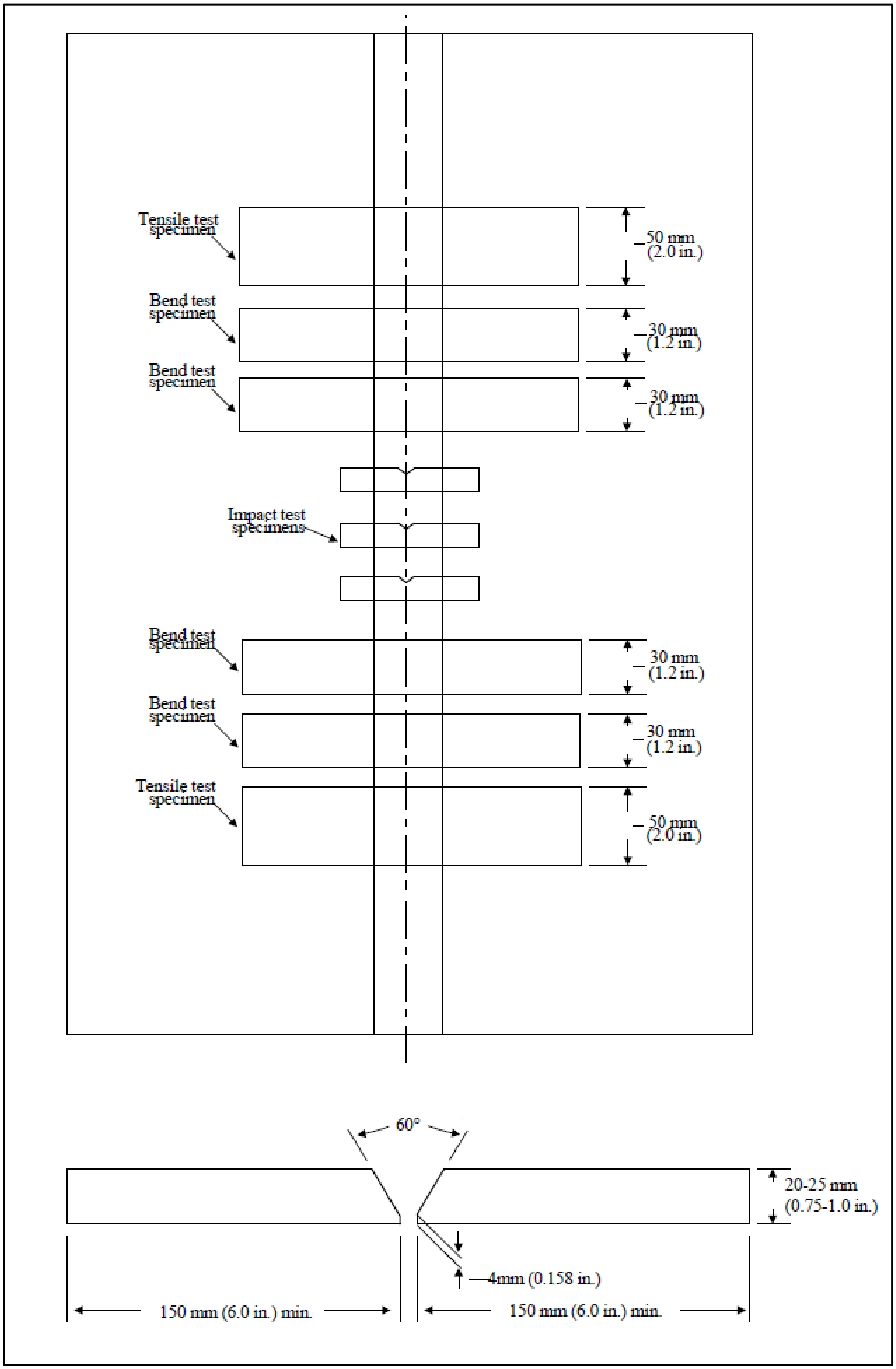


Figure 3.6.10: Butt-Weld Test Assembly for Submerged Arc Welding – Multi-run Technique

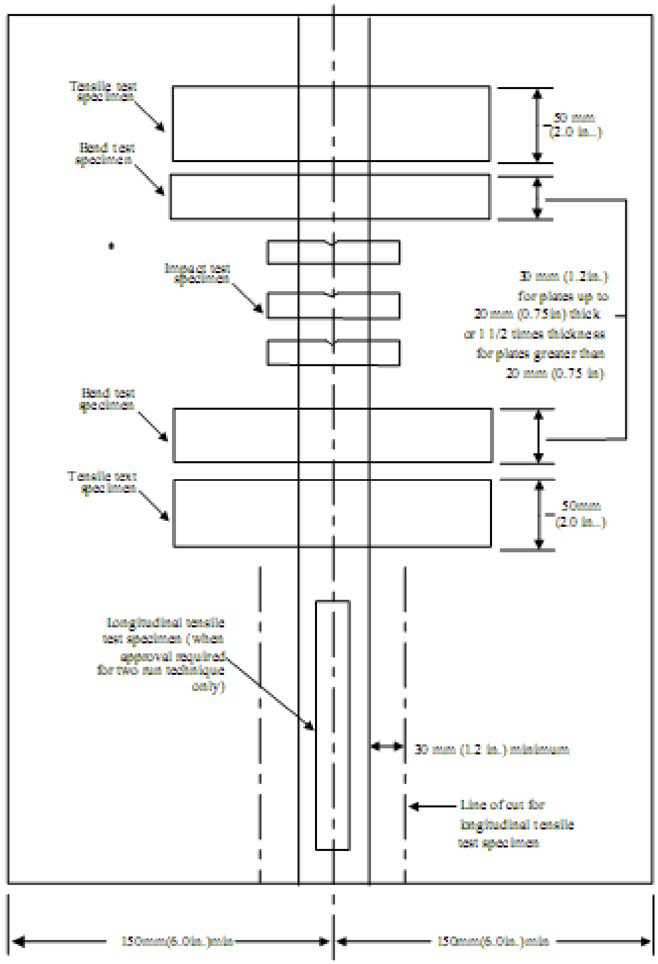


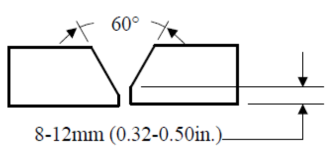
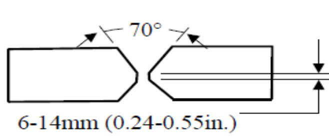
Plate Thickness	Preparation	Maximum sizes of Wire	INTLREG Grades of Steel		
			Wire Flux Grade	Ordinary Strength	Higher Strength
12-15 mm (0.5-0.62 in.)		5 mm (0.20 in.)	1, 1Y	A	AH 32/36
20-25mm (0.75-1.0 in.)		6 mm (0.25 in.)	1, 1Y	A	AH 32/36
			2, 2Y	A/B/D	AH/DH 32/36
			2Y400	-	AH/DH 40
			3, 3Y	A/B/D/E	AH/DH/EH 32/36
			3Y400	-	AH/DH/EH 40
			4Y	-	AH/DH/EH/FH 32/36
			4Y400, 5Y400	-	AH/DH/EH/FH 40
30-35 mm (1.2-1.38 in.)		7 mm (0.28 in.)	2, 2Y	A/B/D	AH/DH 32/36
			2Y400	-	AH/DH 40
			3, 3Y	A/B/D/E	AH/DH/EH 32/36
			3Y400	-	AH/EH/DH 40
			4Y	-	AH/DH/EH/FH 32/36
			4Y400, 5Y 400	-	AH/DH/EH/FH 40

Figure 3.6.11: Butt-Weld Test Assembly for Submerged Arc Welding – Two-run Technique

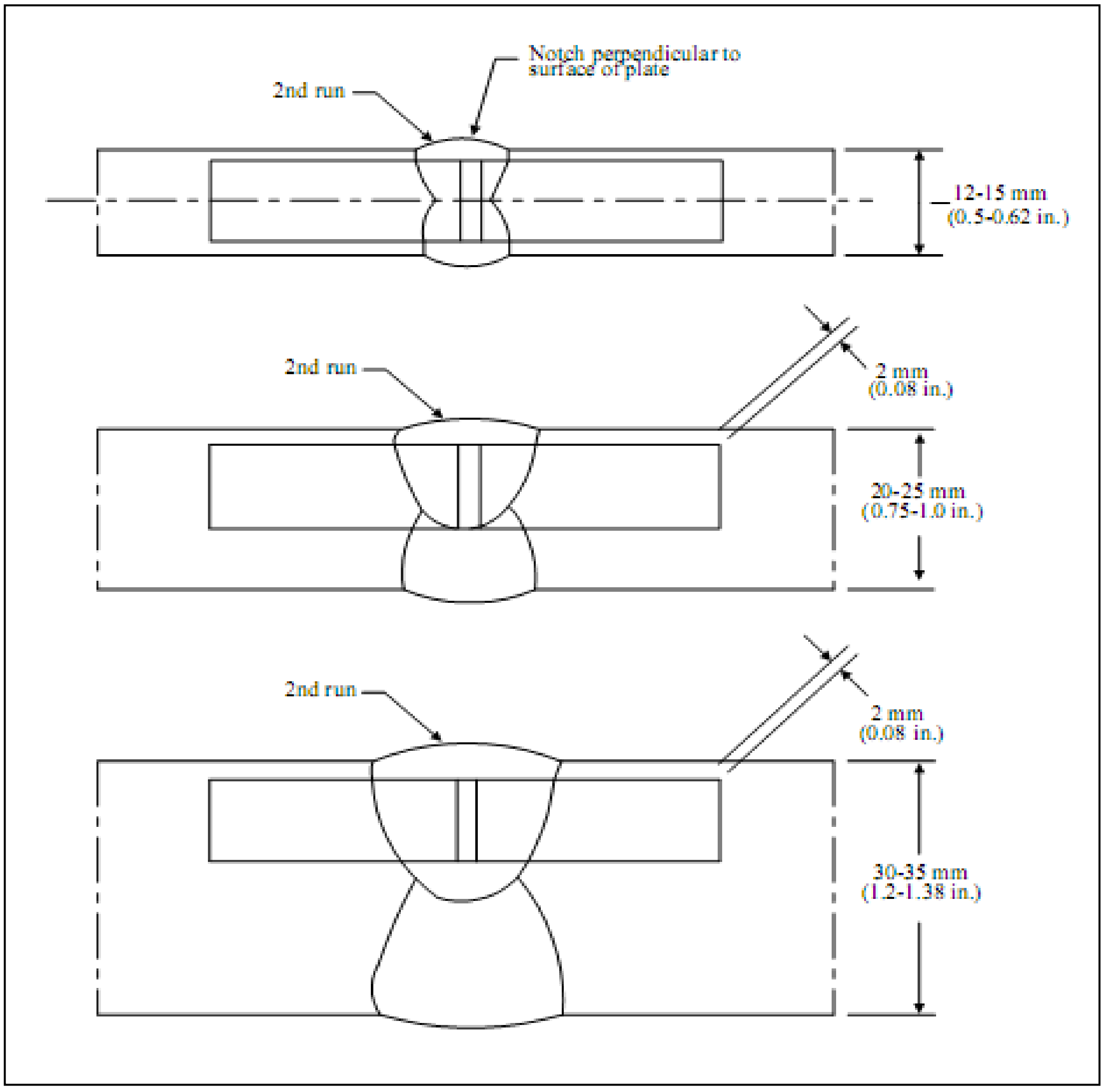


Figure 3.6.12: Butt-Weld Impact Specimen Location for Submerged and Gas-Metal Arc Welding – Two-run Technique

5.4. Wire and Wire Gas Combinations for Gas Metal Arc Welding and Flux Cored Wires for Flux Cored Arc Welding

5.4.1. General

This test program is intended for the approval of wire-gas combinations and flux cored wires with or without shielding gas intended for semi-automatic or automatic arc welding techniques. For both techniques, the welding gun provides continuous wire feed; for semi-automatic welding, the welding gun is held manually, and for automatic welding, the welding gun is machine held with various degrees of controlled motion provided by the machine. The impact requirements for the semi-automatic welding technique and those for the automatic welding technique are indicated separately in Table 3.6.3 and Table 3.6.4 according to the applicable grade. In order to indicate approval for manual semi-automatic or machine-automatic gas-metal arc welding, the suffix SA will be added to the grade. The suffix A will be added to the Grade to indicate approval for machine automatic welding only. In order to indicate approval for two-run (one pass each side) technique for machine automatic welding, an additional suffix T will be added to the grade. As recommended by the manufacturer, wire-gas combinations and flux cored wires approved for semi-automatic welding may be used for automatic welding under the procedure except that for the two-run automatic technique, testing in accordance with [5.4.5] is required. For YQ Grades semi-automatic or automatic welding, a multi run technique is considered. For high heat input process, such as semi-automatic or automatic welding two-run technique which may be considered under [6.1.2.3] and approval by the technical office.

5.4.2. Chemical analysis and shielding gas compositions

The manufacturer shall furnish the chemical analysis of the deposited weld metal. The trade name of the shielding gas, when used, as well as its composition, is to be reported. 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 3.6.5.

Table 3.6.5: 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 (Ref Note 1, 2)
	2	> 0 to 5	--	--	Rest (Ref Note 1, 2)
	3	--	> 0 to 3	--	Rest (Ref Note 1, 2)
	4	> 0 to 5	> 0 to 3	--	Rest (Ref Note 1, 2)
M2	1	> 5 to 25	--	--	Rest (Ref Note 1, 2)
	2	--	> 3 to 10	--	Rest (Ref Note 1, 2)
	3	> 5 to 25	> 0 to 8	--	Rest (Ref Note 1, 2)
M3	1	> 25 to 50	--	--	Rest (Ref Note 1, 2)
	2	--	> 10 to 15	--	Rest (Ref Note 1, 2)
	3	> 5 to 50	> 8 to 15	--	Rest (Ref Note 1, 2)
C	1	100	--	--	--
	2	Rest	> 0 to 30	--	--

Notes:

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.

5.4.3. Deposited Metal Test Assemblies for Semi-Automatic and Automatic Testing

5.4.3.1. Semi-automatic test assemblies

Welding of two deposited metal test assemblies, as illustrated in Figure 3.6.5, is to be carried out in the flat position, one using the smallest size wire intended for approval, and the other using the largest size intended for approval. One test assembly is sufficient if a wire is produced in one size only or if the largest size produced is 1.2 mm (0.045 in.) or less. In accordance with recommended practice, the weld metal is to be deposited in single or multi-run layers and the thickness of each layer of weld metal is to be between 2 mm (5/64 in.) and 6 mm (15/64 in.). In between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After the completion of welding, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in [5.1.8.2]

5.4.3.2. Test specimens for semi-automatic

As shown in Figure 3.6.5, one tension and one set of three impact specimens are to be made from each deposited metal test assembly, and the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade.

5.4.3.3. Automatic test assembly

For automatic welding one test assembly, as indicated in Figure 3.6.9, is to be welded in the flat position using 2.4 mm (3/32 in.) wire or the largest size manufactured. The thickness of each layer is not to be less than 3 mm (1/8 in.). Between each run, the assembly is to be left in still air until it has cooled to 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assembly is not to be subjected to any heat treatment, except hydrogen removal, as permitted in [5.1.8.2].

5.4.3.4. Test specimens for automatic

As indicated in Figure 3.6.9, two tension and one set of three impact specimens are to be prepared from the test assembly, and the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade.

5.4.4. Butt Weld Test Assemblies for Semi-automatic and Automatic Techniques

5.4.4.1. Test assemblies

One butt weld test assembly, as indicated in Figure 3.6.6, is to be welded in each position (flat, vertical-up, vertical-down, overhead, and horizontal) for which the wire is recommended by the manufacturer, except that wires meeting the requirements for flat and vertical positions will be considered as also complying with the requirements for horizontal position. Where the wire is only to be approved in the flat position, one additional test assembly is to be welded in that position.

5.4.4.2. Welding procedure

Generally, the following welding procedure is to be adopted in making the test assemblies:

a) **Flat**: First run using the smallest size wire intended for; remaining runs with the largest size intended for approval. Where a second flat assembly is required, it is to be prepared using wires of different sizes.

b) **Vertical-up, vertical-down, overhead and horizontal**: First run with the smallest size wire intended for approval; remaining runs using the largest size wire intended for approval recommended by the manufacturer for the position involved.

In all cases, the back weld is to be made with the smallest size wire intended for approval, after removing the root run to clean metal. 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 (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld on the surface of the seam. After completion of the welding, the test assemblies are not to be subjected to any heat treatment.

5.4.4.3. Test specimens

As shown in Figure 3.6.6, one tension, one face bend, one root bend, and one set of three impact specimens are to be prepared from each butt-weld test assembly. The results are to comply with the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade, position and welding technique. The results of bend tests are to comply with the requirements of [5.1.11.2].

5.4.5. Butt Weld Test Assemblies for Two-run Technique

5.4.5.1. Test assemblies

Welding of the two butt weld test assemblies, as shown in Figure 3.6.13, are to be carried out in the flat position. One test assembly is to be welded using 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater and one test assembly using 2.4 mm (3/32 in.) wire or the largest size wire recommended by the manufacturer for two-run technique. Each test assembly is to be welded in two runs, one from each side. Between each run, the assembly is to be left in still air until it has cooled to 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After completion of welding, the test assemblies are not to be subjected to any heat treatment.

5.4.5.2. Test specimens

From each butt weld test assembly, as indicated in Figure 3.6.12 and Figure 3.6.13, two tension, one face bend one root bend together with one set of three impact specimens are to be prepared and the results of tension and impact tests are to comply with the requirements as tabulated in Table 3.6.3 and Table 3.6.4 for the applicable grade. If approval is requested for welding plate thicker than 25 mm (1.0 in.), one assembly is to be prepared using plates approximately 20 mm (0.75 in.) in thickness and the other using plates of the maximum thickness for which approval is requested. For assemblies using plates over 25 mm (1.0 in.) in thickness, the edge preparation is to be reported for information. The results of bend tests are to meet the requirements of [5.1.11.2].In order to ensure complete fusion and interpenetration of the welds, the edges of all test specimens and also the discards are to be examined.

5.4.5.3. Longitudinal All-Weld-Metal Tension Test

Where the wire is to be approved for two-run technique only, one longitudinal all-weld-metal tension specimen is to be cut from the thicker butt weld test assembly, as indicated in Figure 3.6.13, and machined to the dimensions indicated in Figure 3.6.1, care being taken that the longitudinal axis coincides with the center of the weld and is about 7 mm (0.28 in.) below the plate surface on the side from which the second run is made. Prior to testing, the test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for hydrogen removal. The results of the test are to conform to the requirements of Table 3.6.3 and Table 3.6.4 for the applicable grade.

5.4.6. Fillet weld tests

5.4.6.1. General

A wire-gas combination or flux cored wire is considered approved for fillet welding in the welding position for which the butt weld test of [5.4.4] was satisfactory. A wire-gas combination or flux cored wire meeting the flat butt weld requirements will be considered as complying with the requirements for horizontal fillet (HF) welds. Where a wire-gas combination or a flux cored wire is submitted for approval for fillet welding only, the butt weld tests indicated in [5.4.4] and [5.4.5]may be omitted, and fillet weld tests are to be carried out and tested in accordance with [5.4.6.2] and [5.4.6.3].

5.4.6.2. Test assemblies

One fillet weld test assembly, as indicated in Figure 3.6.7, is to be welded in each welding position for which the wire is recommended by the manufacturer.

5.4.6.3. Welding procedure

The length L of the fillet weld test assemblies is to be sufficient to allow for the tests prescribed in [5.2.5.3] One side is to be welded using the maximum size wire manufactured and the second side is to be welded using the minimum size wire manufactured and recommended for fillet welding. The fillet size will in general be determined by the wire size and the welding current employed during testing. The fillet welding is to be carried out with the welding equipment and technique recommended by the manufacturer. The manufacturer's recommended current range is to be reported for each wire size and welding position.

5.4.6.4. Test requirements

The results of breaking and hardness tests are to meet the requirements of [5.2.5.4]..

5.4.7. Low hydrogen approval

5.4.7.1. Flux cored wire

a. *Welding conditions for test assemblies*:
When flux cored wires undergo diffusible hydrogen testing as indicated in (b), (c) and (d) below, the following apply unless otherwise specified by the diffusible hydrogen test standard. Welding of diffusible hydrogen test assemblies is to be carried out using the same welding conditions (including contact tip to work distance) that were used in welding the deposited metal test assembly. The travel speed may be adjusted to give a weight of weld deposit per sample similar to manual electrodes.

b. *Ordinary strength wires*:
A flux-cored wire which has satisfied the requirements of grade 2 or 3 may, at the manufacturer's option, be submitted to the diffusible hydrogen test, as

detailed in [5.1.12.2] or [5.1.12.3] A suffix indicating the hydrogen amount will be added to the grade number to indicate compliance with the hydrogen test requirements specified in [5.1.12.4].

c. *YQ-grade wires*:
All flux-cored wires of this grade are to be submitted to the diffusible hydrogen test, as required by[5.1.12.1]. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

d. *Higher strength wires*:
Flux-cored wires submitted for approval according to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400 4Y400 or 5Y400 are to be subjected to a hydrogen test, as detailed in . [5.1.12.2] or [5.1.12.3] Diffusible hydrogen test results are to meet the requirement specified in] [5.1.12.4 for the H15 suffix. Such suffix, however, will not be added to the grade. Flux cored wires meeting H5 or H10 requirements will be so identified. Electrodes meeting the higher-strength requirements, except for the hydrogen test, will require special approval for use on higher strength steel for each user and will be so identified in the list of approved consumables.

5.4.8. Annual check tests

5.4.8.1. General

The annual check tests for each approved technique shall consist of the following:

a. *Semi-automatic and automatic*: In accordance with [5.4.3.1] or [5.4.3.3]as applicable, welding of one deposited metal test assembly is to be carried out using a wire of diameter within the range approved. In accordance with [5.4.5.2] or [5.4.5.4], as applicable, one tension and one set of three impact specimens are to be prepared and tested.

b. *Two-run automatic technique*: In accordance with [5.4.5.1], one butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded. The usage of wire diameter is to be reported. One longitudinal tension, one face bend, one root bend and one set of three impact specimens are to be prepared and tested compliant with [5.4.5.2] and [5.4.5.3] A longitudinal tension test will not be required for wires also approved for multi-run technique.

5.4.8.2. Upgrading and uprating

Upon the request of the manufacturer, upgrading of wire-gas combinations and flux cored wires will be taken into consideration. For semi-automatic and automatic welding, in addition to the deposited metal test as indicated in [5.4.8.1], welding of a butt weld test assembly is to be carried out as indicated in [5.4.4] for each position initially tested, and sets of three impact specimens from each test assembly are to be tested at the upgraded temperature.

Uprating refers to the extension of approval in order to cover welding of higher-strength steels (dual approvals). For this purpose, but weld tests are to be carried out, as indicated in [5.4.4] or [5.4.5], and [5.1.5.2. (c)], as applicable. In addition, the diffusible hydrogen test required by the grade or suffix referred to [5.4.7.1(b)] and [5.4.7.1(d)] is to be conducted.

5.4.9. Electro gas welding

5.4.9.1. General

Where approval is requested for wire-gas combinations other than YQ Grades, (with or without consumable nozzles or self-shielding gas) for use in electro gas welding, two test assemblies of 20-25 mm (0.75-1.0 in.) and 35-40 mm (1.38-1.58 in.) or more in thickness are to be prepared with a minimum root opening of 16 mm (0.63 in.), or with another joint design sufficient to allow the selection of the following test specimens. The chemical composition of the plates including the content of grain refining elements is to be reported.

- 2 Longitudinal tension specimens from the axis to the weld;
- 2 Transverse tension specimens;
- 2 side bend specimens;
- 3 Charpy-V specimens notched at the center of the weld;
- 3 Charpy-V specimens with their notches in the weld metal at 2 mm (5/64 in.) from the fusion line;
- 2 macro-sections.

In accordance with the applicable grade and welding technique, the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4.

5.4.9.2. Annual tests

One butt test assembly of 20–25 mm (0.75–1.0 in.) or more in thickness is to be prepared. One longitudinal tension, one transverse tension, two side bend and two sets of three Charpy V-notch specimens are to be prepared and tested. The notch of the impact specimens is to be located at the center of the weld and 2 mm (0.08 in.) from the fusion line in the weld. One macro-section is also to be examined.

The test results are to conform to the requirements of Table 3.6.3 and Table 3.6.4, according to the applicable grade and welding technique.

5.4.9.3. Upgrading and uprating

Upon the request of the Manufacturer, upgrading and uprating will be taken into consideration. Full tests as indicated in [5.4.9.1] will be required.

In accordance with the applicable grade and welding technique, the results are to comply with the requirements of Table 3.6.3 and Table 3.6.4.

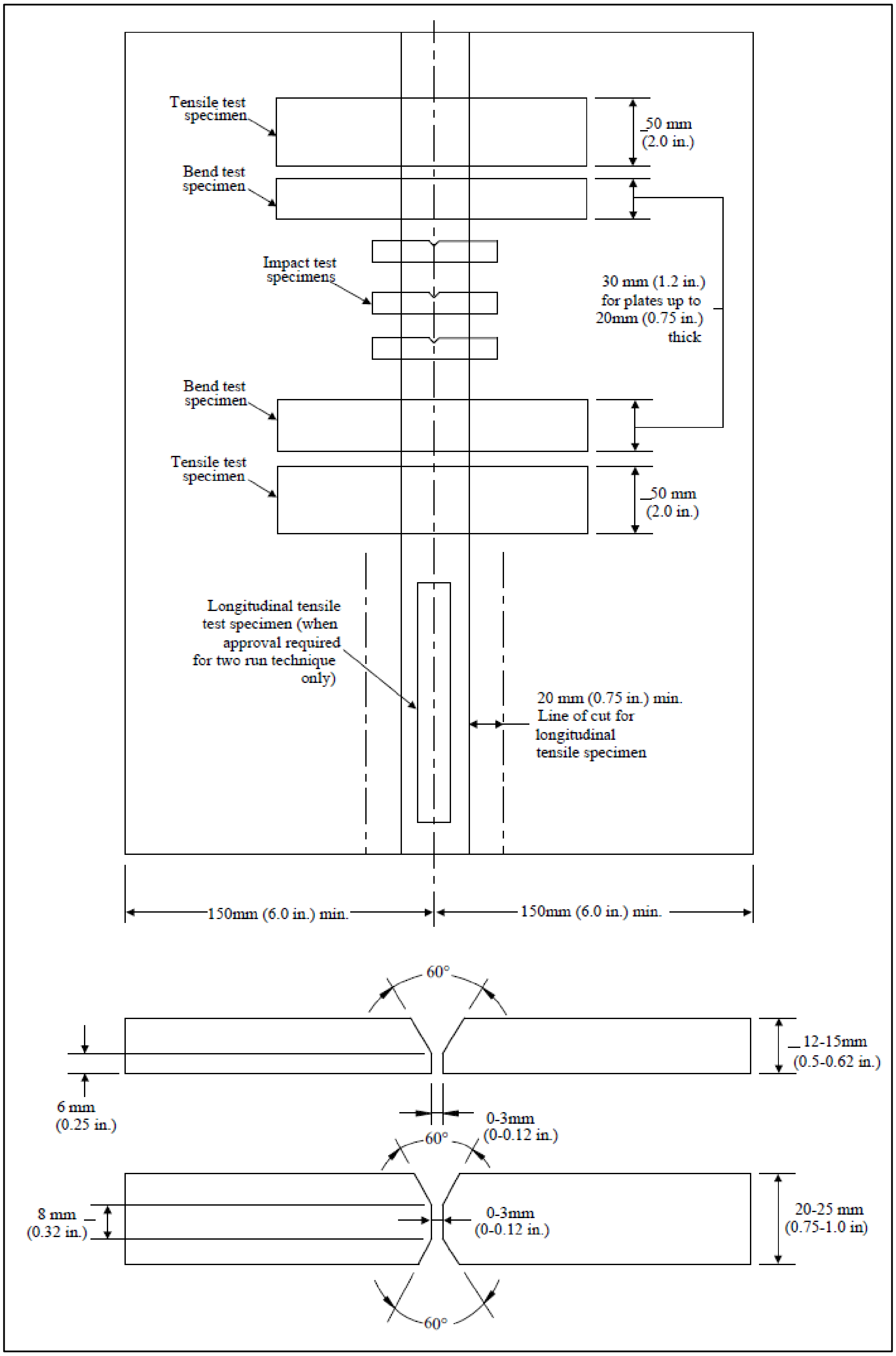


Figure 3.6.13: Butt-Weld Test Assembly for Gas-Metal Arc welding – Two-run Technique

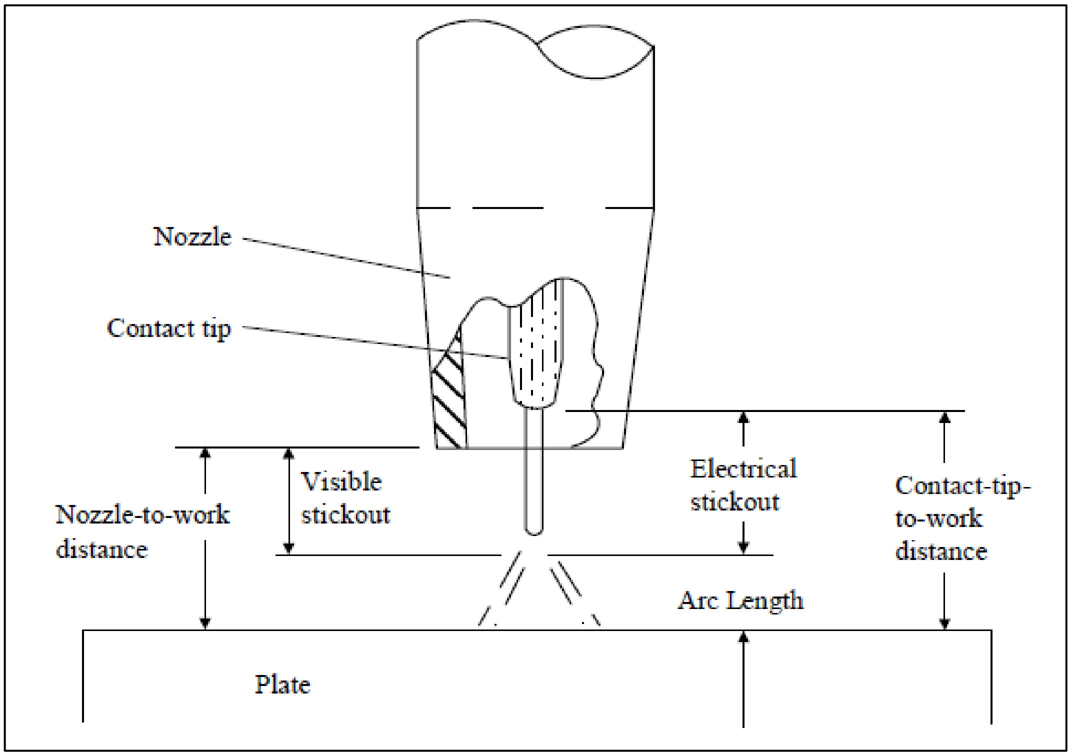


Figure 3.6.14: Contact Tip to Work Distance

5.5. Application of filler metals to INTLREG steels

5.5.1 For welding various INTLREG grades of hull steel, a chart indicating acceptable INTLREG filler metal grades is given Table 3.6.6 below.

Table 3.6.6

INTLREG hull structural steel	Acceptable INTLREG Filler Metal Grade
Ordinary Strength	
A to 12.5 mm (1/2 in.) inclusive	1, 2, 3, 1Y**, 2Y, 3Y, 4Y
A over 12.5 mm (1/2 in.), B, D	2, 3, 2Y, 3Y, 4Y
E	3, 3Y, 4Y
Higher Strength *	
AH 32/36 to 12.5 mm (1/2 in.) inclusive	1Y, 2Y**, 2Y400, 3Y, 3Y400, 4Y, 4Y400, 5Y400
AH 32/36 over 12.5 mm (1/2 in.), DH32/36	2Y, 2Y400, 3Y, 3Y400, 4Y, 4Y400, 5Y400
EH 32, EH 36	3Y, 3Y400, 4Y, 4Y400, 5Y400
FH 32, FH 36	4Y, 4Y400, 5Y400
AH 40, DH 40	2Y400, 3Y400, 4Y400, 5Y400
EH 40	3Y400, 4Y400, 5Y400

FH 40	4Y400, 5Y400
High Strength Quenched and Tempered *	
XQ43	ZYQ420, ZYQ460***, ZYQ500***
XQ47	ZYQ460, ZYQ500***
XQ51	ZYQ500, ZYQ550***
XQ56	ZYQ550, ZYQ620***
XQ63	ZYQ620, ZYQ690***
XQ70	ZYQ690
Note: For X = A or D, Z = 3, 4 and 5 For X = E, Z = 4 and 5 For X = F, Z = 5	

5.5.2 The tensile strength range of INTLREG ordinary strength hull structural steel is 400-520 N/mm^2, (41-53 kgf/mm^2, 58-75 ksi). The tensile strength range for INTLREG H32/H36 higher strength hull structural steel is 440-620 N/mm2 (45-63 kgf/mm^2, 64-90 ksi). For INTLREG H40 higher strength hull structural steel, the tensile strength range is 510-650 N/mm^2 (52-66 kgf/mm^2, 74-94 ksi). The INTLREG filler metal grades for welding ordinary and higher strength hull structural steels are assigned according to Charpy V-notch impact requirements, aimed at providing comparable level of notch toughness of the various grades of steel. Because of inherent differences in the quality of machine automatic versus manual and manual semi-automatic produced welds, the impact strength requirements for both ordinary and high strength filler metal grades are divided into two levels in accordance with the process used either automatic or manual. The specific value requirements may be found in Table 3.6.4.

(*) For welding higher strength steels, non-low hydrogen type electrode and wire approvals are subject to satisfactory procedure tests at the user's plant. Usage of non-low hydrogen electrodes and wires on higher strength steels is restricted to steels with carbon equivalent of 0.41% or less. Refer Ch 1, Sec 3, [3.3.1]. Additionally, these procedure tests should include fabrication of a double fillet weld assembly(ies) representative of material(s) and thickness(es) to be used in production. Prior to the second side welding, the weld on the first side is to be allowed to cool to ambient temperature. Three macro sections (a section from the center, and a section at one inch from each end), taken 72 hours (minimum) after welding are to be free of weld and heat affected zone cracks when etched and examined at 10X magnification.

(**) Grade 1Y not applicable to manual welding electrodes and semi-automatic wire-gas combinations.

(***) Refer, Ch 3, [1.3.4.2] concerning overmatching of electrodes for quenched and tempered steels.

CHAPTER 4 COPPER ALLOYS

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SECTION 1 GENERAL REQUIREMENTS

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1.1. Scope

1.1.1. The Rules in this chapter are applicable to copper and copper alloys used in the manufacture of Steel Vessels.

1.1.2. Materials intended for the manufacture of seamless copper pipes and tubes are to comply with Section 2 & 3 of this chapter. Seamless copper-nickel tube and pipe and Red-brass piping intended for use in general engineering applications requiring seawater corrosion resistance are covered in Section 4 & 5 respectively.

1.1.3. Section 6 of this chapter is applicable to bronze casting used for the manufacture of propeller and propeller blades and also for Ice Strengthening Class.

1.1.4. As deemed necessary by the relevant parts of the Rules related to design and construction, tubes and castings are to be manufactured and tested in compliance with the specific requirements of this Chapter.

1.1.5. Alternatively, tubes and castings which are in accordance with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter and provided that survey is carried out in accordance with the requirements of INTLREG.

1.1.6. Where it is suggested to use an alloy which is not mentioned in this Chapter, details of heat treatment, chemical composition and mechanical properties are to be submitted for approval.

1.2. Manufacture

1.3.1. In principle, it is left to the discretion of the manufacturer to decide the manufacturing procedure and heat treatments suitable to obtain products having the required properties.

1.3.2. The manufacturing process is to make certain that copper or copper alloy products do not have any internal or surface defects which may harm their proper workability and use.

1.3. Identification

1.3.1. A system of identification has to be accepted by the manufacturer which will enable all finished products to be traced, and the Surveyor is to be provided with full facilities to trace the product when needed.

1.3.2. Prior to acceptance, all items tested and inspected satisfactorily are to be clearly marked by the manufacturer with the following details:

a) Identification number, cast number (where applicable) or other markings which will help in tracing the full history.
b) INTLREG or International Register of Shipping and the abbreviated name of INTLREG's local office.
c) Name of manufacturer or trade mark
d) Date of final inspection
e) Personal stamp of the Surveyor responsible for inspection
f) Skew angle, where applicable, if in excess of 25°. Refer to the relevant Rules for the definition of skew angle.
g) Test pressure, where applicable

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

1.3.4. Identification is to be done by stencils or rubber stamp. Hard stamping is not allowed.

1.4. Certification

1.4.1. INTLREG certificate or Manufacturer's Certificate validated by INTLREG is to be issued, refer to Ch 1, Sec 1, [1.4].

1.4.2. It is the responsibility of the manufacturer to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:

a) Name of purchaser and order number.
b) Specification or grade of material
c) Description and dimensions.
d) Identification number.
e) Cast number and chemical composition.
f) Mechanical test results.
g) Full details of heat treatment, where applicable.
h) Ingot or cast analysis, where applicable
i) Hydraulic test report., where applicable
j) Test pressure, where applicable.
k) Results of non-destructive tests and details of test procedures.
l) Final weight, where applicable
m) Skew angle, (where applicable), if in excess of 25°. Refer the relevant Rules for the definition of skew angle.

1.4.3. In addition to [1.4.2], the manufacturer is to provide, where necessary, a statement and and/or sketch showing in details the position and extent of all weld repairs carried out for each casting.

SECTION 2 SEAMLESS COPPER PIPING

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2.1. Scope

2.1.1. The materials specified in this section are in substantial agreement with ASTM B42.

2.1.2. The specifications given below cover seven (7) grades of seamless copper pipes designated as Cu1, Cu2, Cu3, Cu4, Cu5, Cu6 and Cu7.

2.2. General

2.2.1. **Grades Cu1, Cu2, Cu3, Cu4, Cu5, Cu6 and Cu7**

Grades from Cu1 to Cu7 cover seamless copper pipes that are intended for being used in boiler feed-water lines, plumbing and other similar services. Under these grades, pipes ordered in all standard sizes i.e. regular and extra strong, are considered suitable for welding and brazing.

2.2.2. **ASTM Designation**

As per the Table 4.2.1, these grades are in substantial agreement with ASTM.

Table 4.2.1

INTLREG Grade	ASTM designation
Cu1	UNS C10100
Cu2	B42, UNS C10200
Cu3	B42, UNS C10300
Cu4	B42, UNS C10800
Cu5	B42, UNS C12000
Cu6	B42, UNS C12200
Cu7	UNS C14200

2.3. Process of Manufacture

The manufacturing of the material is to be carried out by either hot or cold working operations, or both. Then, unless otherwise specified, it is to be finished by appropriate cold working and annealing or heat treatment, as required to meet the specified properties. Normally, all pipes are to be furnished in the drawn-temper condition, (H55). Hard-drawn temper (H80) may also be furnished. However, when pipe is required for bending, it is to be furnished with a bending temper, or annealed temper (061). All pipes used at working pressures over 10 bars (10.5 kgf/cm^2, 150 psi) are to be tested at the mills under supervision of the Surveyor. All pipes are to be examined by the Surveyor upon purchaser’s request. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

2.4. Marking

2.4.1. **Manufacturer’s Marking**

Each length of pipe is to be clearly marked by stamping or stenciling, including brand of the manufacturer, the designation B42 and the test pressure. If the pipes with small-diameter are bundled, the same information may be marked on a tag attached properly to each bundle.

2.4.2. INTLREG Markings

The INTLREG markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be placed on the material near the markings specified in [2.4.1].

The following details are to be shown on all materials which have been accepted:

a) INTLREG or International Register of Shipping marking.
b) Manufacturer’s name or trade mark.
c) Grade of material or designation code.
d) Identification number and/or initials which will enable the full history of the item to be traced.

2.5. Chemical Composition

The material is to conform to the applicable chemical composition requirements as given in Table 4.2.2.

Table 4.2.2: Chemical Composition for Copper Pipe and Tube

Pipe Grade	Tube Grade	Minimum Copper *, %	Phosphorus, %	Arsenic, %	Maximum Oxygen, ppm
Cu1	CuA	99.99	-	-	-
Cu2	CuB	99.5	-	-	10
Cu3	CuC	99.95 **	0.001 to 0.005	-	-
Cu4	CuD	99.95 **	0.005 to 0.012	-	-
Cu5	CuE	99.9	0.004 to 0.012	-	-
Cu6	CuF	99.9	0.015 to 0.040	-	-
Cu7	CuG	99.4	0.015 to 0.040	0.15-0.50	-

Notes:
* Including silver.
** Total of copper, silver and phosphorus.

2.6. Tension Test

2.6.1. Tension Test Specimens

Tensile test specimens are ideally a full section of the pipe. For larger sizes, these specimens are to comprise of longitudinal strips cut from the pipe in line with ASTM E8.

2.6.2. Tensile Properties

The material is to conform to the applicable tensile properties requirements as given in Table 4.2.3.

Table 4.2.3: Tensile Properties for Copper Pipe and Tube

Temper Designation		Tensile Strength, min. N/mm^2 (kgf/mm^2, ksi)	Yield Strength[(1)] min. N/mm^2 (kgf/mm^2, ksi)
Standard	Former		
061/060	Annealed	205 (21,30)	62 (6,9)[(2)]
H55	Light drawn	250 (25,36)	205 (21,30)
H80	Hard drawn	310 (32,45)	275 (28,40)

Notes:
1. At 0.5% extension under load.
2. Light straightening operation is permitted.

2.7. Expansion Test

After annealing, specimens selected for expansion test able to withstand 25% expansion of the outside diameter when expanded using a tapered pin with a 60-degree included angle. The expanded tube is not to show any cracking or rupture i.e. visible to the unaided eye.

2.8. Flattening Test

For pipes over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, instead of the expansion test, flattening test can be carried out. For this, a section of 100 mm (4 in.) length is to be cut from the end of one of the lengths of the pipe. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at thrice the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested is to develop no cracks or defects visible to the unaided eye. During the flattening test, the specimens are to be slowly flattened by one stroke of the press.

2.9. Hydrostatic Test

2.9.1. Limiting Test Pressures

The equation given below may be used to determine an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi) and each length of the pipe is required to withstand it, without showing weakness or defects. Unless otherwise specified, no pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi). At the option of manufacturer, annealed pipe with wall thickness up to 2.11 mm (0.083 in.) inclusive may be tested in the hard-drawn condition before annealing.

$$P = \frac{K \times S \times t}{(D - 0.8\,t)}$$

Where,

P = pressure in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi)

t = thickness of pipe wall, in mm (in.)

D = outside diameter of the pipe, in mm (in.)

K = 20 (200 for kgf/mm^2, 2 for psi)

2.9.2. Affidavits of Tests

Surveyor may accept an affidavit by the manufacturer covering the hydrostatic tests for each pipe are undertaken as a regular procedure during the process of manufacture.

2.10. Number of Tests

The lot for the test is to comprise of pipe of the same size and temper. The lot size is to be 2270 kg (5000 lb) or a fraction thereof for pipe up to 48.3 mm O.D. (1.5 in. nominal size) incl.; 4550 kg (10,000 lb) or a fraction thereof for pipe over 48.3 mm O.D. (1.5 in. nominal size) to 114.3 mm O.D. (4 in. nominal size) incl., 18,150 kg (40,000 lb) or a fraction thereof for pipe over 114.3 mm O.D. (4 in. nominal size). For test purposes sample pieces are to be taken from each lot as given in Table 4.2.4.

Table 4.2.4

Number of Pieces in Lot	Number of Sample Pieces to Be Taken
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Where required, chemical analyses, tensile tests, expansion tests, flattening tests, bend tests, dimensional examinations and visual examinations are to be completed on each of the sample pieces selected for test.

For each length of the pipe, the hydrostatic test is to be done as specified in [2.9] above.

2.11. Retests

If the tests done to determine the mechanical properties, fails on even one of the specimens this test is to be repeated on each of two additional specimens taken from different pieces and the test results of both the specimens is to conform to the requirements. Even if one of the specimen fail to meet the requirements for a particular property, the entire lot is to be rejected.

2.12. Permissible Variations in Dimensions

The permissible variations in wall thickness and diameter are based on ordered thickness and are to be in compliance with the applicable ASTM designation for acceptance, but for all pipes, the minimum thickness is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

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3.1. Scope

3.1.1. The specifications given below cover seven (7) grades of seamless copper pipes designated as CuA, CuB, CuC, CuD, CuE, CuF and CuG.

3.1.2. The materials specified in this section are in substantial agreement with ASTM B75.

3.2. General

3.2.1. Grades CuA, CuB, CuC, CuD, CuE, CuF and CuG

Grades from CuA to CuG cover seamless copper pipes that are intended for being used in boiler feed water lines, plumbing, and other similar services. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application. Under these grades, tubes ordered are considered suitable for welding and brazing. Seamless round copper tube in standard pipe sizes and schedules is considered to be pipe and is specified in Section 2 of this chapter.

3.2.2. ASTM Designation

As per the Table 4.3.1, these grades are in substantial agreement with ASTM.

Table 4.3.1

INTLREG Grade	ASTM designation
CuA	B75, UNS C10100
CuB	B75, UNS C10200
CuC	B75, UNS C10300
CuD	B75, UNS C10800
CuE	B75, UNS C12000
CuF	B75, UNS C12200
CuG	B75, UNS C14200

3.3. Process of Manufacture

The manufacturing of the material is to be carried out by either hot or cold working operations or both. Then, unless otherwise specified, it is to be finished using appropriate cold working and annealing or heat treatment, as required to meet the specified properties. All pipes are to be furnished in the drawn-temper condition, (H55) and Hard-drawn temper (H80) may also be furnished. However, when pipe is required for bending, it is to be furnished with a bending temper, or annealed temper (O60). All pipes with working pressures over 10 bars (10.5 kgf/cm^2, 150 psi) are to be tested and inspected at the mills to the Surveyors satisfaction. When requested by the purchaser, the pipes are examined by the Surveyor. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

3.4. Marking

3.4.1. Manufacturer's Marking

On each length of the pipe, the name or brand of the manufacturer, the designation B75 and the test pressure are to be legibly marked by stamping or stenciled. If the pipes are with small-diameter and are bundled, the same information may be marked on a tag attached properly to each bundle.

3.4.2. INTLREG Markings

The INTLREG markings, indicating satisfactory compliance with to the Rules, and as furnished by the Surveyor, are also to be placed on the material near the markings specified in [3.4.1]] above.

The following details are to be shown on all materials which have been accepted:

a) INTLREG or International Registrar of Shipping marking.

b) Manufacturer's name or trade mark.

c) Grade of material or designation code.

d) Identification number and/or initials which will enable the full history of the item to be traced.

Identification is to be by rubber stamp or stencils. Hard stamping is not permitted

3.5. Chemical Composition

As detailed in Sec-2, Table 4.2.2, the material is to conform to the applicable chemical composition requirements.

3.6. Tension Test

3.6.1. Tension Test Specimens

Tensile test specimens are to be a full section of the pipe. For larger sizes, these specimens are to comprise of longitudinal strips cut from the pipe in line with ASTM E8.

3.6.2. Tensile Properties

The material is to conform to the applicable tensile properties requirements as given in Sec-2, Table 4.2.3.

3.7. Expansion Test

3.7.1. This test is required for those tubes which are manufactured in the annealed temper.

3.7.2. After annealing, specimens selected for test, are to withstand an expansion of the outside diameter when expanded by a tapered pin with 60-degree included angle to 30 % for tube over 19.0 mm (3/4 in.) in outside diameter and to 40% for smaller sized tube. The expanded tube is not to show cracking or rupture visible to the unaided eye.

3.8. Flattening Test

For pipe over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, instead of the expansion test, flattening test may be carried out. A section of 100 mm (4 in.) length is to be cut from the end of one of the lengths of the pipe. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at thrice the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested is not to develop cracks or defects visible to the unaided eye. During the flattening test, the specimens are to be slowly flattened by one stroke of the press.

3.9. Hydrostatic Test

3.9.1. Limiting Test Pressures

The equation given below may be used to determine an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi) and each length of the pipe is required to withstand it, without showing weakness or defects. Unless otherwise specified, no pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi). At the discretion of the manufacturer, annealed pipe with wall thickness up to 2.11 mm (0.083 in.) inclusive may be tested in the hard-drawn condition before annealing.

$$P = \frac{K \times S \times t}{(D - 0.8\, t)}$$

Where,

P = pressure, in bar (kgf/cm^2, psi)
S = allowable unit stress of the material, 41 N/mm^2 (4.22 kgf/mm^2, 6000 psi)
t = thickness of pipe wall, in mm (in.)
D = outside diameter of the pipe, in mm (in.)
K = 20 (200 for kgf/mm^2, 2 for psi / in.)

3.9.2. **Affidavits of Tests**

Surveyor may accept an affidavit covering the hydrostatic test wherein this test is done for each pipe as a regular procedure during the process of manufacture.

3.10. Number of Tests

The lot for the test is to comprise of tubes of the same size and temper. The lot size is to be of 4540 kg (10,000 lb) or a fraction thereof. From each of the lot, sample pieces are to be taken at random, as given in Table 4.3.2.

Table 4.3.2: Number of Sample Pieces

Number of Pieces in Lot	Number of Sample Pieces to Be Taken
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Where required, chemical analyses, tensile tests, expansion tests, flattening tests, bend tests, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test. For each length of the pipe, the hydrostatic test is to be done as specified in 3.9 of this section.

3.11. Retests

If tests done to determine the mechanical properties, fails on even one of the test are to be repeated on each of two additional specimens taken from different pieces and the test results of both the specimens is to conform with the requirements. Even if one specimen’s test result fails to meet the requirements for a particular property, the entire lot is to be rejected.

3.12. Permissible Variations in Dimensions

The permissible variations in wall thickness and diameter are based on ordered thickness and are to be in compliance with the applicable ASTM designation for acceptance, but for all pipes, the minimum thickness is not to be less than that required by the Rules for a specific application, regardless of prior acceptance.

SECTION 4 COPPER-NICKEL TUBE AND PIPE

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4.1. Scope

4.1.1. The materials specified in this section are in substantial agreement with ASTM B466 and B467.

4.1.2. This specification given here covers four (4) grades of seamless and welded copper-nickel tube and pipe designated as CNi1, CNi2, CNi3 and CNi4.

4.2. General

4.2.1. **Grades CNi1 and CNi2**

Grades CNi1 and CNi2 includes seamless copper-nickel tube and pipe that are intended for being used in general engineering applications requiring seawater corrosion resistance. Under these grades, tube and pipe ordered are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging. Tube is to be ordered to outer diameter and wall thickness specified by the purchaser and approved for the application.

4.2.2. **Grades CNi3 and CNi4**

Grades CNi3 and CNi4 includes welded copper-nickel pipe intended for being used in general engineering application that require seawater corrosion resistance. Under these grades, tube and pipe ordered are considered suitable for welding, and suitable for forming operations involving bending, flaring and flanging.

4.2.3. **ASTM Designation**

As per the Table 4.4.1, these grades are in substantial agreement with ASTM.

Table 4.4.1

INTLREG Grade	ASTM designation
CNi1	B 466, UNS C70600
CNi2	B 466, UNS C71500
CNi3	B 467, UNS C70600
CNi4	B 467, UNS C71500

4.3. Process of Manufacture

The manufacturing of the material is to be carried out by either by hot or cold working operations or both. Unless otherwise specified, tubing is to be finished using appropriate cold working or annealing or heat treatment, as required to meet the specified properties for either annealed or light drawn material. The light drawn properties apply only to grades CNi1 and CNi3 only.

4.3.1. Grades CNi1 and CNi2

Grade CNi1 may be supplied in either annealed (O60) or light drawn (H55) tempers. Grade CNi2 may be supplied in annealed (O60) temper only.

4.3.2. Grades CNi3 and CNi4

Grade CNi3 may be supplied in either the welded from annealed skelp temper (WM50), or the welded and fully finished as annealed temper (WO61). Grade CNi4 may be supplied in the welded and fully finished as annealed temper (WO61). Internal and external flash is to be removed by scarfing and there shall not be any crevice in the weld seam visible to the unaided eye.

4.4. Marking

Identification markings are to be clearly marked by stamping or stenciling on each length of tubular except that in the case of small-diameter tubular which is bundled, the required markings are to be placed on a tag securely attached to the bundle. The markings are to include the information given below in the respective order:

- Name or brand of the manufacturer
- INTLREG Grade or ASTM Designation and Grade
- Temper number
- Diameter
- Wall thickness or Pipe Schedule
- Test Pressure or the letters NDET
- INTLREG markings by the Surveyor
- Manufacturer's name or trade mark.
- Identification number and/or initials which will enable the full history of the item to be traced.

Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

4.5. Chemical Composition

4.5.1. Chemical Requirements

Material is to conform to the chemical requirements as specified in Table 4.4.2.

4.5.2. Chemical Analysis Sampling

Samples may be taken at any stage i.e. at the time when the metal is cast or when in semi-furnished product form, or from finished product itself as per sampling parameters specified in [4.11] of this section.

Table 4.4.2: Chemical composition for Copper Nickel Pipe and Tube

Element	Grade CNi1 Grade CNi3	Grade CNi2 Grade CNi4
Copper	Remainder	Remainder
Nickel + Cobalt	9.0 to 11.0	29.0 to 33.0
Iron	1.0 to 1.8	0.40 to 1.0
Manganese	1.0	1.0
Zinc	0.50	0.50
Lead	0.02	0.02
Carbon	0.05	0.05
Sulfur	0.02	0.02
Phosphorus	0.02	0.02
Note: Single values are maximum.		

4.6. Tension Test

4.6.1. Tension Test Specimens

Tensile test specimens are to be a full section of the pipe. For larger sizes, these specimens are to comprise of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

4.6.2. Seamless Tensile Properties

As given in Table 4.4.3, Seamless material is to conform to the applicable tensile properties requirements.

Table 4.4.3:

Temper Number	**Temper**	**Grade**	**Tensile Strength**, min. N/mm^2 (kgf/mm^2, ksi)	**Yield Strength**, min. N/mm^2 (kgf/mm^2, ksi)
060	Soft anneal	CNi1	260 (27, 38)	90 (9, 13)
		CNi2	360 (37, 52)	125 (13, 18)
H55	Light drawn	CNi1	310 (32, 45)	240 (25, 35)

4.6.3. Welded (WO61) Tensile Properties

The welded and fully finished pipe furnished in the annealed temper (WO61) is to be in compliance with the applicable requirements of tensile properties, yield and elongation as shown in Table 4.4.4 below.

Table 4.4.4:

Grade	**Outside Diameter**, mm (inch)	**Tensile Strength**, min. N/mm^2 (kgf/mm^2, ksi)	**Yield Strength**, min. N/mm^2 (kgf/mm^2, ksi)	**Elongation** %
CNi3	Up to 114 (4.5), incl. over 114 (4.5)	275 (28, 40)	105 (11, 15)	25
		260 (27, 38)	90 (9, 13)	25
CNi4	Up to 114 (4.5), incl. over 114 (4.5)	345 (35, 50)	140 (14, 20)	30
		310 (32, 45)	105 (11, 15)	30

4.6.4. Welded (WO50) Tensile Properties

As specified in Table 4.4.5 below, welded pipe fabricated from annealed strip (WO50) is to be in compliance with the applicable requirements of tensile strength and yield.

Table 4.4.5

Grade	**Outside Diameter**, mm (inch)	**Tensile Strength**, min. N/mm^2 (kgf/mm^2, ksi)	**Yield Strength**, min. N/mm^2 (kgf/mm^2, ksi)
CNi3	up to 114 (4.5), incl.	310 (32, 45)	205 (21, 30)

4.7. Expansion Test

This test is required for tubes manufactured in the annealed temper.

4.7.1. Grades CNi1 and CNi2

As per ASTM B153, annealed specimens which are selected for testing for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30%. The expanded specimen is not to show any signs of cracking or rupture visible to the unaided eye.

4.7.2. Grades CNi3 and CNi4

Annealed specimens selected for testing as per ASTM B153, for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing, are to withstand an expansion of the outside diameter to 30%. As welded specimens are to withstand an expansion of the outside diameter to 20% when similarly tested. The expanded specimen is not to show any signs of cracking or rupture visible to the unaided eye.

4.8. Flattening Test

For pipes over 100 mm outside diameter (4 in. nominal size) in the annealed condition, instead of the expansion test, flattening test may be carried out. For this, a section of at least 450 mm (18 in.) length specimen is to be flattened so that a gauge set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested is not to develop cracks or defects visible to the unaided eye. During the flattening test, the specimens are to be slowly flattened by one stroke of the press. Specimens not initially in the annealed temper (O60) are to be annealed before flattening.

4.9. Nondestructive Examination

4.9.1. Nondestructive Electric Test (NDET)

In accordance with ASTM E243 or equivalent, all tubes are to be eddy-current tested, for Electromagnetic (Eddy- Current) Examination of Copper and Copper-Alloy Tubes or, alternatively, when indicated, may be hydrostatically tested in accordance with Chapter 4 Section 3.9. A calibration reference standard is to be made from a length tube of same type, wall thickness and outside diameter as that to be tested. The standard is to have transverse notches of depth that when rounded to 0.25 mm (0.001 in.) represents 22% of the wall thickness. The notch depth tolerance is to be 0.013 mm (0.0005 in.). Tubulars producing as signal equal to or greater than the calibration defect are to be rejected.

4.9.2. Radiographic Examination

The welds of Grades CNi3 and CNi4 are to be examined by radiography, when specified.

4.10. Hydrostatic Test

4.10.1. **Limiting Test Pressures**

Hydrostatic testing may be performed as an alternate to the eddy-current test. Each tube that is tested to stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm2 (4.92 kgf/mm2, 7000 psi), determined by the following equation for thin hollow cylinders under tension. The tube is not to be tested at a hydrostatic pressure of 69 bar (70.3 kgf/cm2, 1000 psi) unless so specified.

$$P = \frac{K \times S \times t}{(D - 0.8\,t)}$$

Where,

P = pressure in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 48 N/mm2 (4.92 kgf/mm^2, 7000 psi)

t = thickness of tube wall, in mm (in.)

D = outside diameter of the tube, in mm (in.)

K = 20 (200 for kgf/mm^2, 2 for psi / in.)

4.10.2. **Affidavits of Tests**

Surveyor may accept an affidavit covering the hydrostatic test wherein this test is carried out for each pipe as a regular procedure during the process of manufacture.

4.11. Number of Tests

4.11.1. The lot for the test is to comprise of tubes of the same size and temper. The lot size is to be 5000 kg (10000 lb) or a fraction thereof. For Grades CNi3 and CNi4 over 100 mm (4 in.) in diameter, the lot size is to be 9100 kg (20000 lb) or a fraction thereof. Sample pieces are to be taken for test purposes from each lot as given in Table 4.4.6 below.

Table 4.4.6

Number of Pieces in Lot	Number of Sample Pieces to Be Taken
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

4.11.2. Where required, chemical analyses, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be made on each of the sample pieces selected for test.

4.11.3. For each length of the pipe, the hydrostatic test or when specified, a radiographic examination is to be carried out.

4.12. Retests

If tests are made to determine the mechanical properties, fails on even one of the specimens these tests are to be repeated on each of two additional specimens taken from different pieces and the test results of both the specimens are to comply with the requirements. Even if the test results of one of the specimen’s fails to meet the requirements for a particular property, the entire lot is to be rejected.

4.13. Finish

The finish and workmanship of tubes selected for testing are to be examined. These are to be free from cracks, injurious surface flaws and similar defects to the extent that it can be determined by visual or NDET examination. Tubes are to be clean and free from any foreign material that would render them unfit for the intended use.

4.14. Dimensions and Tolerances

Dimensions and tolerances of each sample selected for testing is to be examined.

4.14.1. Diameter

The tubular outside diameter is not to vary from the specified values by more than the amounts shown below in Table 4.4.7. When all minus diameter tolerances or all plus diameter tolerances are specified, the tolerances shown may be doubled.

Table 4.4.7: Average Diameter

Specified Diameter, mm (inch)	**Tolerance**, Plus and Minus, mm (inch)
Up to 15.9 (5/8), incl.	0.064 (0.0025)
Over 15.9 (5/8) to 25.4 (1.0), incl.	0.076 (0.003)
Over 25.4 (1.0) to 50 (2.0), incl.	0.102 (0.004)
Over 50 (2.0) to 76 (3.0), incl.	0.127 (0.005)
Over 76 (3.0) to 100 (4.0) incl.	0.152 (0.006)
Over 100 (4.0) to 125 (5.0), incl.	0.203 (0.008)
Over 125 (5.0) to 150 (6.0), incl.	0.229 (0.009)
Over 150 (6.0) to 200 (8.0), incl.	0.254 (0.010)
Over 200 (8.0) to 255 (10.0), incl.	0.330 (0.013)
Over 255 (10.0) to 305 (12.0), incl.	0.381 (0.015)
Over 305 (12.0)	0.50%

4.14.2. Roundness

As determined at any one cross section, the difference between the major diameter and the minor diameter is not to be more than that specified in Table 4.4.8..

Table 4.4.8: Roundness

Grade	**t/D(2)**	**Tolerance %(3)**
CNi1(1) and CNi2(1)	0.01 to 0.03, incl.	1.5
	Over 0.03 to 0.05, incl.	1
	Over 0.05 to 0.10, incl.	0.8(4)
	Over 0.10	0.7(4)
CNi3 and CNi4	All ratios	3

Note:
1. Drawn, unannealed straight lengths, wall thickness not less than 0.41 mm (0.016 in.)
2. Ratio of wall thickness to outside diameter
3. Percent of outside diameter, to nearest 0.025 mm (0.001 in.)
4. Or 0.051 mm (0.002 in.) whichever is greater

4.14.3. **Wall Thickness Tolerances**

For all tubulars, the permissible variations in wall thickness are based upon the ordered thickness and are to be in compliance with that given in the applicable ASTM designation for acceptance.

4.14.4. **Length**

The length of tubulars is not to be less than that specified when measured at a temperature of 20°C (68°F) and may exceed specified values by the amounts shown. The tolerance for stock lengths and for specific lengths with ends is 25.4 mm (1.0 in.).

Table 4.4.9: Length Tolerance, mm (inch)

Specified Lengths, L	**Grades CNi1 and CNi2**			**Grades CNi3 CNi4**
	≤ 25 mm (1 in.)	> 25.4 mm (1 in.) < 100 mm (4 in.)	> 100 mm (4 in.)	
L ≤150 mm (6 in.)	0.8 (1/32)	1.5 (1/16)	-	1.5 (1/16)
150 < L ≤ 600 mm (6 in. < L ≤ 2 ft)	1.5 (1/16)	2.5 (3/32)	3.0 (1/8)	2.5 (3/32)
600 < L ≤ 2000 mm (2 < L ≤ 6 ft)	2.5 (3/32)	3.0 (1/8)	6.0 (1/4)	3.0 (1/8)
2000 < L ≤ 4000 mm (6 < L ≤ 14 ft), incl.	6.0 (1/4)	6.0 (1/4)	6.0 (1/4)	6.0 (1/4)
L > 4000 mm (14 ft)	12.0 (1/2)	12.0 (1/2)	12.0 (1/2)	12.0 (1/2)

Note:
1. The length tolerance is applicable only to full-length pieces.

4.14.5. **Squareness of Cut**

The departure from squareness of the end of the tube is to not exceed the values given in the Table 4.4.10.

Table 4.4.10

Specified Outside Diameter	**Tolerance**
Up to 15.9 mm (5/8 in.) incl. of CNi1 and CNi2	0.25 mm (0.010 in.)
All diameters of CNi3and CNi4.	0.016 mm/mm (0.016 in./in.) of diameter

4.14.6. **Straightness Tolerances**

For seamless tubulars of any drawn temper, 6.0 mm (0.25 in.) to 100 mm (3.5 in.) in outside diameter, inclusive, but not for redrawn, extruded or annealed tubulars, the straightness tolerances are as shown in Table 4.4.11.

For lengths greater than 3000 mm (10 ft), the maximum curvature is to not exceed 12.5 mm (1/2 in.) in any 3000 mm (10 ft) portion of the total length.

Table 4.4.11: Maximum Curvature

Length	**Depth of Arc**, mm (inch)
>1000 mm (3 ft) ≤ 2000 mm (6 ft)	5.0 (3/16)
> 2000 mm (6 ft) ≤ 2500 mm (8 ft)	8.0 (5/16)
> 2500 mm (8 ft) ≤ 3000 mm (10 ft)	12.0 (1/2)

SECTION 5 SEAMLESS RED-BRASS PIPING

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5.1. Process of Manufacture

The material is to be manufactured by either hot or cold working operations or both. Unless otherwise specified, it is to be finished using appropriate cold working and annealing or heat treatment, as may be required to meet the specified properties. All pipes are to be furnished in the annealed condition. The degree of anneal is to be sufficient to show complete recrystallization and to enable the pipe to meet the test requirements prescribed in these specifications. The pipe may be furnished in the drawn-temper condition instead of the annealed condition if so specified by the purchaser. All pipes for working pressures over 10 bar (10.5 kgf/cm2, 150 psi) are to be tested and inspected at the mills to the satisfaction of the Surveyor. The pipes are examined by the Surveyor when requested by the purchaser. The pipe is to be commercially round and is to be free from defects that interfere with normal applications.

5.2. Marking

5.2.1. Manufacturer's Marking

The name or brand of the manufacturer, the designation B43 and the test pressure is to be legibly marked by stamping or stenciling on each length of pipe. If the pipes with small-diameter are bundled, the same information may be marked on a tag attached properly to each bundle.

5.2.2. INTLREG Markings

The INTLREG markings, in satisfactory conformity to the Rules, and those furnished by the Surveyor, are also to be placed on the material near the markings specified below.

a) Name or brand of the manufacturer
b) INTLREG Grade or ASTM Designation and Grade
c) Temper number
d) Wall thickness or Pipe Schedule
e) Diameter
f) Test Pressure or the letters NDET
g) INTLREG markings by the Surveyor
h) Manufacturer's name or trade mark.
i) Identification number and/or initials which will enable the full history of the item to be traced.
j) Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

5.3. Scope

The specifications cover seamless red-brass pipe in all standard sizes, both regular and extra strong.

5.4. Chemical Composition

The material is to conform to Table 4.5.1. as to chemical composition requirements.

Table 4.5.1

Element	Composition
Copper	84.00% to 86.00%
Lead	0.06% max.
Iron	0.05% max.
Zinc	remainder
Total other elements	0.15%

Regular analysis is to be made only for the elements specifically mentioned in Table 4.5.1. However, if other elements are also present or indicated in the course of routine analysis, further analysis is to be made to determine that the total of these other elements is not in excess of the limit specified.

5.5. Expansion Test

After annealing, specimens are selected for expansion test and are to be able to withstand 25% expansion of the inside diameter when expanded using a tapered pin with a 60-degree included angle. The expanded tube is not to show any sign of cracking or rupture visible to the unaided eye.

5.6. Flattening Test

For pipes over 114.3 mm outside diameter (4 in. nominal size) in the annealed condition, instead of the expansion test, flattening test be carried out. For this, a section of 100 mm (4 in.) length is to be cut from the end of one of the lengths of the pipe. This 100 mm (4 in.) specimen is to be flattened so that a gauge set at thrice the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested shall not develop cracks or defects visible to the unaided eye. During the flattening test, the specimens are to be slowly flattened by one stroke of the press.

5.7. Mercurous Nitrate Test

A test sample 150 mm (6 in.) in length is to be taken from each pipe selected for test and, after proper cleaning, is required to withstand, without cracking, an immersion of 30 minutes in an aqueous mercurous nitrate solution containing 10 grams of mercurous nitrate and 10 milliliters of nitric acid (specific gravity 1.42) per liter of solution. Immediately after removing from the solution, the sample is to be wiped free of excess mercury and examined for cracks.

5.8. Bend Test

In the case of pipe required for bending, annealed full sections of the pipe are to stand being bent cold through an angle of 180 degrees around a pin, the diameter of which is 1.5 times the inside diameter of the pipe, without cracking on the outside of the bent portion. This test is only applicable to sizes 50.8 mm (2 in.) and under in outside diameter.

5.9. Hydrostatic Test

5.9.1. Limiting Test Pressures

Each length of pipe is to stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi). No pipe is to be tested beyond a hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi).

$$P = \frac{K \times S \times t}{(D - 0.8\,t)}$$

Where,

P = pressure, in bar (kgf/cm^2, psi)

S = allowable unit stress of the material, 48 N/mm^2 (4.92 kgf/mm^2, 7000 psi)

t = thickness of pipe wall, in mm (in.)

D = outside diameter of the pipe, in mm (in.)

K = 20 (200 for kgf/mm^2, 2 for psi)

5.9.2. Affidavits of Tests

Surveyor may accept an affidavit covering the hydrostatic test wherein this test is carried out for each pipe as a regular procedure during the process of manufacture.

5.10. Number of Tests

The lot for the test is to comprise of pipe of the same size and temper. The lot size is to be 2270 kg (5000 lb) or a fraction thereof for pipe up to 48.3 mm O.D. (1.5 in. nominal size) incl.; 4550 kg (10,000 lb) or a fraction thereof for pipe over 48.3 mm O.D. (1.5 in. nominal size) to 114.3 mm O.D. (4 in. nominal size) 18,150 kg (40,000 lb) or a fraction thereof for pipe over 114.3 mm O.D. (4 in. nominal size). For test purposes sample pieces are to be taken from each lot as given in Table 4.5.2:

Table 4.5.2

Number of Pieces in Lot	Number of Sample Pieces to Be Taken
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

Where required, expansion, flattening and bend tests are to be made on each of the sample pieces selected for test. Each length of the pipe is to be subjected to the hydrostatic test specified in [5.9.1] of this section.

5.11. Retests

If the results of the tests made to determine the mechanical properties, fails to meet the requirements on even one of the specimens this test is to be repeated on each of two additional specimens taken from different pieces and the test results of both the specimens is to comply with the requirements. Even if the test result of one specimen fails to meet the requirements for a particular property, the entire lot is to be rejected.

5.12. Permissible Variations in Dimensions

The permissible variations in wall thickness are based on ordered thickness and are to be in compliance with the applicable ASTM designation for acceptance, but for all pipes, the minimum thickness is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

SECTION 6 BRONZE CASTINGS

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6.1. For General Purposes

6.1.1. Tensile Properties

The tensile properties of material is given in Table 4.6.1. The bronze castings are to be free from injurious defects.

Table 4.6.1

Type	**Tensile Strength** Minimum, N/mm^2 (kgf/mm^2, psi)	**Elongation** in 50 mm (2 in.) Minimum percent	Stamping
1	205 (21, 30000)	15	**IR/1**

6.1.2. Number of Tests

One tension test is to be made from each melt and the tension test specimen is to be machined to the dimensions shown in Ch 2, Sec 1, Figure 2.1.1 (Round Specimen Alternative C).

6.2. Propellers and Propeller Blades

6.2.1. Foundry Approval

6.2.1.1. Approval

Propellers and all propeller components are to be cast by INTLREG-approved foundries. Foundries are to demonstrate that they have the necessary facilities and skilled personnel to enable proper manufacture of propellers which satisfy these Rules.

Once approval is obtained, it will remain valid for 5 Years, subjected to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted to monitor vital aspects of casting production, including but not restricted to mold preparation and chaplet positioning; pouring times and temperatures; mold breakout; repairs; heat treatment and inspection at any time.

6.2.1.2. Scope of the Approval Test

The following aspects of manufacture are to be taken into consideration:

- Casting types and sizes
- Material specifications
- Repair procedures
- Ladle capacities
- Manufacturing practices and procedures for melting and pouring, molding, heat treatment, welding repairs, hot and cold straightening, destructive and NDT methods and equipment, and chemical and metallographic capabilities.

Cast coupons of the propeller materials involved are to be tested in order to ensure that composition and mechanical properties comply with these Rules.

6.2.1.3. Quality Control

Additionally, information about the company's facilities and Organization, especially as they relate to quality control, is also required to be presented, including certification in accordance with national or international standards, such as ISO standards.

6.2.2. Castings

The castings are to be free from defects.

6.2.3. Chemical Composition

The % chemical composition is to be in compliance with an approved specification, four of which are listed in the Table 4.6.2, as representative of bronze alloys used for propellers and propeller blades. Also refer to [6.2.11] of this section. For chemical analysis, samples may be taken from test coupons or representative castings.

Table 4.6.2: Chemical Composition

Element	Type 2 Mn Bronze	Type 3 Ni-Mn Bronze	Type 4 Ni-Al Bronze	Type 5 Mn-Ni-Al Bronze
Copper	55-60	53.5-57	78 min	71 min
Tin	1.50 max	1.0 max	-	-
Lead	0.40 max	0.20 max	0.03 max	0.03 max
Iron	0.4–2.0	1.0–2.5	3.0–5.0	2.0–4.0
Manganese	1.5 max	2.5–4.0	3.5 max	11.0–14.0
Aluminum	0.5–1.5	2.0 max	8.5–11.0	7.0–8.5
Nickel	0.5 max	2.5–4.0	3.0–5.5	1.5–3.0
Silicon	-	-	-	0.10 max
Zinc	Remainder	Remainder	-	-
Total others	-	-	0.50 max	0.50 max

6.2.4. Zinc Equivalent

Type 2 and Type 3 chemical composition of alloys are to be so controlled that the zinc equivalent, based on the equation given below, does not exceed 45 %.

$$\%\ \text{zinc equivalent} = 100 - \left(\frac{100 \times \%\ \text{copper}}{100 + A}\right)$$

Where,

A is the algebraic sum of the following zinc replacement factors:

Tin	=	$+1.0 \times \%$ Sn
Iron	=	$- 0.1 \times \%$ Fe
Aluminum	=	$+ 5.0 \times \%$ Al
Lead	=	0.0
Manganese	=	$- 0.5 \times \%$ Mn
Nickel	=	$- 2.3 \times \%$ Ni

6.2.5. **Alternative Zinc Equivalent**

The foregoing ‘‘zinc equivalent’’ requirement will be waived when the alpha content of a specimen taken from the end of the acceptance test bar is determined by microscopic measurement to be 20% or more.

6.2.6. **Tensile Properties**

The material represented by the test specimens machined from separately cast test coupons is to be in compliance with the minimum tensile properties given in Table 4.6.3.

Table 4.6.3: Tensile Properties of Separately Cast Test Coupons

Type	**Tensile Strength**		**Yield Strength**		**Elongation**
	N/mm^2	(kgf/mm^2, ksi)	N/mm^2	(kgf/mm^2, ksi)	min. percent (5d Gauge Length)
2	450	(46, 65)	175	(18, 25)	18
3	515	(53, 75)	220	(22.5, 32)	16
4	590	(60, 86)	245	(25, 36)	15
5	630	(64, 91)	275	(28, 40)	18

Notes

1. These properties are generally not representative of the tensile properties of the propeller casting itself, which could be significantly lower than that of a separately cast test coupon.
2. For integral-cast test coupons, the tensile requirements are to be specially approved.
3. Yield strength is to be determined as specified in Ch 2, Sec 1, [1.7.2].

6.2.7. Test Specimens

The tensile test specimen machined from the test-coupon casting is to be of an approved form. The tensile test specimen is to be machined to the dimensions specified in Ch 2, Sec 1, Figure 2.1.1 (Round Specimen Alternative C).. The test coupons may be cast separately or remain integrated with the casting.

6.2.8. Separately Cast Coupons

Separately cast test coupons as shown in Figure 4.6.1 (test coupon as per the broken line may also be accepted) or in line with an International or recognized National standard, are to be poured from the same ladles of metal used to pour the castings, and into molds of the same material as used for the casting. A test coupon is to be furnished for each ladle where more than one ladle of metal is needed for casting. Surveyor has to be provided with satisfactory evidence to identify the test coupons as representing the material to be tested.

6.2.9. Integrally Cast Coupons

Integrally cast coupons are to be furnished as coupons cast on the surfaces of the castings.

6.2.10. Number of Tests

For each casting when integrally cast test coupons are provided, one tension test is to be made and same is to be made from each ladle when separately cast test coupons are provided. The test results are to be in compliance with the requirements as specified in [6.2.6].

6.2.11. Special Compositions

Other bronze alloys have been developed and proven to be satisfactory by tests and service experience may be considered on case-to-case basis by the Society. When propeller materials not meeting the chemical compositions in [6.2.3] are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

6.2.12. Inspection and Repair

A visual examination of the entire surface of the finished propeller is to be carried out. For critical areas and suspect areas, liquid penetrant examination is to be made on all propellers over 2 m (78 in.) in diameter. All inspections and repairs are to be to the satisfaction of the Surveyor.

Controllable Pitch Propeller (CPP) blades are to undergo the following in addition to the requirements above:

- CPP blades (ISO 484/1&2) each of them is to be weighed and recorded for all accuracy classes. The deviation of each blade should be less than the maximum permissible balancing mass as defined by ISO 484/1 & 2 or as specified on the approved drawing.
- Each bolt hole area of a CPP blade is to be air tested in the final delivery condition. The air tightness test is to be conducted with a 5 bar pressure held for 15 minutes, followed by a soap and water check around the bolt hole areas. Or alternatively a 1.5 times hydrostatic working pressure test for 30 minutes minimum as specified in the assembly drawing may be carried out.
- A liquid penetrant examination of the flange and bolt hole area of the CPP blade is to be made regardless of blade size. The PT is to be witnessed by attending Surveyor(s) and should be free from any significant surface defects. Acceptance Criteria shall be in compliance as per National, International standards.

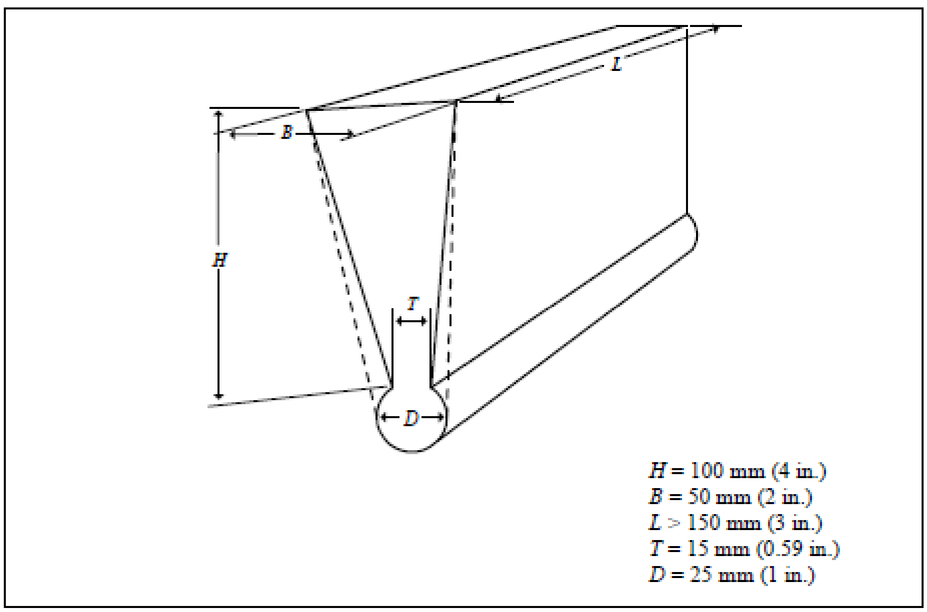

Figure 4.6.1: Test Coupons

6.2.13. Marking

The appropriate identification markings including manufacturer's name are to be stamped on each propeller or propeller blade in such location so that it is clearly identifiable after finishing and assembly. Apart from this, in case of Type 2, 3, 4 and 5 castings, are to be stamped **IR/2**, **IR/3**, **IR/4** or **IR/5** respectively, to indicate satisfactory compliance with Rule requirements. Bronze alloys manufactured as per the specifications other than those covered herein in accordance with the permissibility expressed in [6.2.11] shall have IR/S stamped on them with the applicable specification number.

CHAPTER 5 TESTS, INSPECTION AND APPROVAL

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1.1. Test and Test Data

1.1.1. Witnessed Tests.

The marking (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under INTLREG's Quality Assurance Program.

1.1.2. Manufacturer's Data.

The marking (M) indicates that the manufacturer is to provide the test data without verification by a Surveyor of the procedures used or the results obtained.

1.1.3. Other Tests.

The marking (A) is for those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and the witnessed random tests are in accordance with the requirements of the Rule.

1.2. List

The table below gives the list of destructive and non-destructive tests that are required for the materials represented in Part 2 and the respective responsibility for verification.

The representation given below will be followed in the list:

- **W = Witnessed Tests**
- **M = Manufacturer's Data**
- **A = Other Tests**

Chapter 1, Section 1: **General**	
Chapter 1, Section 1, 1.11	Through Thickness Properties (W)

Chapter 1, Section 2: **Ordinary Strength Hull Structural Steel**	
Chapter 1, Section 2, [2.3.1]	Ladle Analysis (M)
Chapter 1, Section 2, [2.3.2]	Product Analysis (M)
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Chapter 1, Section 2, [2.5.2]	Tension Test (W)
Chapter 1, Section 2, [2.6.1]	Charpy V-notch Impact Test (W)

Chapter 1, Section 3: **Higher Strength Hull Structural Steel**	
Chapter 1, Section 3, [3.1.2]	Ladle Analysis (M)
Chapter 1, Section 3, [3.1.2]	Tension Test (W)
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Chapter 1, Section 5, [5.3.1]	Charpy V-notch Impact Test (W)
Chapter 1, Section 5, [5.3.2]	Drop-weight Test (NDTT) (W)

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Chapter 1, Section 6, [6.4]	Tension Test (W)
Chapter 1, Section 6, [6.7.6]	Magnetic Particle Inspection (A)
Chapter 1, Section 6, [6.7.6]	Dye Penetrant Inspection (A)
Chapter 1, Section 6, [6.7.6]	Ultrasonic Inspection (A)

Chapter 1, Section 7: **Hull Steel Forgings**	
Chapter 1, Section 7, [7.1.4]	Ladle Analysis (M)
Chapter 1, Section 7, [7.4]	Tension Test (W)
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Chapter 2, Section 2: **Steel Plates for Machinery, Boilers, and Pressure Vessels**	
Chapter 2, Section 2, [2.1.4.1]	Ladle Analysis (M)
Chapter 2, Section 2, [2.1.4.2]	check Analysis (M)
Chapter 2, Section 2, [2.1.5.1], [2.1.5.2], [2.1.5.3]	Test Specimens (W)
Chapter 2, Section 2, [2.1.6.1], [2.1.6.2], [2.1.6.3]	Tensile Properties (W)

Chapter 2, Section 2, [2.2]: **Steel Plates for Intermediate Temperature Service**	
Chapter 2, Section 2, [2.2.3]	Chemical Composition (M)
Chapter 2, Section 2, [2.2.5]	Tensile Properties (W)

Chapter 2, Section 2, [2.3]: **Steel Plates for Intermediate and Higher-Temperature Service**	
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Chapter 2, Section 2, [2.3.6]	Tensile Properties (W)

Chapter 2, Section 2, [2.4]: **Steel Plates for Intermediate and Lower-Temperature Service**	
Chapter 2, Section 2, [2.4.4]	Chemical Composition (M)
Chapter 2, Section 2, [2.4.6]	Tensile Properties (W)

Chapter 2, Section 2, [2.5]: **Materials for Low Temperature Service [Below -18°C (0°F)]**	
Those listed in Chapter 1, Section 5 and Chapter 2, Section 2, [2.5]	

Chapter 2, Section 3: **Hot-rolled Steel Bars for Machinery**	
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Chapter 2, Section 5: **Seamless Forged-Steel Drums**	
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Chapter 2, Section 6: **Steel Machinery Forgings**	
Chapter 2, Section 6, [6.1.3], [6.2.1.3], [6.3.1.3], [6.4.1.3]	Chemical Composition (M)
Chapter 2, Section 6, [6.1.6], [6.2.4], [6.3.4], [6.4.4]	Tensile Properties (W)
Chapter 2, Section 6,[6.3.6.1]	Surface Inspection of Tail shaft Forgings (W)
Chapter 2, Section 6, [6.3.6.2]	Ultrasonic Examination of Tail Shaft Forgings (A)
Chapter 2, Section 6, [6.1.8.2], [6.2.4.2], [6.3.5.4], [6.4.4.2]	Hardness Test (W)

Chapter 2, Section 7: **Steel Castings for Machinery, Boilers, and Pressure Vessels**	
Chapter 2, Section 7, [7.1.2]	ASTM designations
Chapter 2, Section 7, [7.4]	Tensile Properties (W)
Chapter 2, Section 7, [7.8]	Magnetic Particle or Dye Penetrant Inspection (W)

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Chapter 2, Section 8, [8.3]	Chemical Composition (M)
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Chapter 2, Section 10, [10.4]	Chemical Composition (M)

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Chapter 2, Section 11, [11.4.3]	Product Test (W) – Refer 2-2-1/Tables 1 & 2

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SECTION 2 PROCEDURE FOR THE APPROVAL OF MANUFACTURERS OF SEMI-FINISHED PRODUCTS FOR HULL STRUCTURAL STEEL

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2.1. Scope

This Section provides the definite requirements, as specified in Ch 1, Sec 1, [1.1.2], for the approval of manufacturers of semi-finished products such as ingots, slabs, blooms and billets for hull structural steels which can also be supplied in the partially-rolled condition.

The manufacturer shall be capable of consistently supplying satisfactory products following effective process and production controls in operation and the manufacturer approval procedure is intended to verify the same, as detailed in Ch 1, Sec 1, [1.1.2.2].

2.2. Documents to be Submitted for Approval Application

2.2.1. Initial approval

For initial approval, the manufacturer is to submit request of approval together with proposed approval test program to the INTLREG .Refer [2.3.1] below and also general information relative to:

a) Manufacturer’s Name and address, location of the workshops, general background information, dimension of the works, estimated total annual yield of semi-finished products for shipbuilding and other applications, as deemed relevant.

b) Organization and Quality:
- Organizational chart;
- Staff employed;
- Organization of the Quality control department and its staff;
- Qualification of the personnel involved in activities related to the quality of the products;
- Certification of compliance of the quality system with IS0 9001 or 9002, if any;
- Approval certificates granted by other Classification Societies, if any.

c) Manufacturing Facilities:
- Manufacturing process flow chart;
- Origin and storage of raw materials;
- Equipment used for systematic control during fabrication;
- Storage of semi-finished products.

d) Details of Inspections and Quality Control Facilities:
- Details of system used for identification of materials at the different stages of manufacturing;
- Detailed list of quality control procedures;
- Equipment for chemical analyses, mechanical tests and metallography and calibration procedures;
- Equipment for non-destructive examinations.

e) Types of Steel (normal or higher strength), Type of Products (ingots, slabs, blooms, billets), Range of Thickness and Target Material Properties are as given below:
- Range of chemical composition and target analyses, including micro alloying and residual elements, grain refining, for various grades of steel if the range of chemical composition depends on thickness and supply condition, these are to be specified, or as appropriate;
- Target maximum carbon equivalent according to IIW (International Institute of Welding) formula;
- Target maximum P_{cm} content for higher strength grades with low carbon content C < 0.13%;
- Production statistics of the chemical composition and, if available at rolling mills,

mechanical properties (ReH, Rm, A% and KV). The statistics are required to demonstrate the manufacturer's capability to produce steel products as per the requirements.

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

g) Approval certificates already granted by the other Classification Societies and documentation of approval tests performed.
h) If any part of the manufacturing process is carried out in some other companies or manufacturing unit, additional information required by INTLREG is to be included.

2.2.2. **Changes to the approval conditions**

Where cases discussed in (a) through (c) are applicable, the manufacturer is to submit the documents required in [2.2.1] together with the request of changing the approval conditions to the INTLREG

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

However, if for the same type of product, the documents are duplicated by the ones at the previous approval, part or all of them may be omitted, except the approval test program .Refer [2.3.1] below.

2.3. Approval tests

2.3.1 Extent of the approval tests

The extent of the test program is detailed in [2.3.6] below. On the basis of the preliminary information submitted by the manufacturer, the test program may be modified.

A reduction in the indicated number of casts, product thicknesses and types to be tested or complete omission of the approval tests may be considered, in the following cases:

i) Approval already granted by other Classification Societies and documentation of approval tests performed.
ii) Types of steel to be approved and availability of long-term historical statistic results of chemical properties and of mechanical properties tested on rolled products.
iii) Change of the approval conditions.

For newly developed types of steel or manufacturing processes, an increase of the number of casts and thicknesses to be tested may be required.

2.3.2 Approval test program

Where numbers of tests differ from those given in [2.3.6] below, the program is to be confirmed by INTLREG prior to the commencement of the tests.

2.3.3 Approval survey

Surveyor witnesses the approval tests at the manufacturer's plant. A plant inspection while operation is required to be carried out by the Surveyor. If the testing facilities are unavailable at the works, the tests are to be carried out at the INTLREG recognized laboratories.

2.3.4 Selection of the test product

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

INTLREG will require selection of one test product of average thickness for initial approval.

For the test product, the selection of the casts is to be based on the typical chemical composition, with particular regard to the specified C_{eq} or P_{cm} values and grain refining micro-alloying additions.

2.3.5 Position of the test samples

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

2.3.6 Tests on base material

2.3.6.1 Type of tests

For the approval of the manufacturing process of semi-finished products, the following tests to be carried out

i) Chemical analysis is to be complete and including micro alloying elements.
ii) Sulphur prints and photo macrograph (acid etched) pictures)

For initial approval and for any upgrade of the approval, additionally INTLREG will require full tests indicated in Ch 5 [3.3] at rolling mill on the minimum thickness semi-finished product.

In case of multi-caster work, full tests on finished products shall be carried out for one caster and reduced tests (chemical analysis Sulphur print and photo macrograph picture) for the others. On the basis of the technical characteristics of the casters, the selection of the caster shall be evaluated, and on case by case basis it is needed to be performed at rolling mill on products manufactured from the minimum thickness semi-finished product.

2.3.6.2 Test specimens and testing procedure

As a rule the test specimens and testing procedures are to be in accordance with Chapter-1, Sec-1 with particular attention to the following:

a) *Chemical Analyses*: Ladle and product analysis are to be reported. 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, Ca, and, for steel made in electric or open-hearth furnace, Sb and B in addition.

b) *Sulphur Prints and Photo macrograph (Acid Etched) Pictures*: Sulphur prints and photo macrograph pictures are to be taken from product edges which are at 90 degrees angle to the axis of the ingot or slab (full transverse cross-section). These Sulphur prints and photo macrograph pictures are to be approximately

600 mm long, taken from the center of the edge chosen (i.e., on the ingot centerline) and are to include the full product thickness.

2.4. Results

2.4.1. Before final approval, all the test results are assessed for compliance with the relevant Rules and Regulations. Based on the findings, limitations or testing conditions may be specified in the approval document as deemed appropriate.

2.4.2. All the information required under Sec-3, [3.2] of this chapter applicable to the products submitted to the tests, is to be collected and incorporated in a single document by the manufacturer along with test results and operation records relevant to steel making, casting, and where applicable, rolling and heat treatment of the tested products.

2.5. Certification

2.5.1. Approval

Approval by INTLREG is granted upon satisfactory completion of the survey. The approval certificate shall state the following:

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

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.

2.5.2. List of approved manufacturers

On approval, the manufacturer shall be entered in a list containing the types of steel and main conditions of approval.

2.6. Renewal of approval

2.6.1. The validity of the approval is five (5) years maximum and its renewable is subject to an audit and assessment of the result of satisfactory survey in the course of the preceding period. The Surveyor's report confirming no process changes, along with mechanical property statistical data for various approved types, is to be made accessible to the INTLREG Engineering / Materials department for review and issuance of renewal letter/certificate.

2.6.2. If the renewal audit cannot be completed within time for operational reasons, the manufacturer will still be considered as approved, if agreement to such extension of audit date is provided in the original approval. In this case, the extension of approval will be backdated to the original renewal date.

2.6.3. Manufacturers who have not produced the approved types and products prior to renewal may be required to carry out approval tests, unless the results of production of similar types of products during the period are evaluated by INTLREG and found acceptable for renewal..

Note: The provisions for renewal of approval are also applicable to all grades and products which were approved by INTLREG prior to an implementation of Ch 1, Sec 1, [1.1.2] and this Section, regardless of any validity of prior approval.

2.7. Withdrawal of approval

Under the following circumstances, the approval may be withdrawn before the expiry of the validity period:

a) In-service failures traceable to product quality
b) Nonconformity of the product revealed during fabrication and construction
c) Discovery of failure of the manufacturer's quality system
d) Changes made by the manufacturer, without prior agreement of INTLREG, to the extent of the approval defined at the time of the approval
e) Evidence of major nonconformities during testing of the products.

SECTION 3 PROCEDURE FOR THE APPROVAL OF MANUFACTURERS OF ROLLED HULL STRUCTURAL STEEL

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3.1. Scope

As per Ch 1, Sec 1, [1.1.2], this section, provides specific requirements for the approval of manufacturers of rolled hull structural steel.

The procedure followed for the manufacturer approval is intended to verify the capability of manufacturer to furnish satisfactory products in a consistent manner under effective processes and production controls during operation including programmed rolling.

3.2. Documents to be submitted for Approval of Application

3.2.1. **Initial Approval**

For initial approval, the manufacturer is to submit to INTLREG request of approval together with proposed approval test program .Refer [3.3.1] below) and also general information relative to:

a) Manufacturer's Name and address, location of the workshops, general background information, dimension of the works, estimated total annual yield of finished products for shipbuilding and for other applications, as deemed useful.

b) Organization and Quality
- Organizational chart
- Staff employed
- Quality control department and its staff;
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with IS0 9001 or 9002, if any.
- Approval certificates already granted by other Classification Societies, if any.

c) Manufacturing Facilities
- Manufacturing process flow chart;
- Origin and storage of raw materials
- Equipment used for systematic control during fabrication
- Storage of finished products

d) Details of Inspections and Quality Control Facilities
- Details of system used for identification of materials at the different stages of manufacturing
- Detailed list of quality control procedures;
- Equipment for chemical analyses, mechanical tests and metallography and relevant calibration procedures;
- Equipment for non -destructive examinations

e) Type of Products (plates, coils, sections), Grades of Steel, Range of Thickness and Target Material Properties are as given below:

- 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
- Target maximum carbon equivalent according to IIW (International Institute of Welding) formula
- Target maximum P_{cm} content for higher strength grades with low carbon content $C < 0.13\%$
- Production statistics of the chemical composition and mechanical properties (ReH, Rm, A% and KV). The statistics are required to demonstrate the

manufacturer’s capability to produce steel products as per the requirements.

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

g) Reheating and Rolling
- Type of furnace and treatment parameters
- Rolling: reduction ratio of slab/billet/bloom to finished product thickness rolling and finishing temperatures
- Capacity of the rolling stands
- Descaling treatment during rolling

h) Heat Treatment
- Type of furnaces, heat treatment parameters with the relevant records
- Precision and calibration of temperature control devices

i) *Programmed Rolling.* For products delivered in the thermo-mechanical rolling (TM) condition or controlled rolling (CR), the following additional information on the programmed rolling schedules is to be provided:

- Description of the rolling process
- Normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them
- Control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

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

k) If some part of the manufacturing process is carried out in other companies or manufacturing units, additional information required by INTLREG is to be included.

l) Approval certificates already granted by other IACS Member Societies and documentation of approval tests performed.

3.2.2. **Changes to the Approval Conditions**

Where any one or more of cases discussed below from (a) through (e) are applicable, the manufacturer is to submit the documents required in [3.2.1] above together with the request of changing the approval conditions to INTLREG.

a) Change of the manufacturing process (steel making, casting , rolling and heat

treatment)
b) Change of the chemical composition, added element, etc.
c) Change of the maximum thickness (dimension)
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, if for the same type of product, the documents are duplicated by the ones at the previous approval, part or all of them may be omitted, except the approval test program .Refer [3.3.1] below.

3.3. Approval Tests

3.3.1. **Extent of the Approval Tests**

In 3.3.6 and 3.3.7, the extent of the test program is specified. On the basis of the preliminary information submitted by the manufacturer, the test program may be amended.

Particularly, a reduction in the indicated number of casts, steel plate thicknesses and grades to be tested or complete omission of the approval tests may be considered, taking into account:

i) Approval already granted by other Classification Societies and documentation of approval tests performed
ii) Grades of steel to be approved and availability of long term historical statistic results of chemical and mechanical properties
iii) Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the target analyses, method of manufacture and condition of supply are similar.
iv) 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.
v) Change of the approval conditions

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

The rolled steel manufacturer is required to get the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with [3.3.6] and [3.3.7] in case of multi-source slabs or change of slab manufacturer. Complete omission or slight reduction of the approval tests may be considered, taking into account previous approval as follows:

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

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

3.3.2. **Approval Test Program**

Before the commencement of the tests, the program is to be confirmed by INTLREG, where numbers of tests are different from those detailed in [3.3.6] and [3.3.7].

3.3.3. **Approval Survey**

The Surveyor shall witness the approval tests at the manufacturer's plant. An inspection of the paint while in operation is to be carried out by the Surveyor. If the testing facilities are unavailable at the works, the tests are to be carried out at recognized laboratories.

3.3.4. **Selection of the Test Product**

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

Additionally, INTLREG will require selection of one test product of average thickness for initial approval.

The selection of casts for the test product is to be based on the typical chemical composition, with special regard to C_{eq} or P_{cm} values and grain refining micro-alloying additions.

3.3.5. **Position of the Test Samples**

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

The position of the samples to be taken in the length of the rolled product, "piece", defined in Ch 2, Sec 3, [3.1] (top and/or bottom of the piece) and as given in Table 7.3.1, the direction of the test specimens with respect to the final direction of rolling of the material.

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

a) *Plates and flats with a width $\geq$ 600 mm*. The test samples are to be taken from one end at a position approximately midway between the axis in the direction of rolling and the edge of the rolled product .Refer Figure 7.3.1(a). Unless otherwise agreed the tension test specimens are to be prepared with their longitudinal axes transverse to the final direction of rolling.

b) *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 [Refer Figure 7.3.1 (b), (c) and (d)] 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 centerline or axis [Refer Figure 7.3.1(c)]. The tension test specimens may be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling

c) *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.

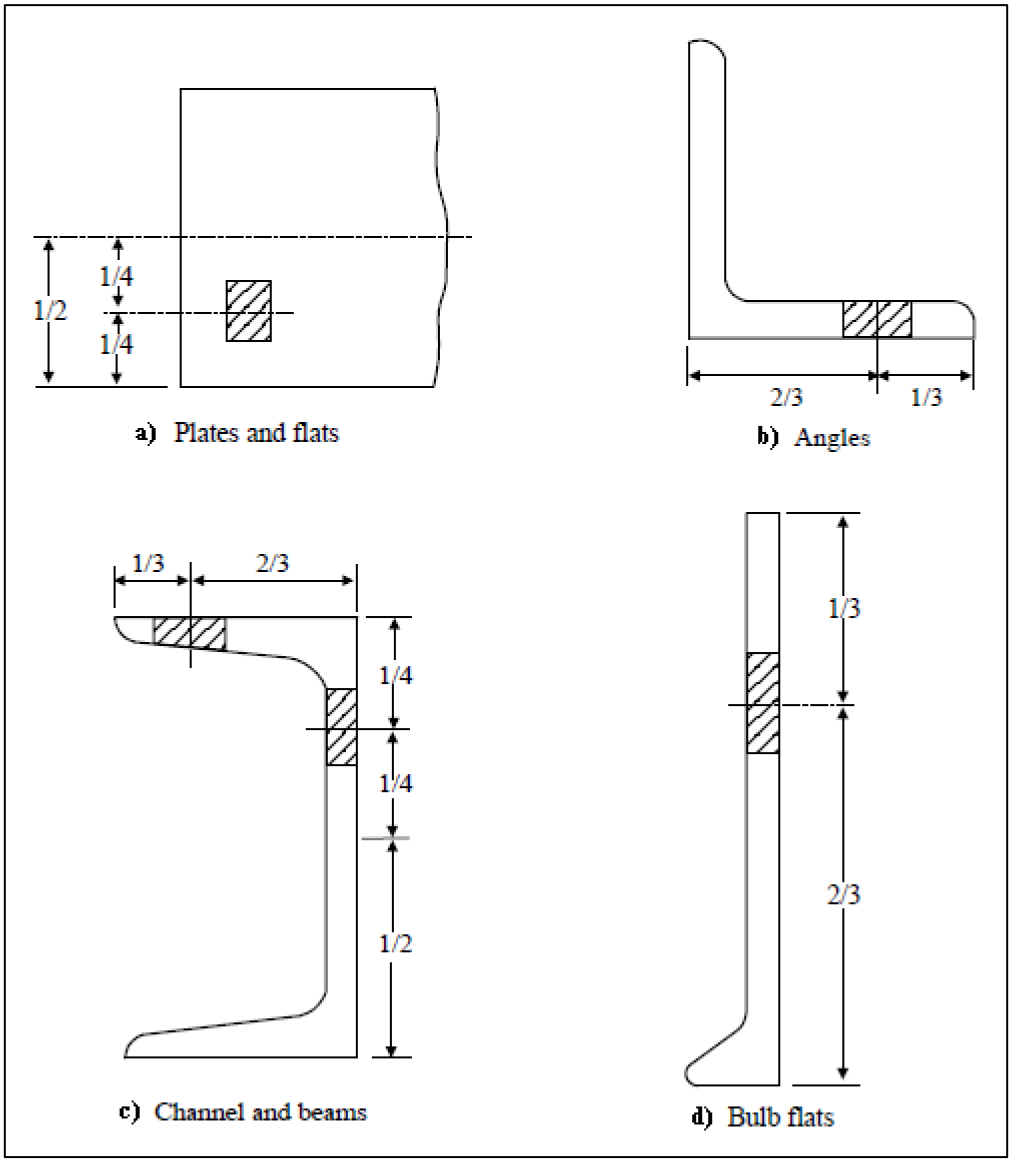

Figure 7.3.1: Test Samples

3.3.6. **Tests on Base Material**

3.3.6.1. Type of Tests

The types of tests given in Table 7.3.1 are to be conducted on the base material.

Table 7.3.1: Tests for Rolled Products Manufacturer Approval

Type of Test	Position of the Samples and Direction of the Test Specimen(1)	Remarks			
Tensile test	Top and bottom transverse(2)	ReH, Rm, A_5(%), RA(%) are to be reported			
Tensile test (stress relieved) For TM steel only	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 (0°C)			
A, B, AH32, AH36, AH40, AQ43-70		+20	0	–20	
D, DH32, DH36, DH40, DQ43-70		0	–20	–40	
E, EH32, EH36, EH40, EQ43-70		0	–20	–40	–60
FH32, FH36, FH40, FQ43-70		–20	–40	–60	–80
A, B, AH32, AH36, AH40, AQ43-70	Top – transverse(4)	+20	0	–20	
D, DH32, DH36, DH40, DQ43-70		0	–20	–40	
E, EH32, EH36, EH40, EH43-70		–20	–40	–60	
FH32, FH36, FH40, FQ43-70		–40	–60	–80	
Impact tests(3) on strain aged specimens(5) for grades:	Top – longitudinal	Testing temperature (0°C)			
AH32, AH36, AH40, AQ43-70		20	0	–20	
D, DH32, DH36, DH40, DQ43-70		0	–20	–40	
E, EH32, EH36, EH40, EQ43-70		–20	–40	–60	
FH32, FH36, FH40, FQ43-70		–40	–60	–80	
Chemical analysis (%)(6)	Top	Complete analysis including micro alloying elements			
Sulfur prints and photo macrographs	Top				
Micro examination	Top				
Grain size determination	Top	For fine grain steel only			
Drop weight test(4)	Top	For grades E, E32, E36, E40, , F32, F36, F40only			
Through thickness tensile tests	Top and bottom	For grades with improved through thickness properties only			

Notes:

1. For hot rolled strips Refer [3.3.6.2] of this section.
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. The impact energy value is reported for information only. However, if impact values obtained during qualification testing do not meet the requirements of Ch 1, Sec 2, [2.6] and Table 1.2.5, Ch 1, Sec 3, Table 1.3.4 or Ch 1, Sec 3, Table 1.4.4, as applicable, additional testing may be requested.
6. Besides product analysis, ladle analysis is also required

3.3.6.2. Test Specimens and Testing Procedure

The test specimens and testing procedures are to be in accordance with Ch 1, Sec 1 in addition to compliance with the following requirements:

a) *Tensile Test*
- One additional tensile specimen is to be taken from the middle of the strip constituting the coil for plates made from hot rolled strip.

- Multiple flat specimens, collectively representing the full thickness, can be used, for plates with thickness higher than 40 mm, when the capacity of the available testing machine is inadequate to allow the use of test specimens of full thickness. Two round specimens with the axis located at one quarter and at mid-thickness can be taken as an alternative.

b) Impact Test
- One additional set of impact specimen is to be taken from the middle of the strip constituting the coil for plates made from hot rolled strip.

- One additional set of impact specimens is to be taken with the axis located at mid-thickness for plates having thickness higher than 40 mm (1.575 in.).

- Along with the determination of the energy value, the percentage crystallinity and lateral expansion are to be reported.

c) *Chemical Analyses*. Report of both the ladle and product analyses are to be submitted to the Surveyor. The material for the product analyses should be taken from the tensile test specimen. 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 in electric or open-hearth furnace, Sb and B.

d) *Sulphur Prints:* From plate edges Sulphur prints and photo macrograph pictures are to be taken from the ingot or slab. These are to be perpendicular to the axis of the ingot or slab. Approximately these Sulphur prints are to be 600 mm long, taken from the center of the edge chosen (i.e., on the ingot centerline) and are to include the full plate thickness.

e) *Micrographic Examination.* The micrographs are to be representative of the full thickness. For thick products, at least three (3) examinations are to be made at surface, one quarter and mid-thickness of the product. All photomicrographs are to be taken at ×100 magnification and where ferrite grain size exceeds ASTM 10, in addition at ×500 magnification. Ferrite grain size should be determined for each photomicrograph.

f) *Drop Weight Test:* Drop weight 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 carried out in accordance with in Ch 1, Sec 1, [1.11]. The test results are to be in line with, where applicable, with the requirements specified for the different steel grades in Chapter 1.

3.3.6.3. Other Tests

Other tests such as large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.), CTOD test or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2, (Materials and Welding), or when deemed necessary by INTLREG.

3.3.7. **Weldability Tests**

3.3.7.1. General

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

3.3.7.2. Preparation and Welding of the Test Assemblies

Generally, following tests are to be carried out:

i) One (1) butt weld test assembly welded with a heat input approx. 15 kJ/cm
ii) One (1) butt weld test assembly welded with a heat input approx. 50 kJ/cm

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that the impact specimens will be in the longitudinal direction.

The edge preparation is preferably to be 1/2V or K.

As far as practicable the welding procedure is to be as per normal welding practice used at the yards for the type of steel in question.

The welding parameters such as consumables designation and diameter, pre-heating temperatures, inter-pass temperatures, heat input, number of passes, etc. are to be reported.

3.3.7.3. Type of Tests

The following test specimens are to be taken from the test assemblies:

a) One (1) cross weld tensile test

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

c) Hardness tests HV 5 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:
   - Fusion line
   - HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

   The maximum hardness value is to be not higher than the following:

- Steel with a specified min. yield strength $R_{eH} \le 420$ MPa:
  350HV10
- Steel with a specified min. yield strength 420 MPa < $R_{eH} \le 690$ MPa:
  420 HV10

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

3.3.7.4. Other Tests

In the case of newly developed type of steel, outside the scope of Part 2, (Materials and Welding), or when deemed necessary by INTLREG, additional tests such as cold cracking tests (CTS, Cruciform, Implant, Tekken, Bead-on plate), CTOD, or other tests may be required.

3.4. Results

Before final approval, all the test results are evaluated for compliance with the Rules. Depending on the test results, limitations or testing conditions, as appropriate may be specified in the approval document.

All information as required in [3.2] is incorporated in a single document by the manufacturer along with test results and operation records relevant to steel making, casting, and when applicable, rolling and heat treatment of the tested products as these are applicable to the products submitted to the tests.

3.5. Certification

3.5.1. Approval
Approval by INTLREG is granted only after satisfactory completion of the survey.

3.5.2. List of Approved Manufacturers
A list containing the types of steel and the main conditions of approval is maintained in the list of approved manufacturers.

3.6. Renewal of Approval

3.6.1. The validity of the approval is five (5) years maximum and its renewable is subject to audit and assessment of the result of satisfactory survey at the time of the preceding period. For review and issuance of renewal letter/ certificate, the Surveyor's report confirming no process changes, along with mechanical property statistical data for various approved grades, is to be made available to the INTLREG Engineering/Materials department for review and issuance of renewal letter/ certificate.

3.6.2. If for operational reasons, the renewal audit cannot be carried out within the validity of approval, the manufacturer will still be considered as being approved, if agreement to such extension of audit date is provided for in the original approval. In such case, the extension of approval will be back dated to the original renewal date.

3.6.3. Manufacturers who have not produced the approved grades and products during the period preceding the renewal may be required to carry out approval tests, unless the results of production of similar types of products during the period are assessed by INTLREG and found acceptable for renewal.

Note: The provisions for renewal of approval are also applicable to all grades and products which were approved by INTLREG before implementation of Ch 1, Sec 1, [1.2] and this Section, regardless of any validity of prior approval.

3.7. Withdrawal of the Approval

Withdrawal of approval before the expiry of the validity period may be considered in the following cases:

i) In-service failures traceable to product quality
ii) Noncompliance with the product revealed during fabrication and construction
iii) In case where the manufacturer's quality system fails
iv) Changes made by the manufacturer, without prior agreement of INTLREG, to the extent of the approval defined at the time of the approval
v) Proof of major non-conformities during product testing.

SECTION 4 PROCEDURE FOR THE APPROVAL OF MANUFACTURERS OF HULL STRUCTURAL STEELS INTENDED FOR WELDING WITH HIGH HEAT INPUT

Contents

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4.2. Application for Certification 427
4.3. Confirmation tests 427
4.4. Results 429
4.5. Certification 430
4.6. Grade Designation 430

4.1. Scope

The weldability confirmation procedures of normal and higher strength hull structural steels are specified in Ch 1, Sec 2 and Ch 1, Sec 3 and are specified in this Section for welding with high heat input over 50 kJ/cm (127 kJ/in.). This procedure is to be generally applied at manufacturer's option and is valid for certifying that the steel has acceptable weldability for high heat input welding under testing conditions.

Demonstration of conformance to the requirements of this Section approves a particular steel mill to manufacture grades of steel to the exact chemical composition range, melting practice, and processing practice to which compliance was established. However, the approval scheme does not qualify the welding procedures to be undertaken by shipyards.

4.2. Application for Certification

The manufacturer is to submit a request for certification of the proposed weldability test program (Refer 4.3.2 below) and technical documents to INTLREG that are relevant to the following:

i) Outline of steel plate to be certified

- Material grade
- thickness range
- de-oxidation practice
- intended range of chemical composition
- fine grain practice
- intended maximum C_{eq} and P_{cm}
- production statistics of mechanical properties (tensile and Charpy V-notch impact tests), if any.

ii) Manufacturing control points to prevent toughness deterioration in heat affected zones of high heat input welds, relevant to chemical elements, casting, steel making, rolling, heat treatment etc.

iii) Welding control points to improve joint properties on strength and toughness.

4.3. Confirmation tests

4.3.1. Range of Certification

For steel grades range of certification is to be based on the following, unless otherwise agreed by INTLREG:

i) Approval tests on normal strength level cover only that strength level.

ii) Approval tests on the lowest and highest toughness levels cover the intermediate toughness level.

iii) For high tensile steels, approval tests on one strength level cover strength level immediately below it.

iv) Tests may be separately conducted, provided the same manufacturing process is applied.

v) At the discretion of INTLREG, certification and documentation of confirmation tests performed by another Classification Society may also be accepted.

4.3.2. Weldability Test Program

The extent of the test program is as specified in [4.3.5], but in accordance with the contents of certification it may be modified. For newly developed types of steel, welding consumable and welding method or when deemed necessary by INTLREG, additional test assemblies and/or test items may be required. Where the content of tests varies from those stated in [4.3.5], the program is to be confirmed by INTLREG before the tests are carried out.

4.3.3. Test Plate

An INTLREG approved process is is to be followed in the manufacture of test plates in accordance with the requirements of Section 2 & 3. For each manufacturing process route, two test plates with different thickness are to be chosen by the manufacturer. The thicker plate (t) and thinner plate (less than or equal to t/2) are too be proposed by the manufacturer.

At the discretion of INTLREG, minor changes in manufacturing processing (e.g. within the TMCP process) may be considered for acceptance without testing.

4.3.4. Test Assembly

One butt weld assembly (welded with heat input 50 kJ/cm or more) is to be made with the weld axis transverse to the plate rolling direction.

Test Assembly dimensions are to be sufficient to take all the required test specimens as specified in 4.3.3. The welding procedures should be in accordance with the normal practices applied at shipyards for the test plate concerned, and include the following:

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

4.3.5. Examinations and Tests for the Test Assembly

The test assembly is to be examined and tested as detailed below, unless otherwise agreed by INTLREG.

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

ii) *Macroscopic test.* One macroscopic photograph is to be representative of transverse section of the welded joint and is too shown no cracks, lack of fusion and other injurious defects.

iii) *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 centerline, fusion line and at a distance 2, 5, 10 and a minimum 20 mm (0.8 in.) from the fusion line. The test result is provided for information purpose only.

iv) *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 centerline, fusion line and each 0.7 mm (0.28 in.) 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.

v) *Transverse tensile test.* Two transverse (cross weld) tensile specimens are to be taken from the test assembly and these along with the testing procedures are to conform to the requirements of Ch 3,.Sec 4

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

vi) *Bend test.* Two transverse (cross weld) test specimens are to be taken from the test assembly and bent on a mandrel with diameter of four (4) times specimen thickness. Bending angle is to be at least 120 degrees. Test specimens are to conform to the requirements of Ch 3,.Sec 4

For plate thickness up to 20 mm (0.8 in.), one face-bend and one root-bend specimens or two side bend specimens are to be taken. For plate thickness over 20 mm (0.8 in.), two side-bend specimens are to be taken. After testing, the test specimens shall not reveal any crack or other open defect in any direction greater than 3 mm (0.12 in.).

vii) *Impact test.* Charpy V-notch impact specimens (three specimens for one set) are to be taken within 2 mm (0.08 in.) below plate surface on face side of the weld with the notch at right angles to the plate surface.

One set of the specimen's transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and a minimum 20 mm (0.8 in.) 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 particular steel grade.

For steel plates with thickness greater than 50 mm (2.0 in.) or one side welding for plate thickness greater than 20 mm (0.8 in.), one additional set of the specimen is to be taken from the root side of the weld with the notch located at each of the same positions as for the face side.

The average impact energy at the specified test temperature is to conform to the requirements of Chapter-1, Table 1.2.5 or Table 1.3.4, 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 INTLREG.

viii) *Other tests.* 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 may be required at the discretion of INTLREG. Refer [4.3.2].

4.4. Results

The manufacturer is to submit the complete test report to INTLREG including all the results and required information relevant to the confirmation tests specified in [4.3]. It is to be reviewed and evaluated by INTLREG as per this weldability confirmation scheme.

4.5. Certification

Where the test report is found satisfactory, INTLREG will issue a certificate wherein following information is to be included:

a) Manufacturer
b) Grade designation with notation of heat input (refer to [4.6])
c) Fine grain practice
d) De-oxidation practice
e) Plate thickness tested
f) Welding process
g) Condition of supply
h) Actual heat input applied.
i) Welding consumable (manufacturer, brand, grade).

4.6. Grade Designation

After the certificate is issued, 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 (762 kJ/in.) applied]. The value of this notation is not to be less than 50 and every 10 added.

SECTION 5 RECOMMENDATION FOR NONDESTRUCTIVE EXAMINATION OF MARINE STEEL CASTINGS

Contents

5.1. Scope 432
5.2. Surface Inspection 432
5.3. Volumetric Inspection 435

5.1. Scope

5.1.1. Unless otherwise approved or specified, this recommendation contains general guidance for the non-destructive examination methods, the extent of examination and the minimum recommended quality levels to be be complies with for marine steel castings.

5.1.2. This document has recommendations on “Surface Inspections” .Refer [5.2] by visual examination, liquid penetrant testing, magnetic particle testing and “Volumetric Inspection” Refer[5.3] by ultrasonic testing and radiographic testing.

5.1.3. The requirements for machinery components, this recommendation may apply correspondingly considering their materials, shapes, kinds and stress conditions being subjected.

5.1.4. Examination of the castings shall be carried out in the final delivery condition. Refer [5.2.5.2] and [5.3.4.2] for specific requirements.

5.1.5. The manufacturer has to submit the documentation of the results of intermediate inspections which have been performed upon request of the Surveyor.

5.2. Surface Inspection

5.2.1. General

5.2.1.1. Surface inspections are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.

5.2.1.2. The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to conform to a recognized National or International Standard.

5.2.1.3. Personnel engaged in visual examination are to have sufficient knowledge and experience. Those engaged in magnetic particle testing or liquid penetrant testing are to be qualified in accordance with National/ International standards.

5.2.2. Products

5.2.2.1. The accessible surfaces of the steel castings are to be subjected to a 100% visual examination by the attending Surveyor.

5.2.2.2. Surface inspections by magnetic particle and/or liquid penetrant methods apply to the hull steel castings indicated in Fig. 7.5.1 to Fig. 7.5.6 of this Section.

5.2.3. Location for Surface Inspections

5.2.3.1. Surface inspections are to be carried out at the locations detailed below:

- Accessible fillets and changes of section
- Where surplus metal has been removed by scarfing, flame cutting, or arc-air gouging
- In way of weld repairs
- In way of fabrication weld preparation, for a band width of 30 mm (1.2 in.)

5.2.3.2. The quality levels mentioned below are considered for magnetic particle testing (MT) and/or liquid penetrant testing (PT):

- Level MT1/PT1 – fabrication weld preparation and weld repairs.
- Level MT2/PT2 – other locations specified in [5.2.3.1].

The required quality level is to be shown on the manufacturer's drawings.

5.2.4. Surface Condition

The surfaces of castings are to be examined and are to be free from dirt, grease, scale or paint and are to be shot blasted or ground.

5.2.5. Surface Inspection

5.2.5.1. The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with recognized national or international standards. Magnetic particle inspection is to be carried out with the following exceptions, when liquid penetrant testing is to be permitted:

- Austenitic stainless steels
- Interpretation of open visual or magnetic particle indications
- At the instruction of Surveyor.

5.2.5.2. Unless otherwise specified in the order, the magnetic particle test is to be performed on a casting in the final delivery condition and final thermally treated condition or within 0.3 mm (0.012 in.) of the final machined surface condition for AC techniques [0.8 mm (0.03 in.) for DC techniques.

5.2.5.3. Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor.

5.2.5.4. For magnetic particle testing, the contact between the casting and the clamping devices of stationary magnetization benches to avoid local overheating or burning damage in its surface is to be given special attention. On finished machined items, prods are not permitted.

5.2.5.5. When indications are detected after the surface inspection, the acceptance or rejection is to be decided as per [5.2.6].

5.2.6. Acceptance Criteria

5.2.6.1. Acceptance Criteria – Visual Inspection

All castings shall be free of cracks, crack-like indications, laps, seams, hot tears, folds or other injurious indications. Thickness of the remains of sprues, heads or burrs is to be within the casting dimensional tolerance. Upon Surveyor's request, additional tests like magnetic particle, liquid penetrant and ultrasonic testing may be required in order to do a more detailed evaluation of surface irregularities.

5.2.6.2. Acceptance Criteria – Magnetic Particle Testing and Liquid Penetrant Testing

The definitions given below are applicable as relevant to indications:

- *Linear indication.* An indication in which the length is at least thrice the width.
- *Nonlinear indication.* An indication of circular, or elliptical shape with a length less than three times the width.
- *Aligned indication.* Three or more indications in a line, separated by 2 mm

(0.08 in.) or less edge-to-edge.

- *Open indication.* This indication is visible even after removal of the magnetic particles and/or that can be detected by the use of contrast dye penetrant.
- *Non-open indication.* This indication that is not visually detectable after removal of the magnetic particles and/or that cannot be detected by the use of contrast dye penetrant.
- *Relevant indication.* An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications with dimensions greater than 1.5 mm (0.06 in.) are to be considered relevant.

For evaluating indications, the surface is to be divided into reference band length of 15 cm (6 in.) for level MT1/PT1 and into reference areas of 225 cm^2 (35 in^2) for level MT2/PT2. The band length and/or area are to be taken in the most unfavorable location relative to the indication being assessed.

The allowable size and number of indications in the reference band length and/or area is given in Table 7.5.1. Hot tears and cracks are not acceptable.

5.2.7. Rectification of Defects

Defects and unacceptable indications are to be rectified as detailed in [5.2.7.2] and as given below.

5.2.7.1. Defective parts of material shall be removed by chipping and grinding, or by arc air-gouging and grinding. All grooves are to have a bottom radius of approx. thrice the groove depth and should be smoothly blended to the surface area with a finish equal to the adjacent surface.

5.2.7.2. Repairs by welding are defined as given below:

Major repairs:

- Where the depth is greater than 25% of the wall thickness or 2.5 cm whichever is the less, or
- Where the total weld area on a casting exceeds 2% of the casting surface, or
- Where the weld area (length × width) exceeds 1250 cm^2 (*Note:* where a distance between two welds is less than their average width, they are considered as one weld)

Minor repairs:

- Where the total weld area (length × width) exceeds beyond 5 cm^2.
  Cosmetic repairs:

- All other welds.
  a) Approval of Major repairs shall be given before the repair is carried out. The repair should be carried out prior to final furnace heat treatment.
  b) Minor repairs do not require approval before the repair is executed but should be recorded on a weld repair sketch as a part of the manufacturing procedure documents. Prior to final furnace heat treatment, these repairs may be carried out.
  c) Before the repair is executed, cosmetic repairs do not require approval but should be recorded on a weld repair sketch and may be carried out after final furnace heat treatment but are subject to a local stress relief heat treatment.

Thermal methods of metal removal should only be allowed prior to the final heat treatment. After heat treatment only, chipping or grinding should be allowed. Weld repairs should be appropriately classified. Parts which are repaired should be examined by the same method as at initial inspection as well as by additional methods as required by the surveyor.

5.2.8. Record

The record of the test results of surface inspections are to be recorded with the following items:

a) Date of testing
b) Product number for identification
c) Names and qualification level of inspection personnel
d) Grade of steel
e) Kind of product
f) Kind of testing method
- For magnetic particle testing: method of magnetizing, test media and magnetic field strength
- For liquid penetrant testing: test media combination

g) Heat treatment
h) Stage of testing
i) Locations for testing
j) Surface condition
k) Testing condition
l) Test standards used
m) Statement of acceptance/non acceptance
n) Details of weld repair including sketch Results

Table 7.5.1: 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** mm (in.) (2)
MT1/PT1	4 in a 15 cm (6 in.) length	Linear	4(1)	3 (0.12)
		Nonlinear	4(1)	5 (0.20)
		Aligned	4(1)	3 (0.12)
MT2/PT2	20 in a 225 cm^2 (35 in^2) area	Linear	6	5 (0.2)
		Nonlinear	10	7 (0.28)
		Aligned	6	5 (0.2)

Notes:
1. 30 mm (1.2 in.) min. between relevant indications.
2. In weld repairs, max. dimension is to be < 2 mm (0.088 in.)

5.3. Volumetric Inspection

5.3.1. General

5.3.1.1. Volumetric inspection is to be done by ultrasonic testing by contact method with straight beam and/or angle beam technique.

5.3.1.2. The apparatus, testing procedures and conditions of ultrasonic testing are to conform to the recognized National or International standards. The DGS (distance-gain size) procedure is to be applied using straight beam probes and/or angle beam probes with 1 to 4 MHz and an inspection should be carried out using a twin crystal 0° probe for near surface scans [25 mm (in.)] along with a 0° probe for the rest of the volume. Fillet radii should be examined using 45°, 60° or 70° probes.

5.3.1.3. Radiographic testing is to be carried out in accordance with an approved plan.

5.3.1.4. Personnel engaged in ultrasonic or radiographic testing are to be qualified as per National/ International Standards. The qualification is to be verified by valid certificates.

5.3.2. Products

5.3.2.1. Volumetric inspection by ultrasonic or radiographic testing is applicable to the hull steel castings indicated in Fig.7.5.1 to Fig.7.5.6 of this Section.

5.3.2.2. The list of castings is not definitive. Criteria for the examination of other castings not indicated in these guidelines/ recommendations will be subject to prior agreement

5.3.3. Location for Volumetric Inspection

5.3.3.1. Volumetric inspection is to be carried out in line with an approved inspection plan. The extent of the examination, the examination procedure, the quality level or, if necessary, levels for different locations of the castings are to be specified in the inspection plan.

5.3.3.2. Ultrasonic testing is to be carried out in the following locations:

- All accessible fillets and changes of section
- In way of fabrication weld preparation at a distance of 50 mm from the edge
- Those subjected to subsequent machining (including bolt holes)
- In way of weld repairs where original defect was detected by ultrasonic testing

5.3.3.3. The quality levels to be considered for ultrasonic testing (UT) is detailed as below:

Level UT1:

- 50 mm (2 in.) depth from the final machined surface including bolt holes
- Fabrication weld preparation for a distance of 50 mm (2 in.)
- Fillet radii for a depth of 50 mm (2 in.) and within distance of 50 mm (2 in.) from the radius end

Level UT2:

- Other locations

The required quality levels are to be provided in the manufacturer’s drawings.

5.3.4. Surface Condition

5.3.4.1. Examinations of the surfaces of castings are to be carried out in such manner that adequate coupling can be established between probe and the casting and that excessive wear of the probe can be avoided. The surfaces are to be free from dirt, grease, scale or paint.

5.3.4.2. The ultrasonic testing is to be carried out after the steel castings have been machined to a condition appropriate for this type of testing and after the final heat treatment. After removal of the oxide scale by either shot blasting methods or flame descaling, the black castings are to be inspected.

5.3.5. Acceptance Criteria

Acceptance criteria of volumetric inspection by ultrasonic testing are shown in Table 7.5.2.

5.3.6. Record

The record of the test results of volumetric inspection are to be recorded with the following information:

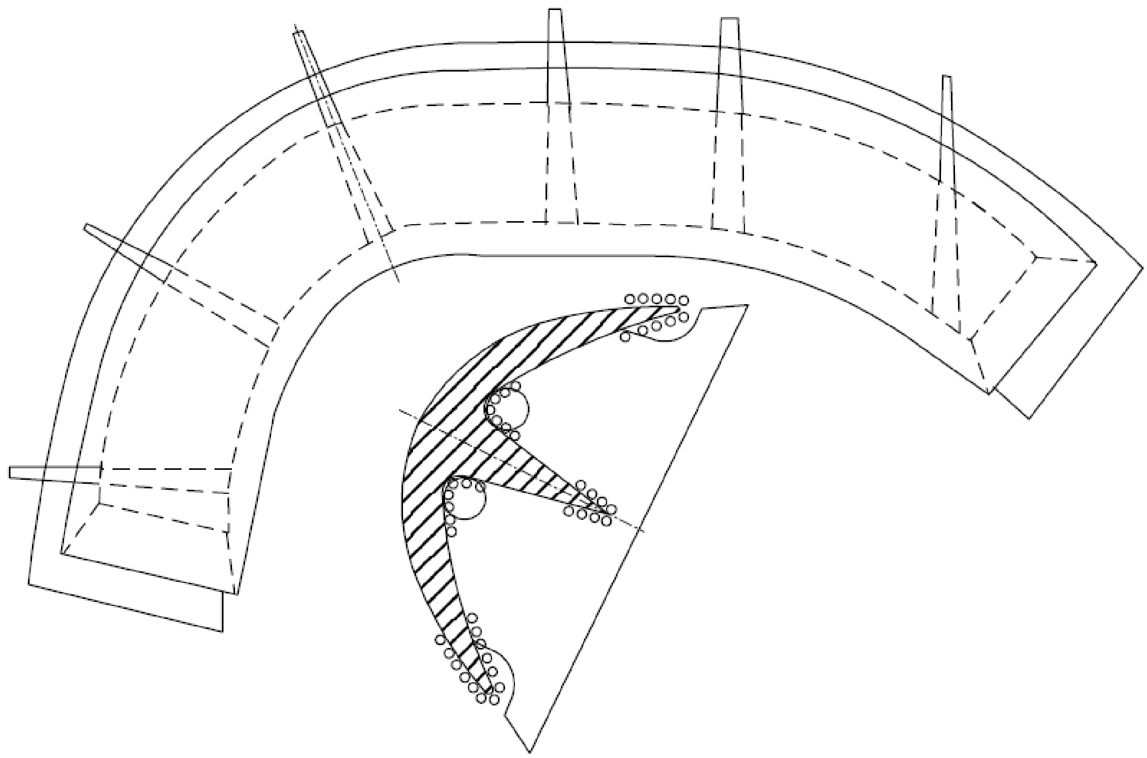
a) Date of testing
b) Names and qualification level of inspection personnel
c) Grade of steel
d) Kind of testing method
e) Kind of product
f) Product number for identification
g) Heat treatment
h) Stage of testing
i) Locations for testing
j) Surface condition
k) Testing condition
l) Test standards used
m) Statement of acceptance/non acceptance
n) Results

Table 7.5.2: Acceptance Criteria for Steel Castings

Quality Level(1)	Allowable Disk Shape According to DGS(2)	Max. Number of Indications to be Registered	Allowable Length of Linear Indications mm (in.)
UT1	6	3	10 (0.4)
UT2	12	5	50 (2.0)

Notes:

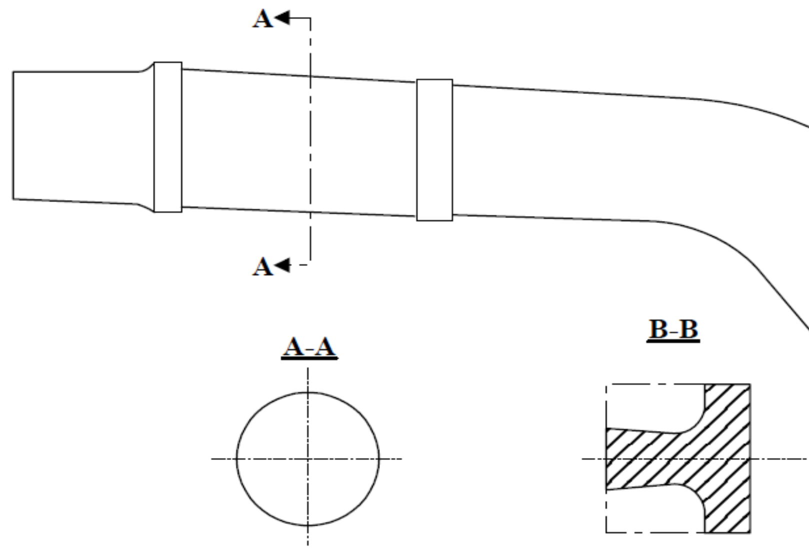
1. For the castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness is to comply with the acceptance criteria for level UT 1.
2. DGS: Distance- Gain Size.



Location of nondestructive examination:

1. All surfaces: Visual examination
2. Location indicated with (OOO): Magnetic particle testing and ultrasonic testing
3. The detailed extents of examinations and quality levels are given in Sec-[5.2] and Sec-[5.3].

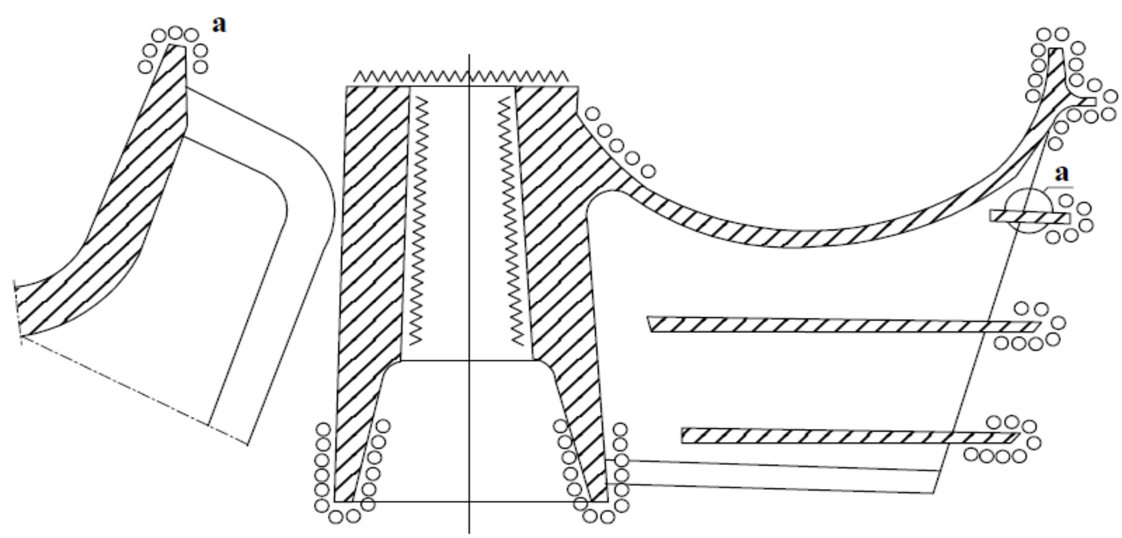
Figure 7.5.1: Stern Frame



Location of nondestructive examination:

1. All surfaces: Visual examination.
   Magnetic particle testing and Ultrasonic testing
2. The detailed extents of examinations and quality levels are given in Sec-[5.2] and Sec-[5.3.]

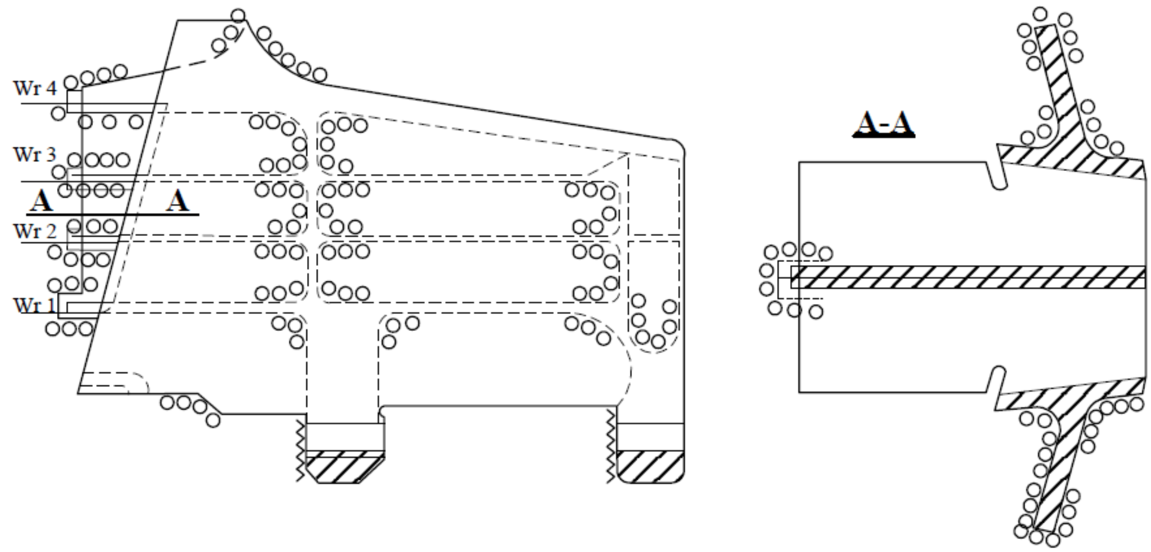
Figure 7.5.2: Rudder Stock



Location of nondestructive examination:

1. All surfaces: Visual examination.
2. Location indicated with (OOO): Magnetic particle testing and Ultrasonic testing.
3. Location indicated with (^ ^ ^): Ultrasonic testing
4. The detailed extents of examinations and quality levels are given in Sec-[5.2] and Sec-[5.3]. Radiography testing is permitted in lieu of Ultrasonic testing.

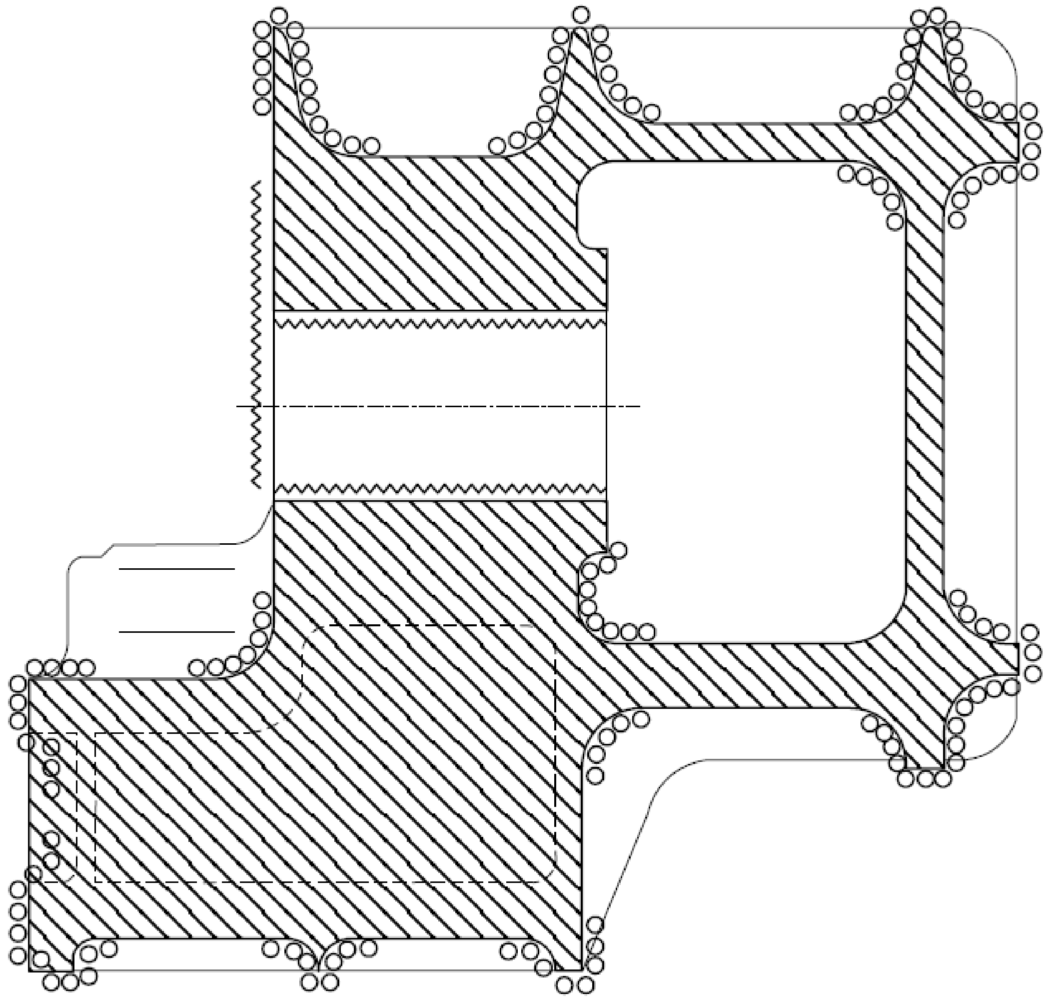
Figure 7.5.3: Stern Boss



Location of nondestructive examination:

1. All surfaces: Visual examination.
2. Location indicated with (OOO): Magnetic particle testing and Ultrasonic testing.
3. Location indicated with (^ ^ ^): Ultrasonic testing
4. The detailed extents of examinations and quality levels are given in Sec-[5.2] and Sec-[5.3].
5. Radiography testing is permitted in lieu of Ultrasonic testing.

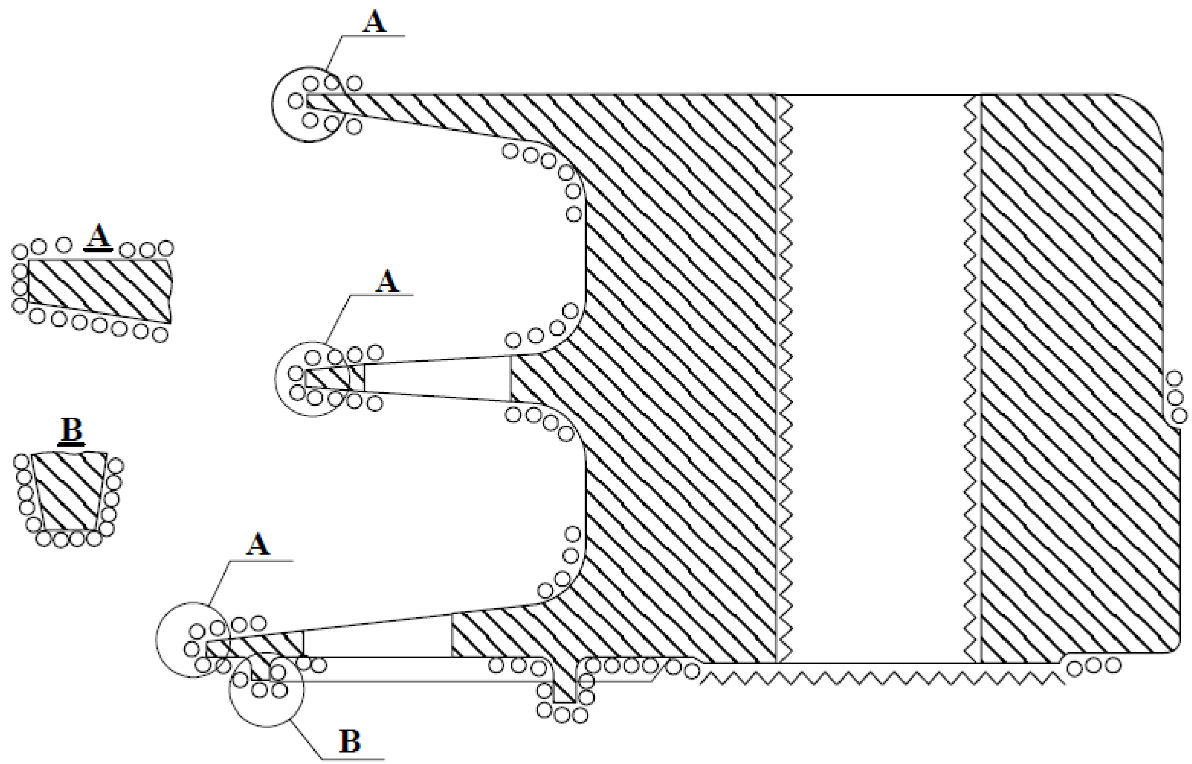
Figure 7.5.4: Rudder Hangings



Location of nondestructive examination:

1. All surfaces: Visual examination.
2. Location indicated with (o o o): Magnetic particle testing and Ultrasonic testing.
3. Location indicated with (^ ^ ^): Ultrasonic testing
4. The detailed extents of examinations and quality levels are given in Sec-[5.2] and Sec-[5.3].
5. Radiography testing is permitted in lieu of Ultrasonic testing.

Figure 7.5.5: Rudder (Upper Part)



Location of nondestructive examination:

1. All surfaces: Visual examination.
2. Location indicated with (o o o): Magnetic particle testing and Ultrasonic testing.
3. Location indicated with (^ ^ ^): Ultrasonic testing
4. The detailed extents of examinations and quality levels are given in Sec-[5.2] and Sec-5.3.
5. Radiography testing is permitted in lieu of Ultrasonic testing.

Figure 7.5.6: Rudder (Lower Part)

SECTION 6 RECOMMENDATION FOR NONDESTRUCTIVE EXAMINATION OF HULL AND MACHINERY STEEL FORGINGS

Contents

6.1. Scope 444
6.2. Surface Inspection 444
6.3. Volumetric Inspection 452

6.1. Scope

6.1.1. This Section complements the INTLREG recommendations for "Hull and machinery steel forgings" and "Parts of internal combustion engines for which non-destructive tests are required", and provides 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.

6.1.2. This document includes recommendations on "Surface Inspections" .Refer [6.2] by visual examination, liquid penetrant testing, magnetic particle testing and "Volumetric Inspection" Refer [6.3] by ultrasonic testing.

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

6.1.4. Examination of the Forgings shall be carried out in the final delivery condition. Refer [6.2.5.2] and [6.3.4.2] of this section for specific requirements.

6.1.5. The manufacturer has to submit documentation of the results of intermediate inspections, if carried out upon the request of the Surveyor.

6.1.6. The quality level of final finished machined components is taken into consideration by the manufacturer, where a forging is supplied in semi-finished condition.

6.2. Surface Inspection

6.2.1. General

6.2.1.1. In this Section surface inspections are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.

6.2.1.2. The apparatus, testing procedures and conditions of magnetic particle testing and liquid penetrant testing are to conform to a recognized National or International standard.

6.2.1.3. Personnel engaged in visual examination are to have sufficient knowledge and experience. Those engaged in magnetic particle testing or liquid penetrant testing are to be qualified in accordance with National or International Standard. The qualification of all the personnel is to be verified by valid certificates.

6.2.2. Products

6.2.2.1. The steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rids, piston rods, gearing, etc. are to be subjected to a 100% visual examination by the Surveyor. In case of mass produced forgings, the extent of examination is established at the discretion of the attending Surveyor.

6.2.2.2. Surface inspections by magnetic particle and/or liquid penetrant methods apply to the steel forgings detailed below:

i) Crankshafts with minimum crankpin diameter not less than 100 mm (4 in.)
ii) Propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm (4 in.)

iii) Connecting rods, piston rods and crosshead with minimum diameter not less than 75 mm (3 in.) or equivalent cross section
iv) Bolts with minimum diameter not less than 50 mm (2 in.) are subjected to dynamic stresses such as cylinder cover bolts, crankpin bolts, tie rods, main bearing bolts, propeller blade fastening bolts

6.2.3. Zones for Surface Inspections

As indicated in Fig. 7.6.1 to Fig. 7.6.4, magnetic particle, or liquid penetrant testing as permitted, is to be carried out in the zones I and II.

The list of castings is not definitive. Criteria for the examination of other castings not indicated in these guidelines/ recommendations will be subject to prior agreement

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

6.2.5. Surface Inspection

6.2.5.1. As per illustrations in Fig. 7.6.1 to Fig. 7.6.4, magnetic particle inspections are to be carried out with the following exceptions, when liquid penetrant testing is permitted:
- Austenitic stainless steels
- Interpretation of open visual or magnetic particle indications
- At the instruction of Surveyor.

6.2.5.2. Unless otherwise specified in the order, the magnetic particle test is to be carried out on a forging in the final machined surface condition and final thermally treated condition or within 0.3 mm (0.012 in.) of the final machined surface condition for AC techniques [(0.8 mm (0.0315 in.) for DC techniques]

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

6.2.5.4. For magnetic particle testing, the contact between the forging and the clamping devices of stationary magnetization benches to avoid local overheating or burning damage in its surface is to be paid special attention. On finished machined items, prods are not permitted.

6.2.5.5. When indications are detected after the surface inspection, the acceptance or rejection is to be decided as per [6.2.6] below.

6.2.6. Acceptance Criteria

6.2.6.1. Acceptance Criteria Visual Inspection

All forgings are to be free of cracks, crack-like indications, seams, laps, folds or other injurious indications. At the request of the Surveyor, additional tests like magnetic particle, liquid penetrant and ultrasonic testing may be carried out for a more detailed evaluation of surface irregularities.

The bores of hollow propeller shafts are to be visually examined for imperfections not revealed by the machining operation. Machining marks are to be ground to a smooth profile.

6.2.6.2. Acceptance Criteria Magnetic Particle Testing and Liquid Penetrant Testing
The following definitions relevant to indications apply:

- *Linear indication.* An indication in which the length is at least thrice the width.
- *Nonlinear indication.* An indication of circular or elliptical shape with a length less than three times the width.
- *Aligned indication.* Three or more indications in a line, separated by 2 mm (0.08 in.) or less edge-to-edge.
- *Open indication.* This indication is visible even after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
- *Non-open indication.* This indication is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
- *Relevant indication.* An indication that is caused by a condition or type of discontinuity that requires evaluation. Indications with dimensions greater than 1.5 mm (0.06 in.) are to be considered relevant.

For evaluating indications, the surface is to be divided into reference areas of 225 cm^2 (35 in^2.) and is to be taken in the most unfavorable location relative to the indication being evaluated.

The allowable size and number of indications in the reference area is given in Table 7.6.1 for crankshaft forgings and in Table 7.6.2 for other forgings, respectively. Cracks are not acceptable. The Surveyor may reject the forging if the total number of indications is excessive irrespective of the results of non-destructive examination.

The list of castings is not definitive. Criteria for the examination of other castings not indicated in these guidelines/ recommendations will be subject to prior agreement.

Table 7.6.1: Crankshaft Forgings- Allowable Number and Size of Indications in a Reference Area of 225 cm^2 (35 in^2.)

Inspection Zone	Max. Number of Indications	Type of Indication	Max. Number for Each Type	Max. Dimension mm, (in.)
I (Critical Fillet Area)	0	Linear	0	---
		Nonlinear	0	---
		Aligned	0	---
II (Important Fillet Area)	3	Linear	0	---
		Nonlinear	3	3.2 (0.125)
		Aligned	0	---
III (Journal Surfaces)	3	Linear	0	---
		Nonlinear	3	5 (0.20)
		Aligned	0	---

Table 7.6.2: Steel Forgings Excluding Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm^2 (35 in^2.)

Inspection Zone	Max. Number of Indications	Type of Indication	Max. Number for Each Type	Max. Dimension mm (in.)
I	3	Linear	0(1)	---
		Nonlinear	3	3.2 (0.125)
		Aligned	0(1)	---
II	10	Linear	3(1)	3.2 (0.125)
		Nonlinear	7	5.0 (0.20)
		Aligned	3(1)	3.2 (0.125)

Note:

1. Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts, cylinder cover bolts.

6.2.7. Rectification of Defects

6.2.7.1. Defects and unacceptable indications are to be rectified as indicated below and detailed in [6.2.7.2] thru [6.2.7.6].

a) Defective parts of material may be removed by grinding, or by chipping and grinding. All grooves are to 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 is to be 0.08 mm (0.003 in.) minimum to 0.25 mm (0.01 in.) 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 surveyor on a case-by-case basis.

6.2.7.2. Zone I in Crankshaft Forgings

Neither indications nor repair are permitted in this zone.

6.2.7.3. Zone II in Crankshaft Forgings

Indications are to be removed by grinding to a depth no greater than 1.5 mm (0.06 in.) Indications detected in the journal bearing surfaces are to be removed by grinding to a depth no greater than 3.0 mm (0.12 in.). The total ground area is to be less than 1% of the total bearing surface area concerned. Non-open indications, except those evaluated as segregation, are to be depressed but need not be removed.

6.2.7.4. Zone I in Other Forgings

Indications are to be removed by grinding to a depth no greater than 1.5 mm (0.06 in.). However, grinding is not permitted in way of finished machined threads.

6.2.7.5. Zone II in Other Forgings

Indications are to be removed by grinding to a depth no greater than 2% of the diameter or 4.0 mm (0.16 in.), whichever is smaller.

6.2.7.6. Zones Other than I and II in All Forgings

Defects detected by visual inspection are to be removed by grinding to a depth no greater than 5% of the diameter or 10 mm (0.40 in.) whichever is smaller. The total ground area is to be less than 2% of the forging surface area.

6.2.8. Record

Test results of surface inspections are to be recorded with the following information:

i) Date of testing

ii) Names and qualification level of inspection personnel

iii) Kind of testing method
- For magnetic particle testing: Method of magnetizing, test media and magnetic field strength
- For liquid penetrant testing: Test media combination

iv) Kind of product

v) Product number for identification

vi) Grade of steel

vii) Heat treatment

viii) Stage of testing

ix) Position (zone) of testing

x) Surface condition

xi) Test standards used

xii) Testing condition

xiii) Results

xiv) Statement of acceptance/non acceptance

xv) Detail of weld repair including sketch

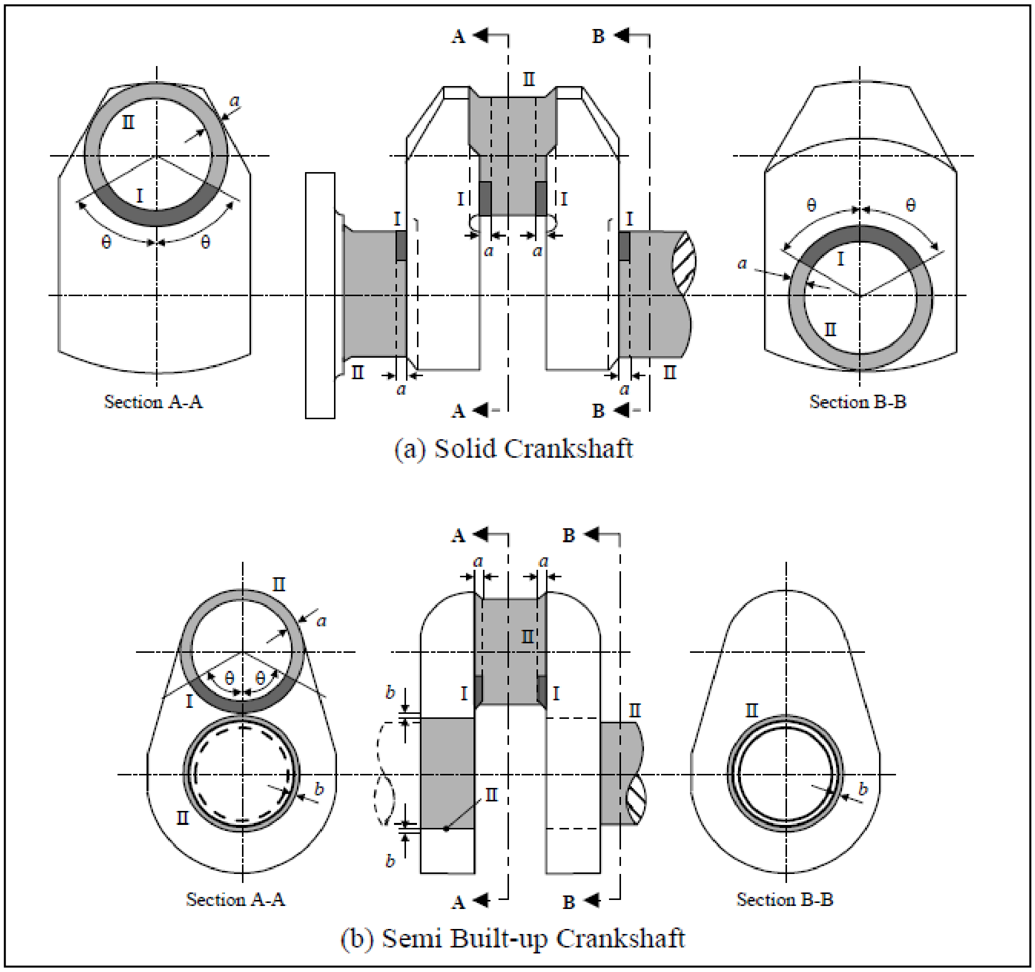
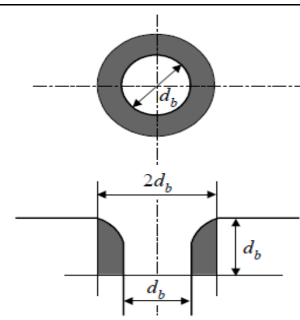
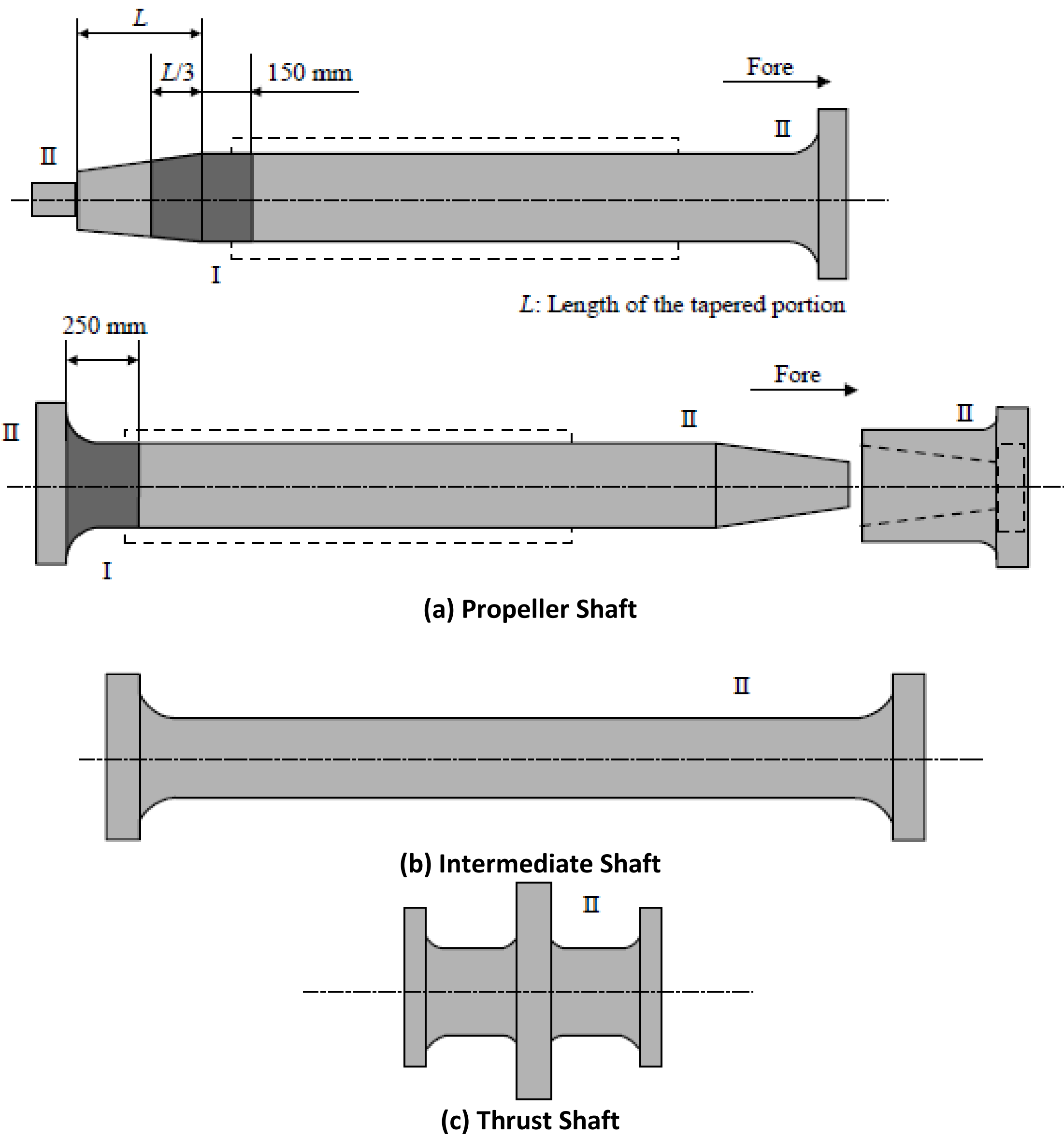


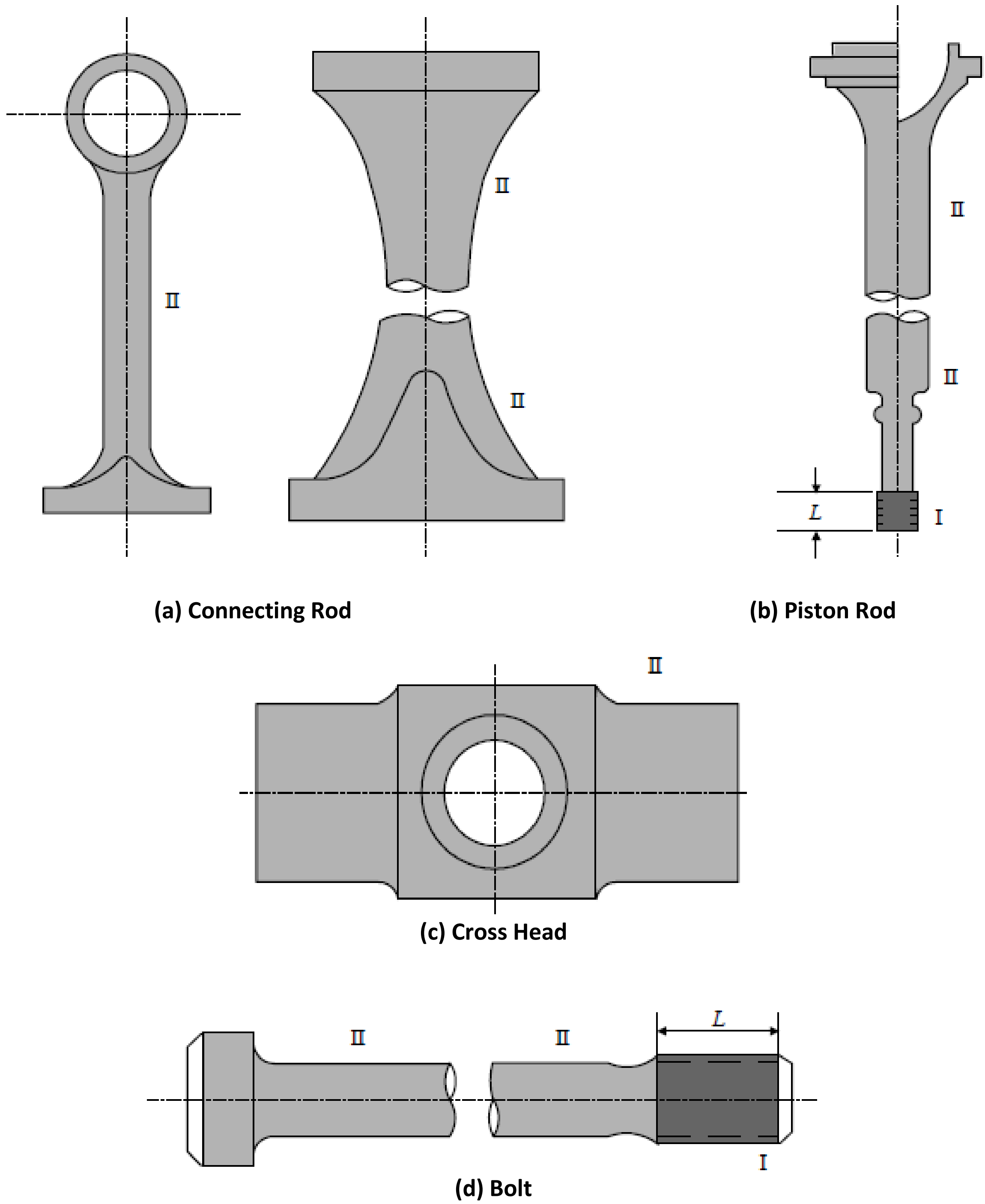
Figure 7.6.1: Zones for Magnetic Particle/Liquid Penetrant Testing on Crankshafts

<table>
<tr><td colspan="2">NOTE: (Refer Figure 7.6.1)</td></tr>
<tr><td colspan="2">1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I. (Refer the figure in the right.)</td></tr>
<tr><td>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</td><td rowspan="2">
d_b : Oil hole bore diameter</td></tr>
<tr><td>3. Identification of the Zones (Similar in Fig. 7.6.1 to Fig. 7.6.4):
: Zone I
: Zone II</td></tr>
</table>



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 treated as Zone I.

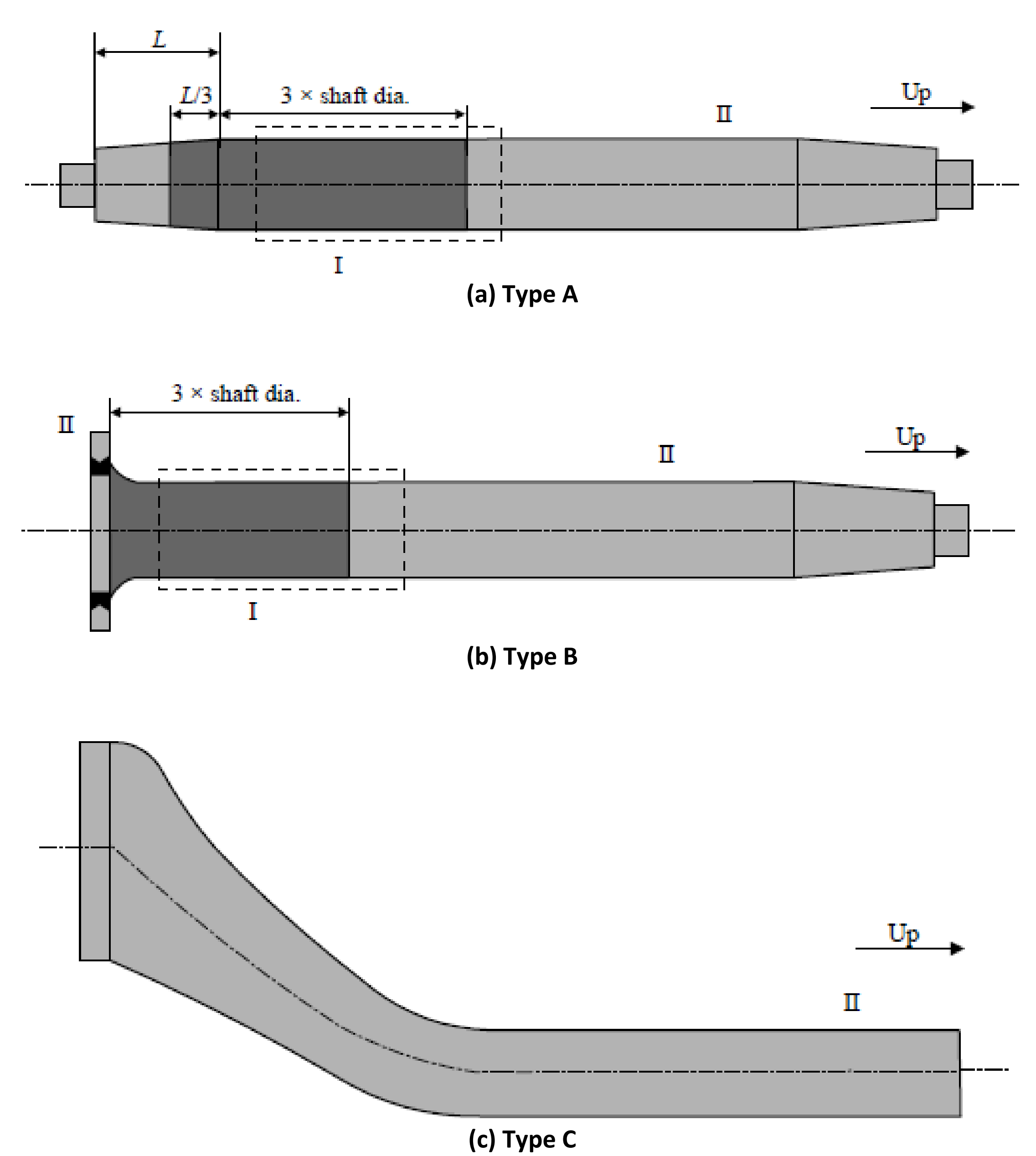
Figure 7.6.2: Zones for Magnetic Particle/Liquid Penetrant Testing on Shafts



Note:

1. For connecting rods, the threads, holes and their circumstances are to be treated as Zone I.
2. L = Length of thread

Figure 7.6.3: Zones for Magnetic Particle/Liquid Penetrant Testing on Machinery Components



Note:
1. Welded areas are to be treated as Zone I.
2. L = Length of the tapered portion.

Figure 7.6.4: Zones for Magnetic Particle/Liquid Penetrant Testing on Rudder Stocks

6.3. Volumetric Inspection

6.3.1. General

6.3.1.1. In this Section Volumetric inspection is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique.

6.3.1.2. The apparatus, testing procedures and conditions of ultrasonic testing are to conform to the recognized National or International standards. In general, 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 [25 mm (1 in.)] plus a 0° probe for the rest of the volume. Fillet radii should be examined using 45°, 60° or 70° probes.

6.3.1.3. Persons engaged in ultrasonic testing are to be qualified in accordance with National or International Standard .Refer [5.1.6] / [5.1.7]. The qualification is to be verified by valid certificates.

6.3.2. Products

Generally, volumetric inspections by ultrasonic testing apply to the steel forgings detailed below:

i) Crankshaft with minimum crankpin diameter not less than 150 mm (6 in.)

ii) Tail shafts with minimum diameter not less than 200 mm (8 in.) and up to 455 mm (18 in.). UT of propeller shafts 455 mm (18 in.) in diameter and over is to be carried out in accordance with Nation or International standards and to the satisfaction of the Surveyor.

iii) Intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm (8 in.)

iv) Connecting rods, piston rods and crossheads are to be examined as given in Pt 5A, Ch 2, Table 2.1.1.

6.3.3. Zones for Volumetric Inspection

Ultrasonic testing is to be carried out in the zones I to III as indicated in Figure 7.6.5 to Figure 7.6.8. At the discretion of the Surveyor, areas may be upgraded to a higher zone. The list of forgings is not definitive. Criteria for the examination of other forgings not indicated in these guidelines/ recommendations will be subject to prior agreement.

6.3.4. Surface Condition

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

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

6.3.5. Acceptance Criteria

Acceptance criteria of volumetric inspection by ultrasonic testing are specified in Tables 7.6.1 and Tables 7.6.2.

6.3.6. Record

The records of the test results of volumetric inspection are to at least include the following items:

i) Date of testing

ii) Names and qualification level of inspection personnel

iii) Kind of testing method

iv) Kind of product

v) Product number for identification

vi) Heat treatment

vii) Grade of steel

viii) Stage of testing

ix) Position (zone) of testing

x) Surface condition

xi) Testing condition

xii) Test standards used

xiii) Statement of acceptance/non acceptance

xiv) Results

Table 7.6.3: Acceptance Criteria for Crankshafts

Type of Forging	Zone	Allowable Disk Shape According to DGS (1)	Allowable Length of Indication	Allowable Distance Between Two Indications (2)
Crankshaft	I	d ≤ 0.5 mm (0.02 in.)	---	---
	II	d ≤ 2.0 mm (0.08 in.)	≤ 10 mm (0.40 in.)	≥ 20 mm (0.8 in)
	II	d ≤ 4.0 mm (0.16 in.)	≤ 15 mm (0.60 in.)	≥ 20 mm (0.8 in)

Notes:

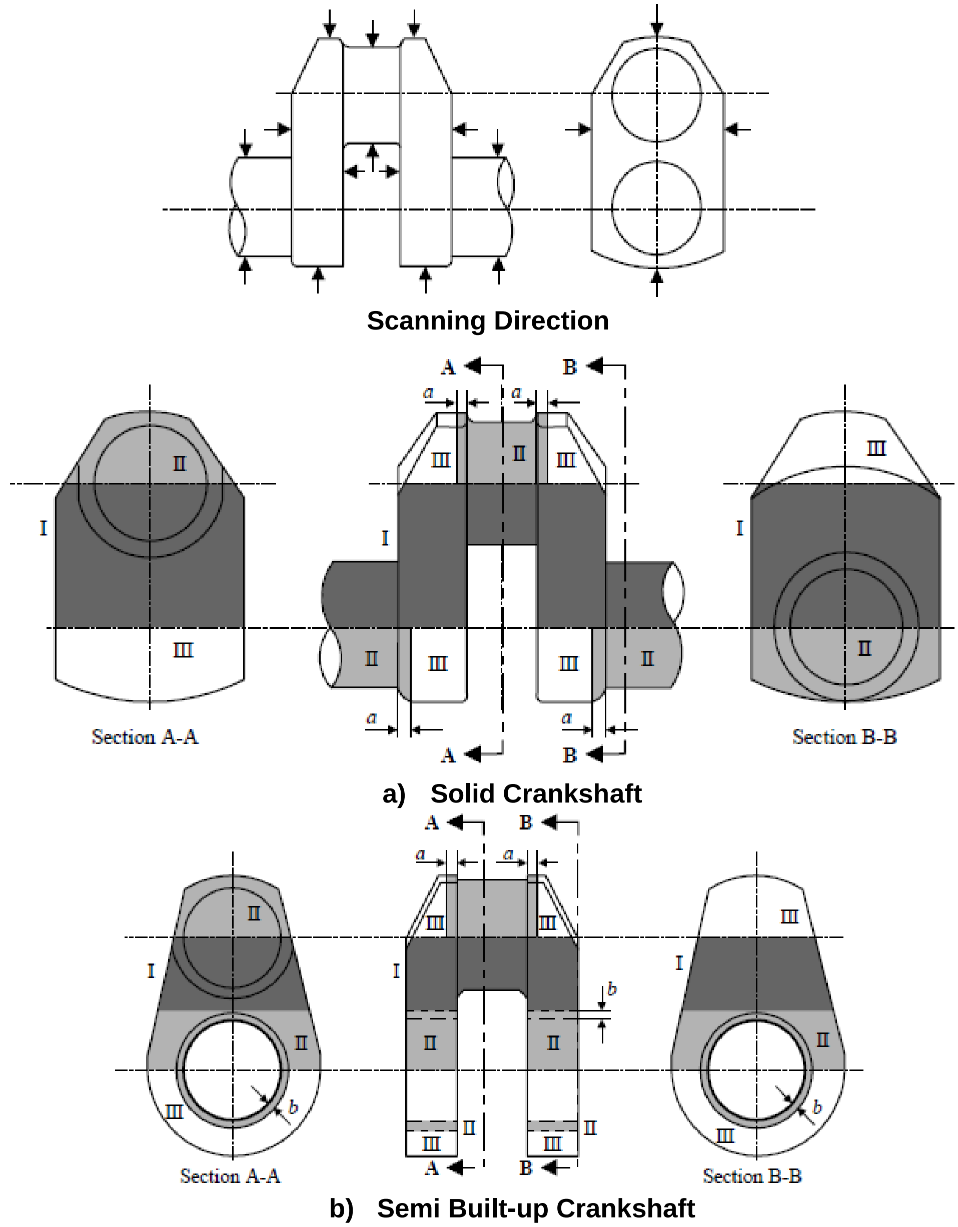
1. DGS: Distance Gain Size
2. In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighboring indications is to be at least the length of the bigger indication. This applies as well to the distance in axial direction as to the distance in depth. Isolated indications with less distances are to be determined as one single indication.

Table 7.6.4: Acceptance Criteria for Shafts and Machinery Components

Type of Forging	Zone	Allowable Disk Shape According to DGS (1,2)	Allowable Length of Indication	Allowable Distance Between Two Indications (3)
Tail Shaft, Intermediate Shaft, Thrust Shaft, Rudder Stock	II	outer: d ≤ 2 mm (0.08 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
		inner: d ≤ 4 mm (0.16 in.)	≤ 15 mm (0.6 in.)	≥ 20 mm (0.8 in.)
	III	outer: d ≤ 3 mm (0.12 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
		inner: d ≤ 6 mm (0.24 in.)	≤ 15 mm (0.6 in.)	≥ 20 mm (0.8 in.)
Connecting Rod, Piston Rod, Crosshead	II	d ≤ 2 mm (0.08 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
	III	d ≤ 4 mm (0.16 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)

Notes:

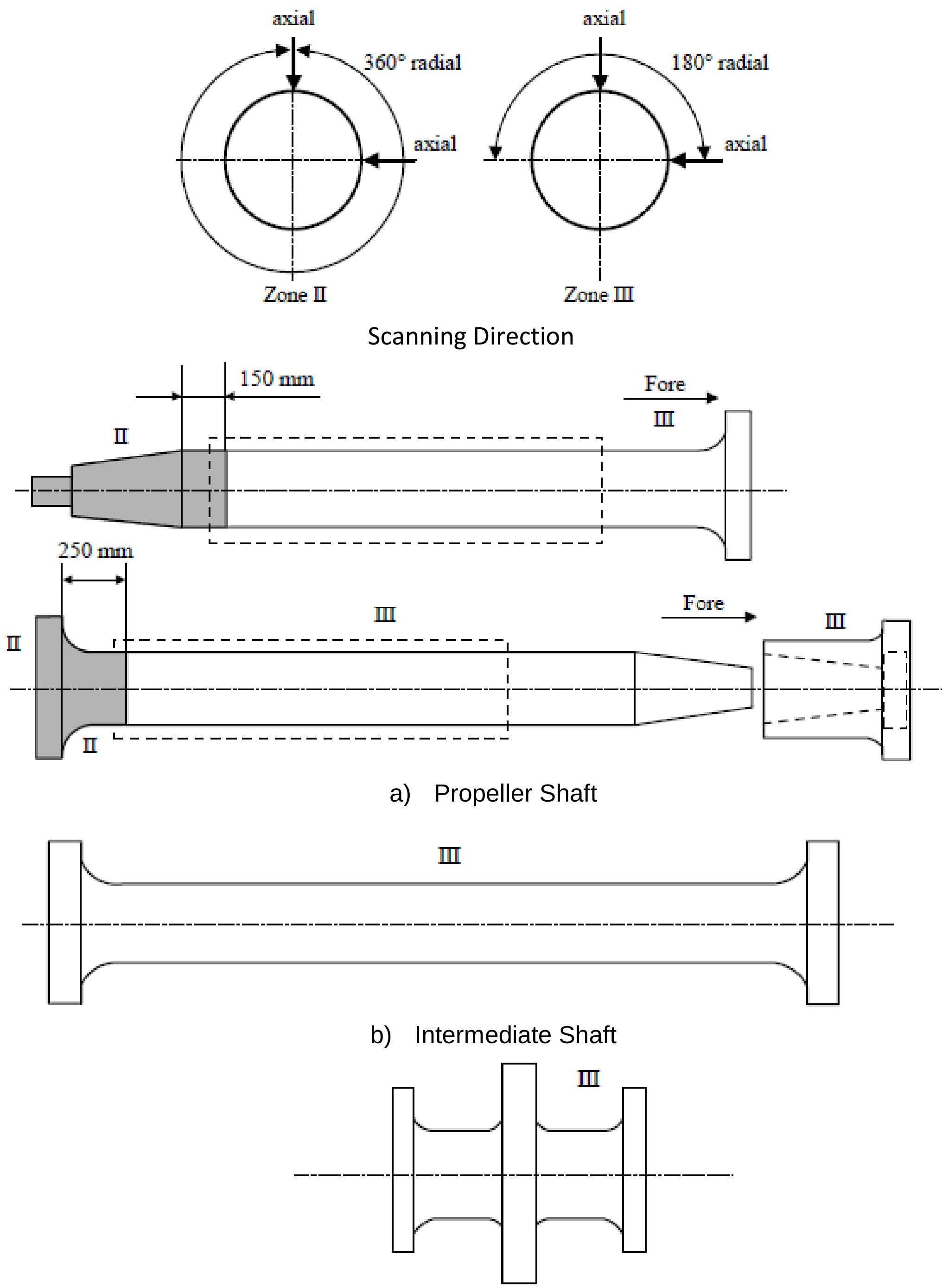
1. DGS: Distance Gain Size
2. The “outer part” means the part beyond one third of the shaft radius from the center, the “inner part” means the remaining core area.
3. In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighboring indications is to be at least the length of the bigger indication.



Notes

1. In the above figures, "a" and "b" mean:
   a = 0.1d or 25 mm (1 in.) , whichever greater
   b = 0.05d or 25 mm (1 in.), 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 Section 6.3 Figure 7.6.5 through Figure 7.6.8):
   : Zone I
   : Zone II
   : Zone III

Figure 7.6.5: Zones for Ultrasonic Testing on Crankshafts



a) Propeller Shaft

b) Intermediate Shaft

c) Thrust Shaft

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 7.6.6: Zones for Ultrasonic Testing on Shafts

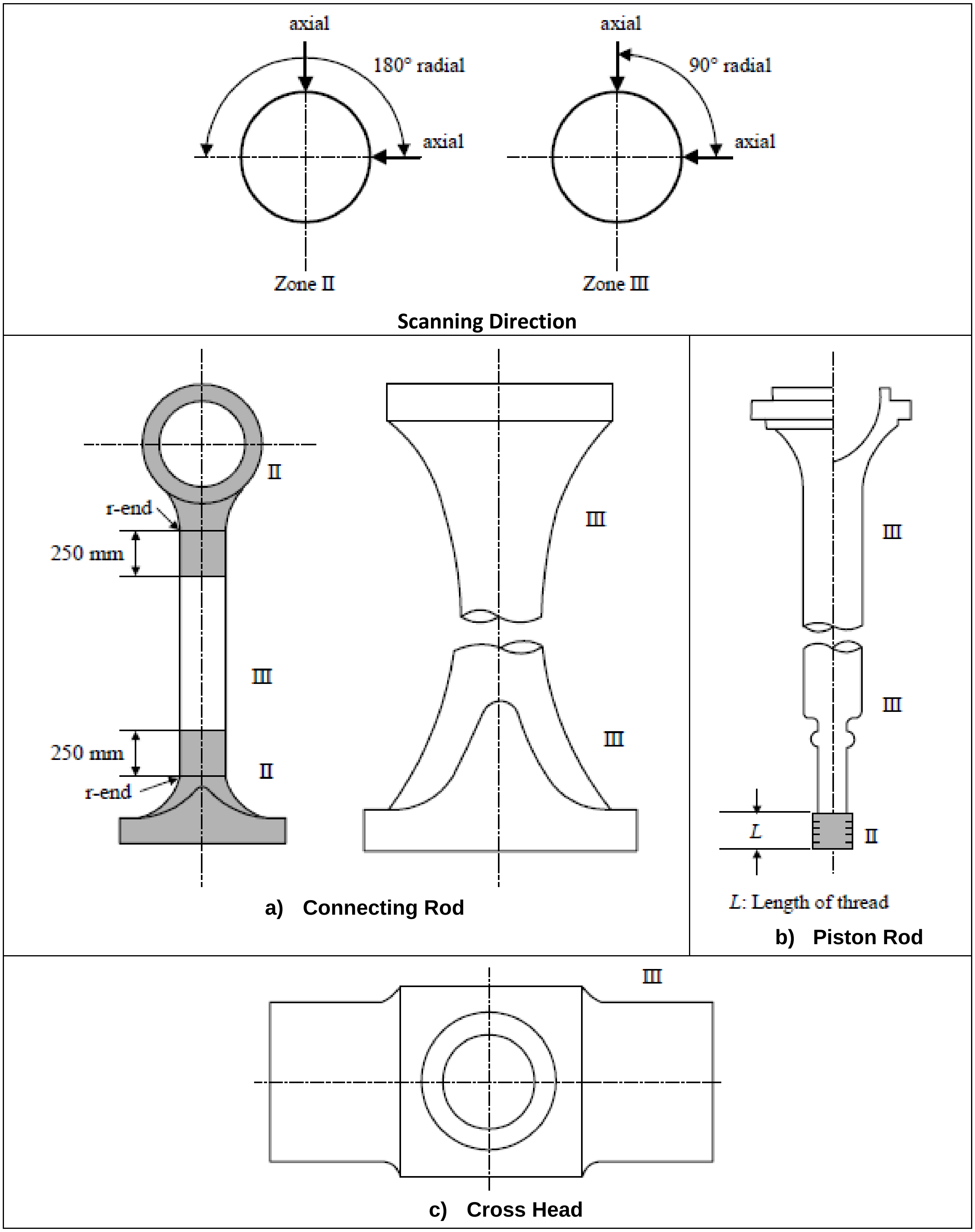
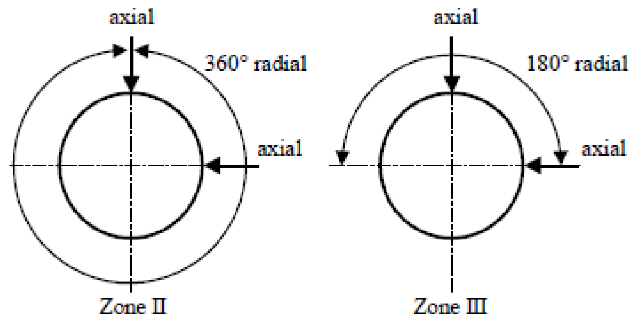
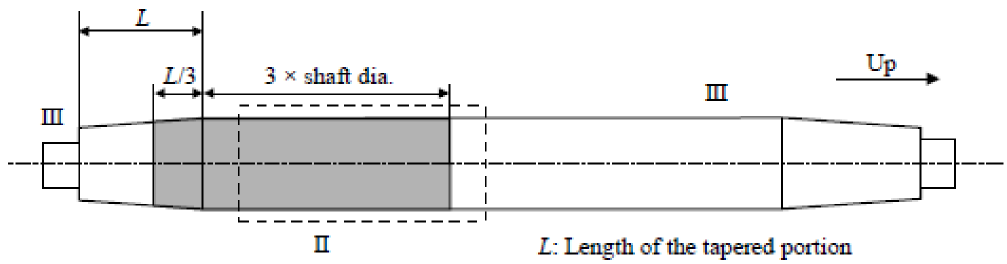


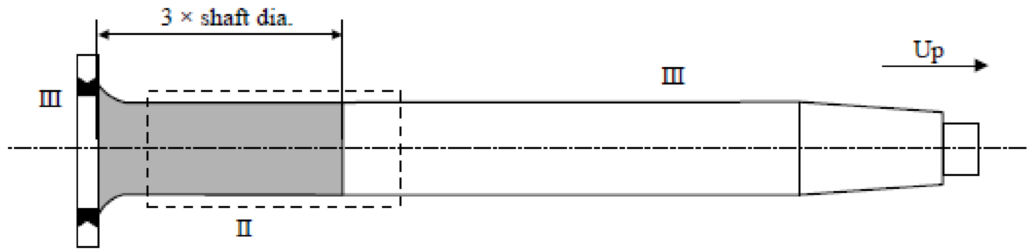
Figure 7.6.7: Zones for Ultrasonic Testing on Machinery Components



Scanning Direction for Type A and Type B

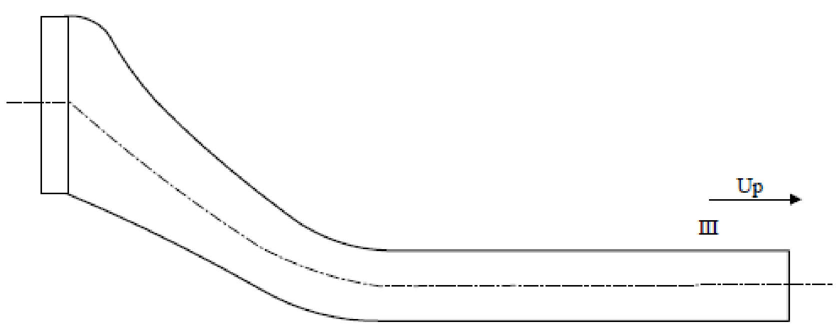


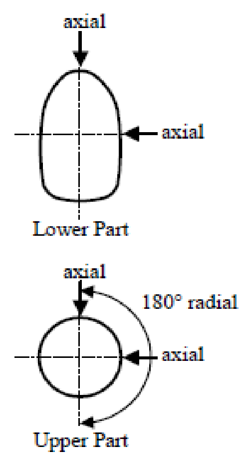
a) Type A



Note: Special consideration is given to the welded areas.

b) Type B





c) Type C Scanning Direction for Type C

Figure 7.6.8: Zones for Ultrasonic Testing on Rudder Stocks

SECTION 7 ADDITIONAL APPROVAL PROCEDURE FOR STEEL WITH ENCHANCED CORROSION RESISTANCE PROPERTIES

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7.1 Scope

7.1.1 INTLREG approval is to be carried out in accordance with the requirements of Part 2 herein and together with the additional requirements for corrosion testing specified in this Section

7.1.2 The corrosion tests and assessment criteria are to be in accordance with this section and Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers [MSC.289 (87)].

7.2 Application for Approval

7.2.1 The manufacturer to submit to INTLREG a request for approval, together with the following:

7.2.1.1 Corrosion test plan and details of equipment and test environments.

7.2.1.2 Technical data related to product assessment criteria for confirming corrosion resistance.

7.2.1.3 Technical background/s detailing how the variation in added and controlled elements improves resistance to corrosion.

7.2.1.4 The grades, the brand name and maximum thickness of steel with enhanced corrosion resistance properties to be approved. Designations for steels with enhanced corrosion resistance properties are given in Table 7.7.1.

7.2.1.5 Brand name of welding consumables and the welding process to be used for approval

Table 7.7.1: Designations for Steels with Enhanced Corrosion Resistance Properties

Steel Type	Location where Steel is Effective	Enhanced Corrosion Resistance Properties Designation
Rolled steel for hull	For strength deck, ullage space.	RCU
	For inner bottom	RCB
	For both strength deck and inner bottom plating	RCW

7.3 Approval of Test Plan

7.3.1 The manufacturer shall prepare and submit a Test Program and this shall be reviewed by INTLREG. It will be approved and returned to the manufacturer for acceptance, if found satisfactory, but prior to tests being carried out. Tests that need witnessing by INTLREG Surveyor shall be clearly identified in the Test Program.

7.3.2 Method for selection of the test samples shall conform to the following:

7.3.2.1 The numbers of test samples shall be in accordance with the requirements of the Performance Standard for Alternative Mean of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers .MSC.289 (87)

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

7.3.2.3 Additional tests may be required by ABS when reviewing the test program against [7.3.2.2].

7.3.3 In addition to [7.3.2] above, INTLREG may require additional test in the following cases:

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

7.3.3.2 When INTLREG infers that the data of the corrosion resistance test result obtained for setting the control range of chemical composition varies too widely;

7.3.3.3 When the INTLREG surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition, and INTLREG determines that additional testing is necessary in order to confirm the validity of the test result data;

7.3.3.4 When INTLREG infers that the validity of the corrosion resistance test result for setting the control range of chemical composition is insufficient, or has some flaws;

7.3.3.5 When INTLREG infers that it is necessary, for reasons other than cases i) to iv) above.

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

7.4 Carrying out the Approval Test

7.4.1 The manufacturer is to carry out the approval test in accordance with the INTLREG approved Test Plan.

7.5 Witness by INTLREG Surveyor

7.5.1 INTLREG surveyor presence is to be ensured, when the test samples are being identified and for approval tests. Refer [7.3.1]

7.6 Test Results

7.6.1 The manufacture is to prepare the test report, after completion of the approval test, and submit the same to INTLREG.

7.6.2 Where approval tests are considered by the society to have given satisfactory results based on the data submitted in accordance with the provisions of this Section, INTLREG will give approval for steel with enhanced corrosion resistance properties.

7.6.3 Manufacturer’s name, period of validity of the certificate, the grades and thickness of the approved steel, welding methods and approved welding consumables shall be indicated in the certificate of approval.

7.7 Welded Joints – Assessment Criteria for Results of Corrosion Resistance Tests

7.7.1 The results of the test will be assessed by INTLREG in accordance with the acceptance criteria specified in Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks .MSC.289 (87).

SECTION 8 WELDING PROCEDURE QUALIFICATION TESTS OF STEELS FOR HULL CONSTRUCTION AND MARINE STRUCTURES

Contents

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8.1 Scope

8.1.1 This section covers weld procedure qualification.

8.2 General

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

8.2.2 Welding procedure tests are to replicate the fabrication conditions with respect to welding equipment, weld preparation, preheating, post weld heat treatment and inside or outside fabrication. It is the responsibility of the manufacturer to establish and document whether a procedure is suitable for the particular application.

8.2.3 For the approval of welding procedure, welding procedure qualification tests are to be carried out with satisfactory results. Welding procedure specifications are to reference the weld qualification test results achieved during welding procedure qualification testing.

8.2.4 The approved WPS shall be restricted to the contractor or subcontractor performing the qualification. If the approved WPS's are to be applied at workshops or yards belonging to the contractor or subcontractor, they are to be under the same technical management and working to the same quality assurance procedures and program.

8.3 Welding Procedure Specification- pWPS and WPS

8.3.1 Preliminary Welding Procedure Specification (pWPS) and Welding Procedure Specification (WPS)

8.3.1.1 pWPS

The manufacturer or shipyard is to submit a pWPS to INTLREG for review prior to the Weld Procedure Qualification Tests (WPQT). The pWPS can be modified and amended during the WPQT as deemed necessary. The pWPS is to define all the variables (Refer to AWS D.1.1, ISO 15614 or other recognized standards) that will be included in the WPS. In case the test pieces welded according to the pWPS show unacceptable results the pWPS is to be adjusted by the manufacturer or shipyard. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

8.3.1.2 WPS

Upon completion of the WPQT and satisfactory review, the pWPS is given approval and becomes the WPS. The WPS is to be used as a basis for production welds. The approval range of the WPS is to be in compliance with ,Ch 5 Sec 8, [8.5].

Note: The generic term WPS is sometimes applied to a document before and after qualification tests, this can be accepted. The use of pWPS helps identify that the document has not yet been qualified by satisfactory tests.

8.4 Welding Procedure Qualification Test – WPQT

8.4.1 General

8.4.1.1 Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

8.4.1.2 Preparation and welding of test specimen pieces are to be carried out in accordance with the pWPS and under the general condition of production welding which it represents.

8.4.1.3 If tack welds and/or start and stop points are a condition of the weld process, they are to be fused into the joint and are to be included in the test assemblies.

8.4.2 Butt Welds

8.4.3.1 Assembly of Test Pieces

The test assembly is to be in accordance with Figure 7.8.1 with the following minimum dimensions:

- Manual or Semi-automatic welding:

Thickness = t
Width = 2a,
where a= 3 x t. Minimum width to be not less than 150 mm (6 in.)
Length b= 6 x t. Minimum length to be not less than 350 mm (14 in.)

- Automatic Welding

Thickness = t
Width = 2a,
where a= 3 x t. Minimum width to be not less than 150 mm (6 in.)
Length b= 6 x t. Minimum length to be not less than 350 mm (14 in.)

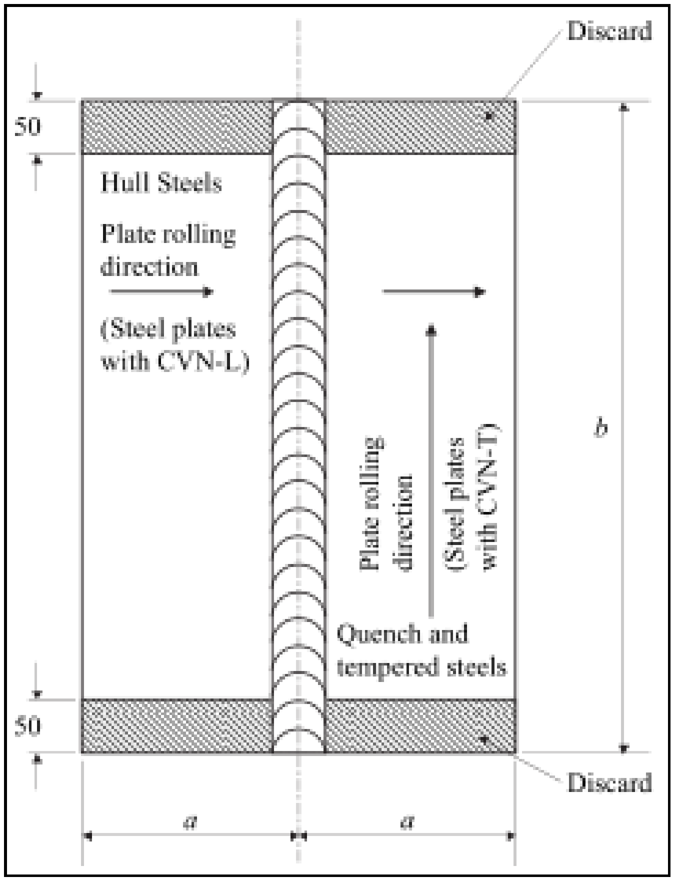


Figure 7.8.1: Butt Weld Test Assembly

8.4.3.2 Examination and Tests

Test assemblies are to be examined nondestructively and destructively in accordance with the following requirements and Figure 7.8.2:

- Visual testing : 100%
- Surface crack detection : 100%
  (Surface crack detection by either dye penetrant testing or magnetic particle testing)
- Radiographic or Ultrasonic testing : 100%
- Transverse tensile test : Two specimens as per [8.4.3.2] (b) below
- Longitudinal tensile test : As per [8.4.3.2] (c) below
- Transverse bend test : Four specimens as per [8.4.3.2] (d) below
- Charpy V-notch impact test : As per [8.4.3.2] (e) below
- Macro examination : One specimen as per [8.4.3.2] (f) below
- Hardness test : Required as per [8.4.3.2]. (g) below

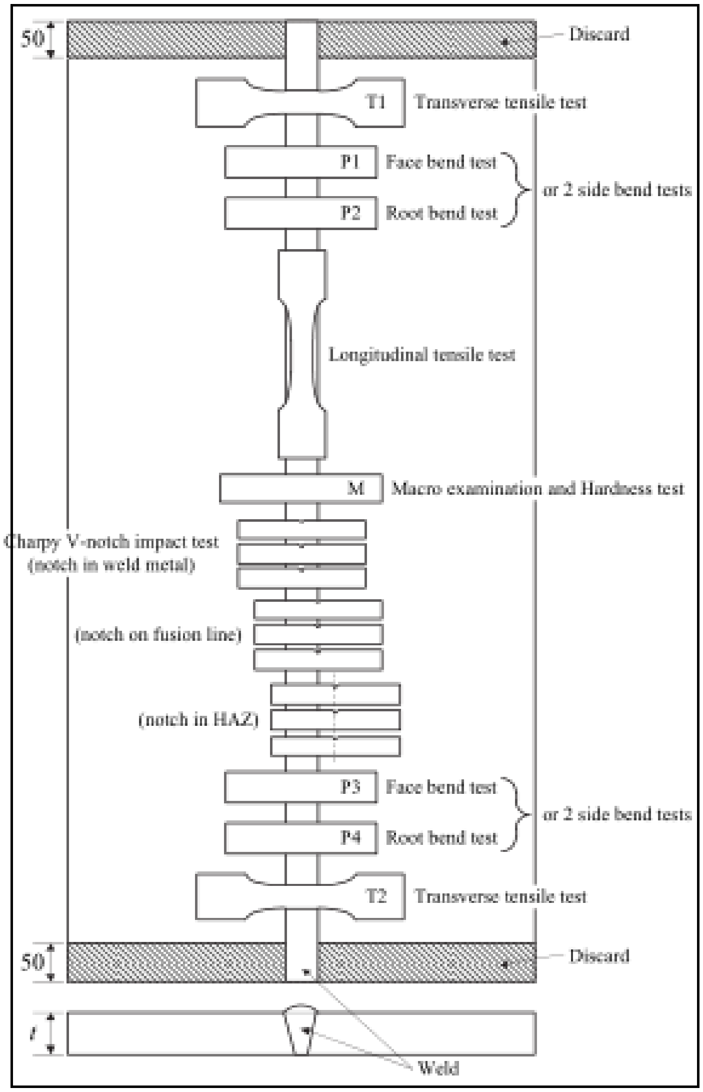


Figure 7.8.2: Test Sampling

a. **Nondestructive Testing:** Prior to cutting of test specimens, test assemblies are to be examined by visual and by nondestructive testing prior to the cutting of test specimens. In case Nondestructive testing is to be carried out after heat treatment if any post-weld heat treatment is required or specified. nondestructive testing is to be performed after heat treatment. For steels with specified minimum yield strength of 420 N/mm 2 and above the nondestructive testing is to be delayed for a minimum of 48 hrs, unless post weld heat treatment has been carried out. NDT procedures are to be to the satisfaction of the Surveyor.

Imperfections detected by visual or nondestructive testing are to be assessed in accordance with ISO 5817, Class B, except for excess weld metal and excess penetration for which the level C applies.

b. **Transverse Tensile Test:** The testing is to be carried out in accordance with Figure 3.5.1. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal. When butt welds are made between plates of different grades plates of different grades are butt welded, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength. If a lower strength consumable is proposed the details are to be submitted to INTLREG for consideration.

c. **Longitudinal Tensile Test.** Where the welding consumable is not INTLREG approved, longitudinal tensile test of deposited weld metal taken lengthways from the weld is required.

Testing is to be carried out in accordance with Ch 3, Sec 6, Figure 3.6.1. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable.

Where more than one welding process or type of consumable has been used to make the test weld, test specimens are to be taken from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

d. **Bend Test:** Transverse bend tests for butt joints are to be in accordance with Ch 3, Sec 5, Figure 3.5.5 and Figure 3.5.6. The mandrel diameter to thickness ratio (i.e., D/t) is to be in accordance with Ch 3, Sec 5, Figure 3.5.7.

The bending angle is to be 180°. After testing, the test specimens are not to have any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested. For butt weld joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

e. **Impact Test:** Requirements for Normal and higher strength hull structural steels, high strength quenched and tempered steels and weldable C and C-Mn hull steel castings and forgings are provided below:

i. Normal and Higher Strength Hull Structural Steels:
The positions of specimens are to be in accordance with these requirements. Dimensions and testing are to be in accordance with the requirements of Ch 1, Sec 1, [1.6.6].

Test specimens with Charpy-V-notch are to be used and sampled from 1 to 2 mm below the surface of the base metal, transverse to the weld and on the side containing the last weld run. V-notch specimens are located in the butt-welded joint as indicated in Appendix 1, Annex 1, Figure 1 and Figure 2, and the V-notch is to be cut perpendicular to the surface of the weld.

When butt welds are made between different steel grades or types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.

Test temperature and absorbed energy are to be in accordance with Ch 5, Sec 8, Table.7.8.1.
The testing of sub-size specimens is to be in accordance with Ch 1, Sec 2 and Ch 1, Sec 1, Figure1.13.

ii. High Strength Quenched and Tempered Steels:

Impact tests are to be performed as described in i) above. V-notch specimens are located in the butt welded joint as indicated in Appendix 1, Annex 1, Figure 1 and Figure 2. The V-notch is to be cut perpendicular to the surface of the weld.

Test temperature and absorbed energy are to be in accordance with the requirements of the base metal.

iii. Weldable C and C-Mn Hull Steel Castings and Forgings:

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.

<table>
<tr><th rowspan="3">Grade of Steel</th><th rowspan="3">Testing Temperature (º C)</th><th colspan="3">Value of Minimum Average Absorbed Energy (J)</th></tr>
<tr><th colspan="2">For Manual or Semi- automatic Welded Joints</th><th rowspan="2">For Automatically Welded Joints</th></tr>
<tr><th>Down hand, Horizontal, Overhead</th><th>Vertical Upward, Vertical Downward</th></tr>
<tr><td>A[(3)]</td><td>20</td><td rowspan="11">47</td><td rowspan="7">34</td><td rowspan="7">34</td></tr>
<tr><td>B[(3)], D</td><td>0</td></tr>
<tr><td>E</td><td>-20</td></tr>
<tr><td>AH32, AH36</td><td>20</td></tr>
<tr><td>DH32, DH36</td><td>0</td></tr>
<tr><td>EH32, EH36</td><td>-20</td></tr>
<tr><td>FH32, FH36</td><td>-40</td></tr>
<tr><td>AH40</td><td>20</td><td rowspan="4">39</td><td rowspan="4">39</td></tr>
<tr><td>DH40</td><td>0</td></tr>
<tr><td>EH40</td><td>-20</td></tr>
<tr><td>FH40</td><td>-40</td></tr>
<tr><td colspan="5">Notes:
1. For thickness above 50 mm impact test requirements reference is to be made to INTLREG Rules, Pt 2, Ch 3, Table 3.5.2.
2. These requirements apply to test pieces with butt weld perpendicular to the plate rolling direction.
3. For Grade A and B steels average absorbed energy on the fusion line and in the heat affected zone is to be minimum 27 J.</td></tr>
</table>

Table 7.8.1: Impact Test Requirements for Butt Joints (t ≤ 50 mm)

f. **Macro Examination:** Test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, and heat affected zone. Macro examination is to include approximately 10 mm (0.40 in.) of unaffected base metal.

The examination is to reveal a regular weld profile, fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion, etc.

g. **Hardness Tests:** Hardness tests are required for steels with specified minimum yield strength of R eH ≥ 355 N/mm^2. The Vickers method HV 10 is normally used. The indentations are to be made in the weld metal, the heat affected zone and the base metal. The hardness values are to be measured and recorded. At least two rows of indentations are to be carried out in accordance with Appendix 1, Annex 2, Figure 1 and 2.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). A typical example is shown in Annex 2.

The results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength R eH ≤ 420 N/mm^2: 350 HV10
- Steel with a specified minimum yield strength 420 N/mm^2< R eH ≤ 690 N/mm^2: 420 HV10

8.4.3 Fillet Welds

8.4.3.1 Assembly of Test Pieces:

The test assembly is to be in accordance with Appendix 1, Annex 2, Figure 3 with the following minimum dimensions:

- Manual and Semi-Automatic Welding:

  Thickness = t

  Width a = 3 x t. Minimum width is to be no less than 150 mm (6 in.)

  Length b = 6 x t, Minimum length is to be no less than 350 mm (14 in.)

- Automatic Welding:

  Thickness = t

  Width a = 3 x t. Minimum width is to be no less than 150 mm (6 in.)

  Length b = 6 x t, Minimum length is to be no less than 1000 mm (40 in.)

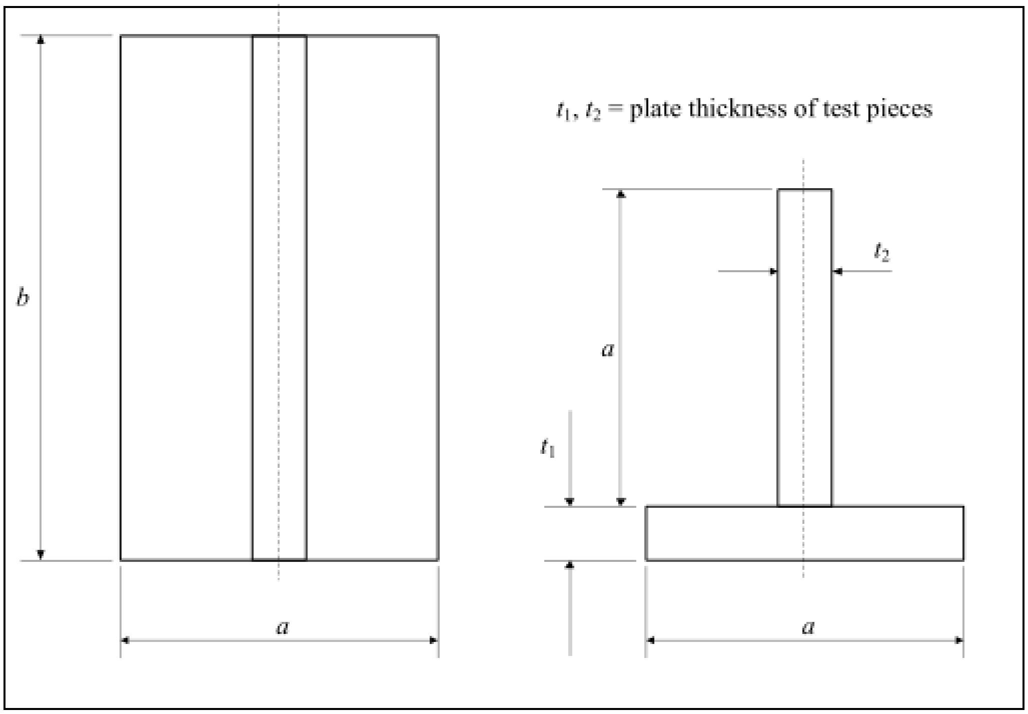


Figure 7.8.3: Test Assembly for Fillet Weld

8.4.3.2 Welding of Test Pieces

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. The test assembly is welded on one side only.

8.4.3.3 Examinations and Tests

Examination of test assemblies (both nondestructive and destructive) shall be carried out in accordance with the following:

- Visual testing :100%
- Surface crack detection :100% (dye penetrant testing or magnetic particle testing)
- Macro examination : Two specimens as per [8.4.3.3] (b)
- Hardness test : Required as per [8.4.3.3] (c)
- Fracture test : Required as per [8.4.3.3] (d)

(a) Nondestructive Testing

Test assemblies are to be examined by visual and by nondestructive testing prior to the cutting of test specimens. In case any post-weld heat treatment is required or specified nondestructive testing is to be performed after heat treatment. For steels with specified minimum yield strength of 420 N/mm^2 and above, nondestructive testing is to be delayed for a minimum of 48 hours, unless post weld heat treatment has been carried out. NDT procedures are to be to the satisfaction of the Surveyor.

Imperfections detected by visual or nondestructive testing are to be assessed in accordance with ISO 5817, class B except for excess convexity and excess throat thickness for which the level C applies.

(b) Macro Examination
Test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone.

Macro examination is to include approximately 10 mm unaffected base metal. The examination is to reveal a regular weld profile, fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion, etc.

(c) Hardness Test
Hardness test is required for steels with specified minimum yield strength of R eH ≥ 355 N/mm^2. The Vickers method HV10 is normally used. The indentations are to be made in the weld metal, heat affected zone, and base metal. The hardness values are to be measured and recorded. At least two rows of indentations are to be carried out in accordance with Appendix 1, Annex 2, Figure 3, 4A, 4B.

For each row of indentations there is to be a minimum of 3 individual indentations in the weld metal, heat affected zone (both sides), and base metal (both sides). A typical example is shown in Appendix 1, Annex 2.

Results from the hardness test are not to exceed the following:

- Steel with a specified min. yield, ReH ≤ 420 N/mm^2 :350 HV10

- Steel with a specified min. yield, 420 N/mm^2< R eH ≤ 690 N/mm^2 :420 HV10

(d) Fracture Test
The fracture test is to be carried out 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. Imperfections that are detected are to be assessed in accordance with ISO 5817, Class B.

8.4.4 Re- testing

8.4.4.1 If the test piece fails to comply with any of the requirements for visual or nondestructive 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.

8.4.4.2 If any test specimens fail to comply with the relevant requirements for mechanical 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.

8.4.4.3 Re-testing in accordance with Ch 1, Sec 2, [2.5.5] is to be carried out, if tensile test specimen fails to meet the requirements.

8.4.4.4 If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

8.4.4.5 Re-testing of Charpy impact specimens is to be carried out in accordance with the requirements of Ch 1, Sec 2, [2.6.4].

8.4.4.6 Where there is insufficient welded assembly remaining to provide additional test specimens, a further assembly is to be welded using the same procedure to provide the additional specimens.

8.4.5 Test Record

8.4.5.1 The welding procedure or PQR or WPQR to provide a detailed record of welding conditions for test assemblies and test results.

8.4.5.2 Each welding procedure test shall be followed by a statement of the results of assessing each test piece, including repeat tests. The relevant items listed for the WPS of these requirements are to be included.

8.4.5.3 A statement that the test piece was made according to the particular welding procedure is to be signed by the attending INTLREG Surveyor, witnessing the test and is to include the INTLREG stamp.

8.5 Range of Approval

8.5.1 General

All the conditions governing the range of approval stated below are to be met independently of each other. Changes outside the specified range require a new welding procedure test.

Shop primer may have an influence on the quality of the fillet welds and is to be considered. Welding procedure qualification with shop primer will quality those without but not the opposite.

8.5.2 Base Metal

8.5.2.1 Ordinary Strength Hull Structural Steel:

For each grade tested, welding procedures are considered applicable to that grade and the lower toughness designation (grades)

8.5.2.2 Higher Strength Hull Structural Steel

(a) For each strength level tested, welding procedures are considered applicable to that strength level, and any of the lower toughness designations (grades) in that strength level.

(b) For each toughness designation (grade) tested, welding procedures are considered applicable to that toughness designation (grade) and two lower strength levels in that toughness designation (grade), including the lower toughness designations (grades) of the lower strength levels.

(c) For applying the above [8.5.2.2](a) and [8.5.2.2](b) to high heat input processes above 50 kJ/cm, e.g., the two-run technique with either submerged arc or gas shielded metal arc welding, electroslag and electro gas welding, the welding procedure is applicable to that toughness grade tested and one strength level below.

(d) Where steels used for construction are supplied with different delivery conditions from those during tests, INTLREG may require additional tests.

8.5.2.3 High Strength Quenched and Tempered Steels

(a) For each strength level tested, welding procedures are considered applicable to that strength level and the lower toughness designations (grades) in that strength level.

(b) For each toughness designation (grade) tested, welding procedures are considered applicable to that toughness designation (grade) and two lower strength levels in that toughness designation (grade).

(c) The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

8.5.2.4 Weldable C and C-Mn Hull Steel Forgings

(a) Welding procedures are considered applicable to that strength level and strength levels lower than that tested.

(b) The approval of quenched and tempered hull steel forgings does not qualify other delivery conditions and vice versa.

8.5.2.5 Weldable C and C-Mn Hull Steel Castings

(a) Welding procedures are considered applicable to that strength level and strength levels lower than that tested.

(b) The approval of quenched and tempered hull steel castings does not qualify other delivery conditions and vice versa.

8.5.3 Thickness

8.5.3.1 The thickness t used in a WPQT is valid for the thickness range as in Table 7.8.2.

Thickness of Test Piece t (1) (mm)	Range of Approval	
	Butt and T Joint welds with single Run or Single Run from Both Sides	Butt and T-Joint Welds with Multi-run and Fillet Welds (2)
$3 < t \leq 12$	70%x t to 110%x t	3 to 2xt
$12 < t \leq 100$	70%x t to 110%x t(3)	50%xt to 200%xt

Notes:

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 50 kJ/cm, the upper limit of range of approval is to be maximum 1.0 × t.
4. Thicknesses above 150 mm are subject to special consideration.

Table 7.8.2: Approval Range of Thickness for Butt and T-Joint Welds and Fillet Welds

8.5.3.2 In addition to the requirements of Table 7.8.2, the range of approval of throat thickness “a” for fillet welds is to be as follows:

Single run: 75% x a to 150% x a

Multi run: as for butt welds with multi-run (ie, a=t)

8.5.3.3 For vertical-down welding, the test piece thickness “t” is always taken a the upper limit of the range of application.

8.5.3.4 For unequal plate thickness of butt welds the lesser thickness is the governing dimension.

8.5.3.5 Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated [8.4.3.2](g) and [8.4.3.3](c).

8.5.4 Welding Position

Approval for a test made in any position is restricted to that position (Refer Appendix 1, Annex 3). To qualify a range of positions, test assemblies are to be welded using the highest heat input position and the lowest heat input position, and all applicable tests are to be made on those assemblies.

8.5.5 Welding Process

8.5.5.1 The approval is only valid for the welding process (es) followed in the welding procedure test. It is not permitted to change from a multi-run process to a single run process.

8.5.5.2 For multi-process procedures the welding procedure approval may be carried out with separate welding procedure tests for each welding process. It is also possible to make the welding procedure test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

8.5.6 Welding Consumable

Except high heat input processes over 50 kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in Ch 3, ~~S~~ Sec 5 with the welding consumable tested.

8.5.7 Heat Input

8.5.7.1 The upper limit of heat input approved is 25% greater than that used in welding the test piece 55 kJ/cm whichever is smaller, except that the upper limit is 10% greater than that for high input processes over 50 kJ/cm.

8.5.7.2 The lower limit of heat input approved is 25% lower than that used in welding the test piece. New materials will be subject to special approval.

8.5.8 Preheating and Interpass Temperature

8.5.8.1 The minimum preheating temperature is not to be less than that used in the qualification test.

8.5.8.2 The maximum interpass temperature is not to be higher than that used in the qualification test

8.5.9 Post-Weld Heat Treatment

The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

8.5.10 Type of Joint

8.5.10.1 Range of approval depending on type of welded joints for test assembly is to be as specified in the table below:

Type of Welded Joint for Test Assembly				**Range of Approval**
Butt Welding	One Side	With Backing	A	A,C
		Without Backing	B	A,B,C,D
	Both Side	With Gouging	C	C
		Without Gouging	D	C,D

8.5.11 Other Variables

Other variables may also be considered in determining the range of approval.

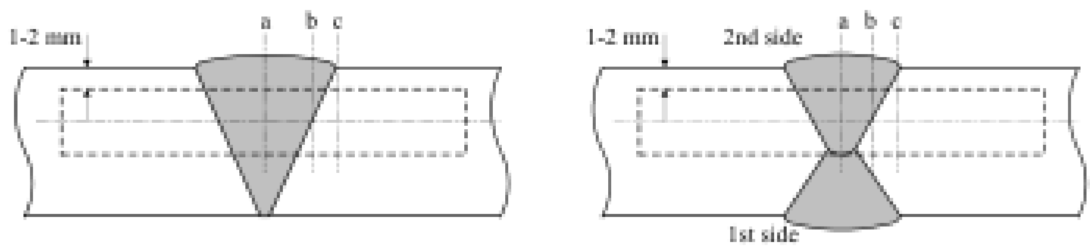
APPENDIX 1:

WELDING PROCEDURE QUALIFICATION TESTS OF STEELS FOR HULL CONSTRUCTION AND MARINE STRUCTURES

ANNEX 1: LOCATION OF CHARPY V-NOTCH IMPACT TEST

FIGURE 1
Locations of V-notch for Butt Weld of Normal Heat Input (Heat Input ≤ 50 kJ/cm)

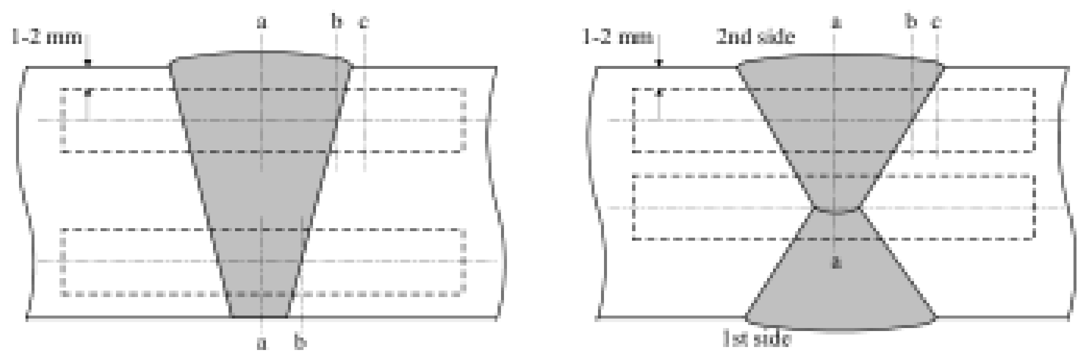
a) $t \leq 50$ mm (1)



Note:

1 For one side single run welding over 20 mm notch location "a" is to be added on root side.

b) $t > 50$ mm



Notch locations:

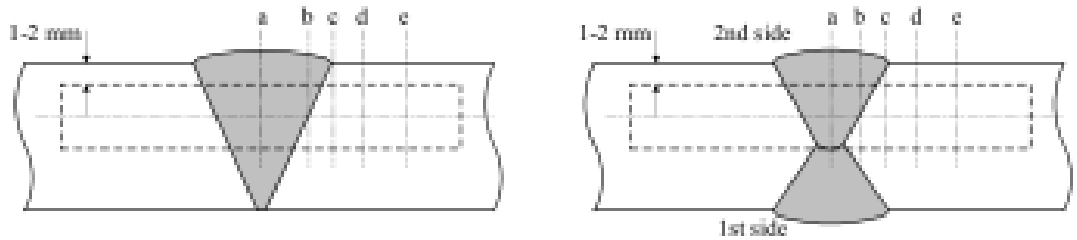
a: center of weld "WM"

b: on fusion line "FL"

c: in HAZ, 2 mm from fusion line

FIGURE 2
Locations of V-Notch for Butt Weld of High Heat Input (Heat Input > 50 kJ/cm)

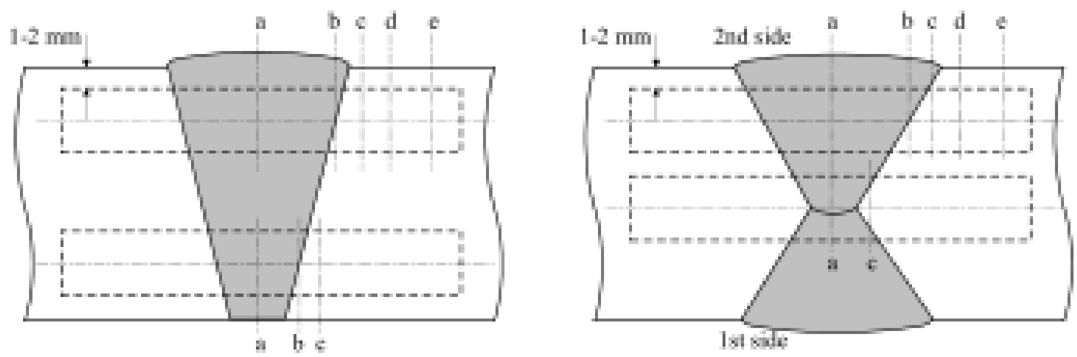
a) $t \leq 50$ **mm** (1)



Note:

1 For one side welding with thickness over 20 mm notch locations "a", "b" and "c" are to be added on root side.

b) $t > 50$ **mm**



Notch locations:

a: center of weld "WM"

b: on fusion line "FL"

c: in HAZ, 2 mm from fusion line

d in HAZ, 5 mm from fusion line

e in HAZ, 10 mm from fusion line

APPENDIX 1:

WELDING PROCEDURE QUALIFICATION TESTS OF STEELS FOR HULL CONSTRUCTION AND MARINE STRUCTURES

ANNEX 2: Hardness Test (Typical examples of hardness test)

FIGURE 1
Examples of Hardness Test with Rows of Indentations (R) in Butt Welds

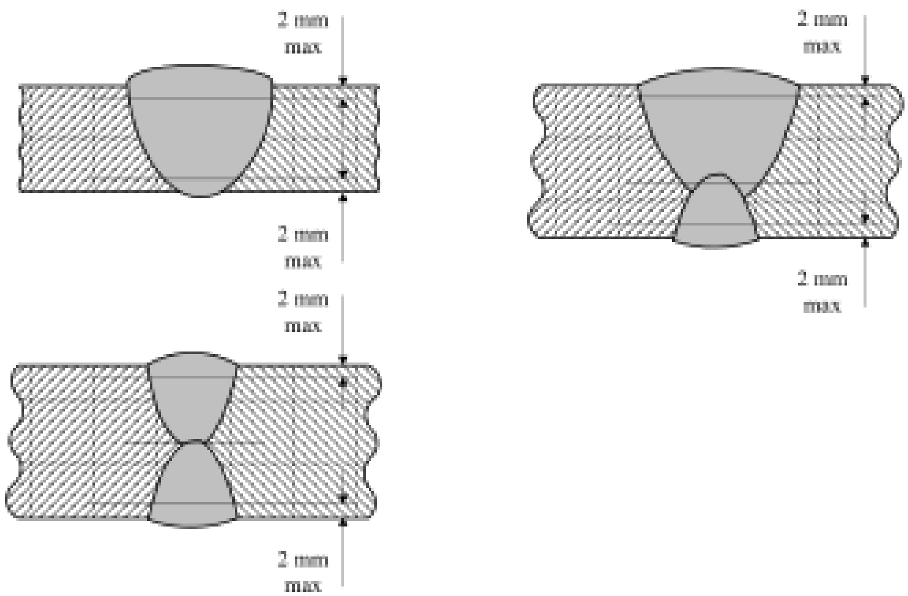


TABLE 1
Recommended Distances ℓ Between Indentations for Hardness Test in the Heat Affected Zone

Vickers Hardness Symbol	*Distance Between Indentations ℓ (mm)*
HV 10	1

The distance of any indentation from the previous indentation is not to be less than the value allowed for the previous indentation by ISO 6507/1.

FIGURE 2
Example Showing the Position of the Indentations for Hardness Test in the Weld Metal, the Heat Affected Zone and the Base Metal of a Butt Weld (dimensions in mm) *(1 July 2014)*

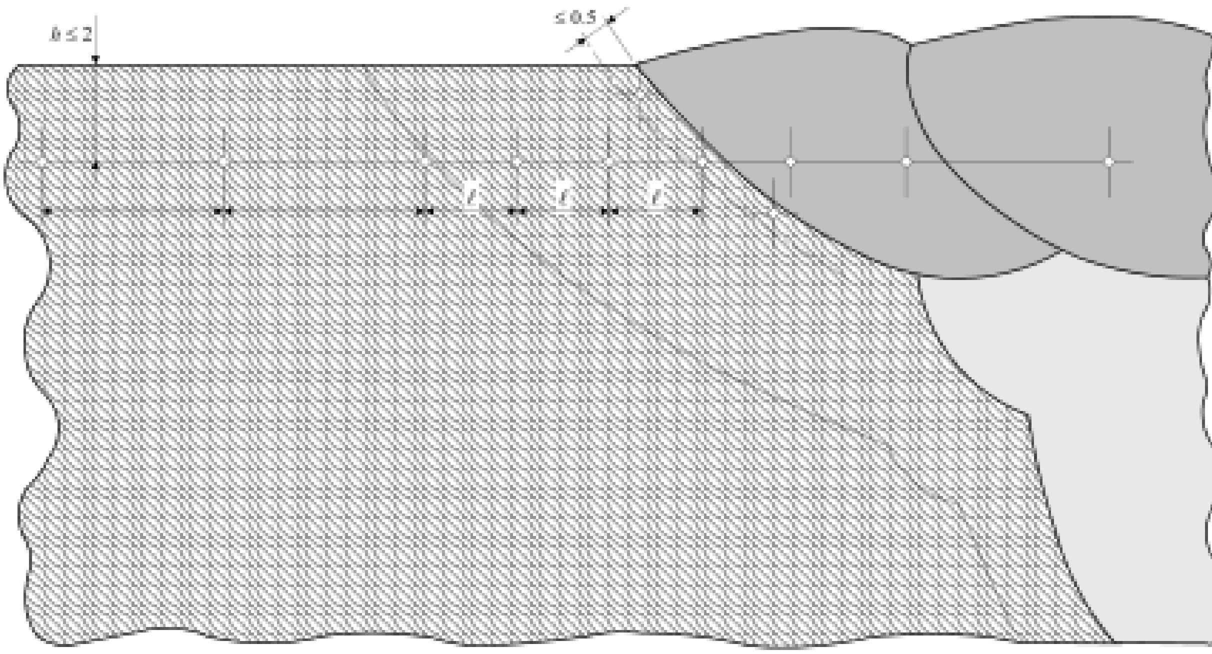


FIGURE 3
Examples of Hardness Test with Row Indentation (R) in Fillet Welds and in T-Joint Welds *(1 July 2014)*

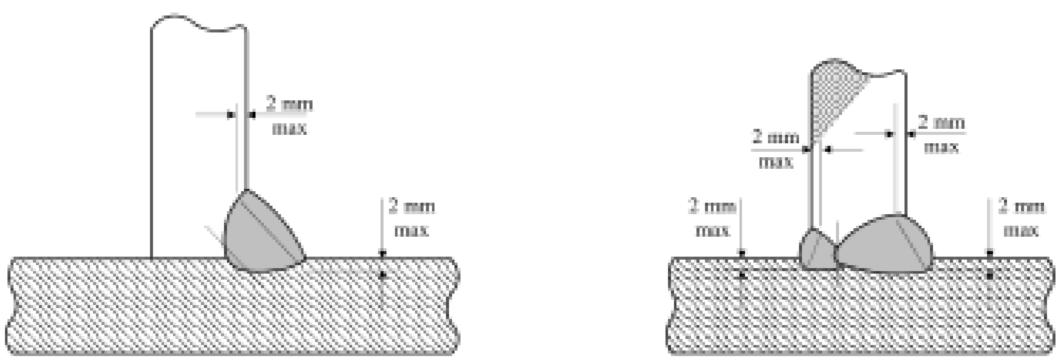
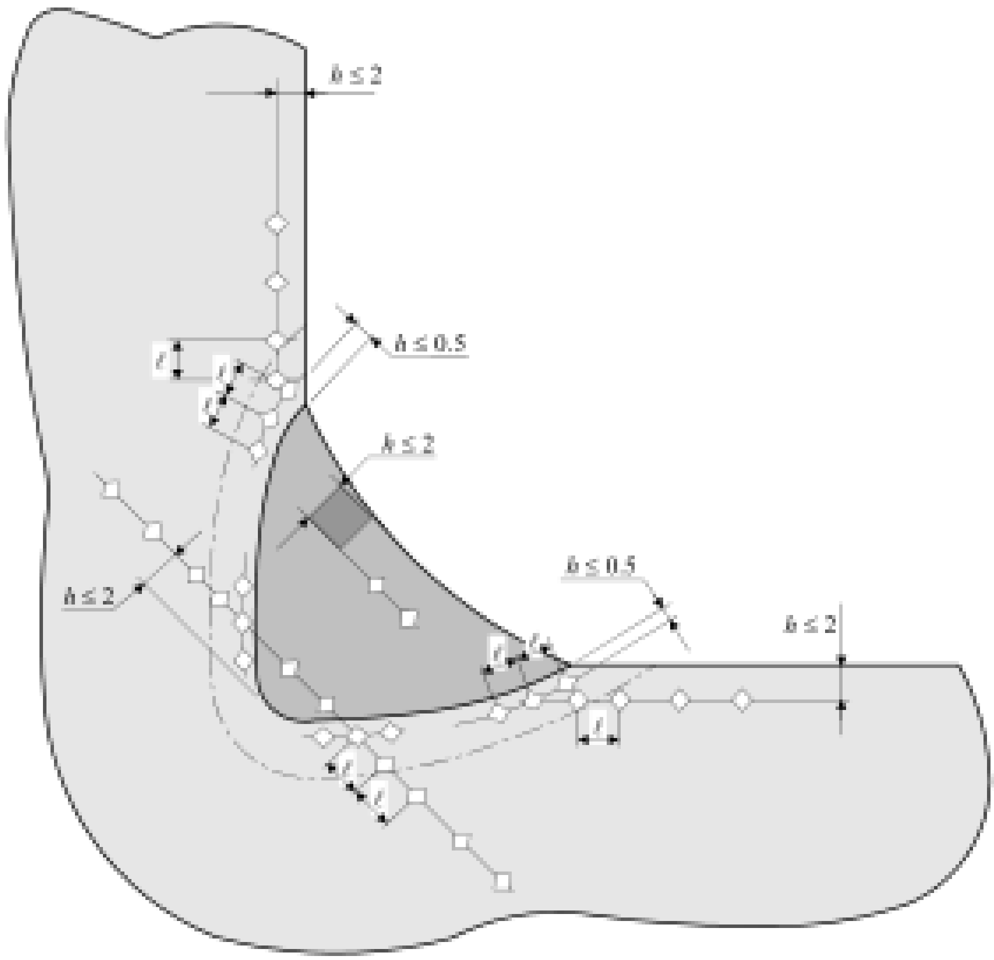
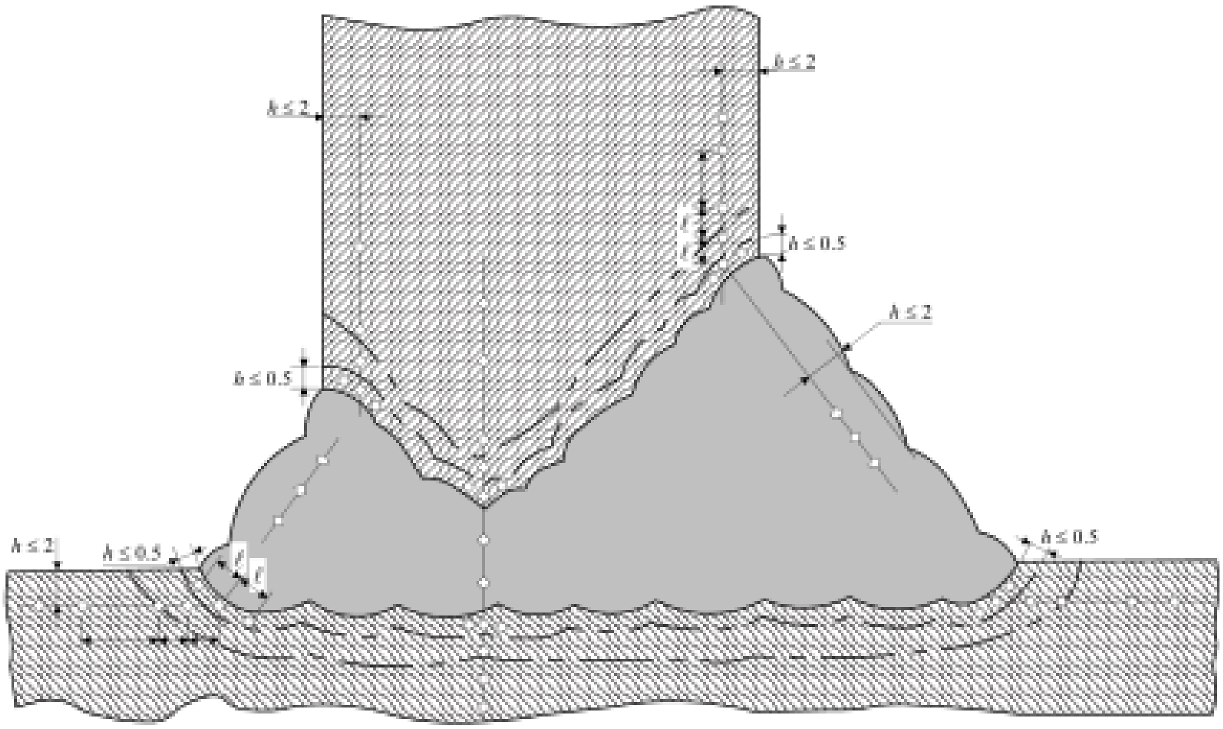


FIGURE 4A
Example Showing the Position of the Indentations for Hardness Test in the Weld Metal, the Heat Affected Zone and the Base Metal of a Fillet Weld (dimensions in mm) *(1 July 2014)*



Note: Where the measurement at less than 0.5 mm of heat affected zone from fusion is impractical, the greater distance than 0.5 mm may be accepted.

FIGURE 4B
Example Showing the Position of the Indentations for Hardness Test on the Weld Metal, the Heat Affected Zone and the Base Metal of a T-Joint Weld (dimensions in mm)



Note: Where the measurement at less than 0.5 mm of heat affected zone from fusion is impractical, the greater distance than 0.5 mm may be accepted.

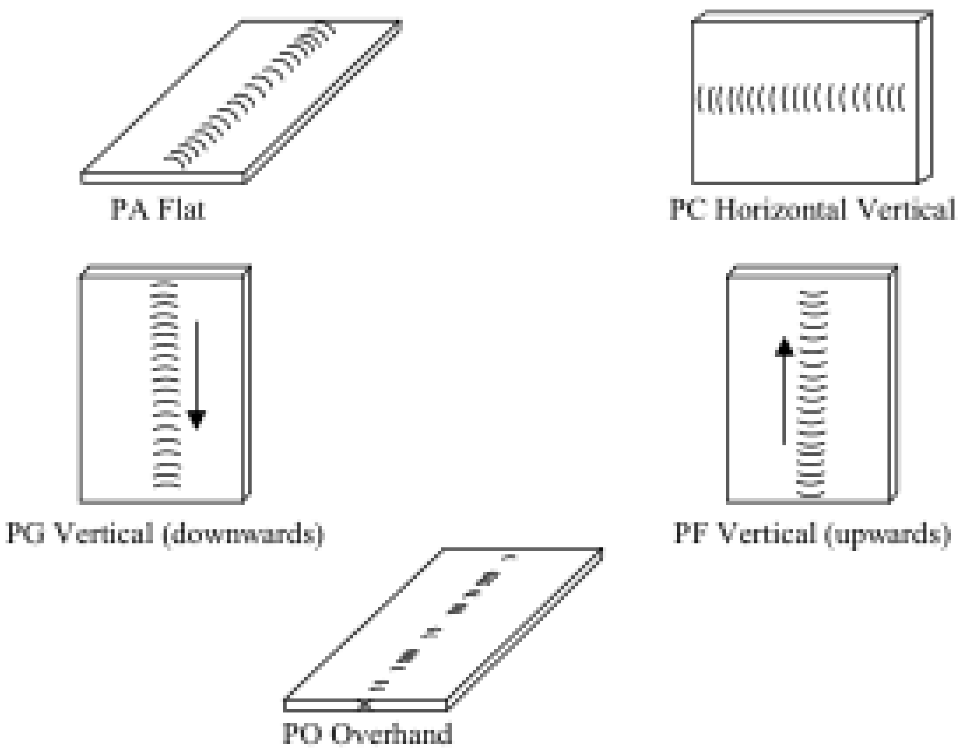
APPENDIX 1:

WELDING PROCEDURE QUALIFICATION TESTS OF STEELS FOR HULL CONSTRUCTION AND MARINE STRUCTURES

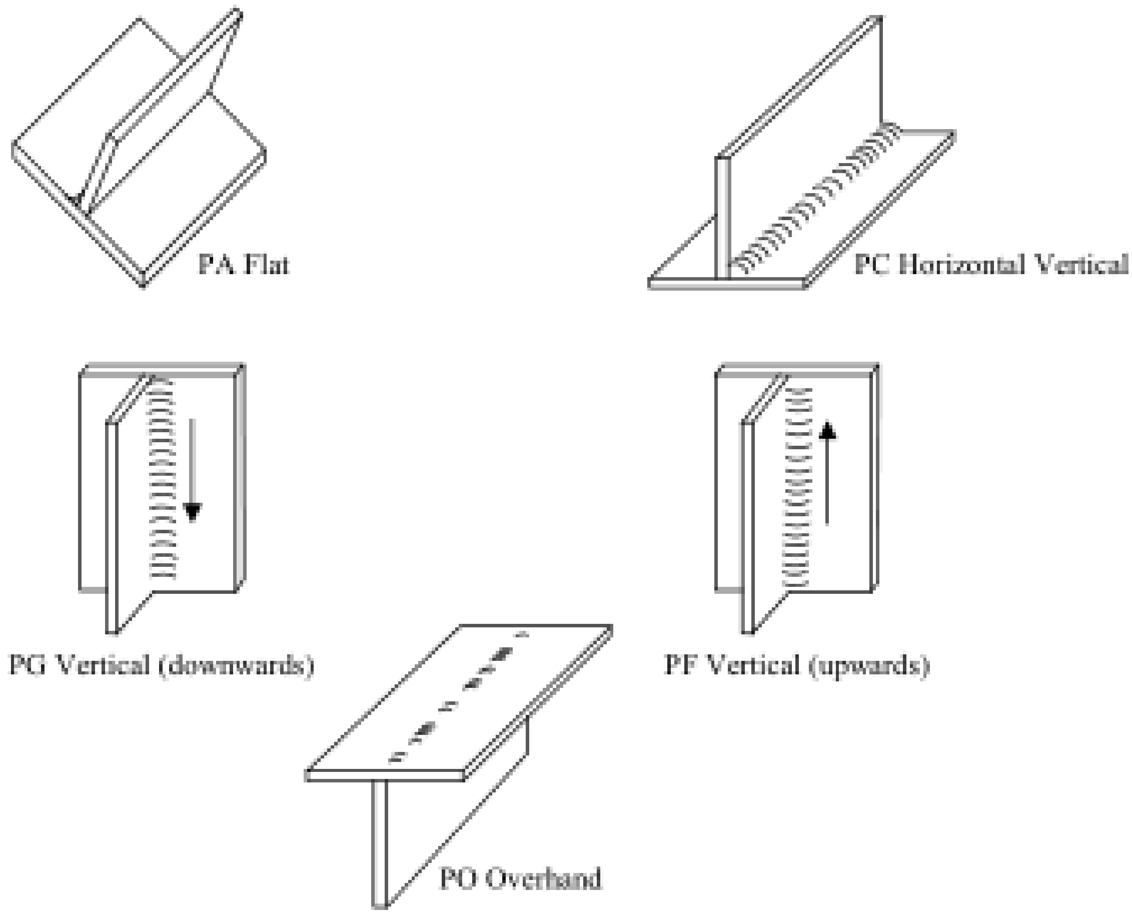
ANNEX 3: Welding Positions

1 Welding Positions According to ISO Standard

a) Butt Welds for Plates

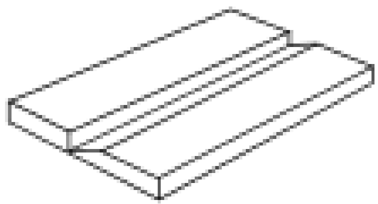


b) **Fillet Welds for Plates**

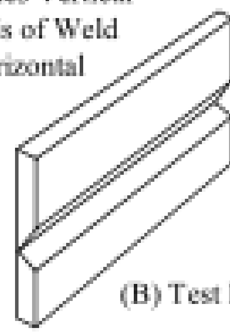


3 Welding Positions According to AWS-Code

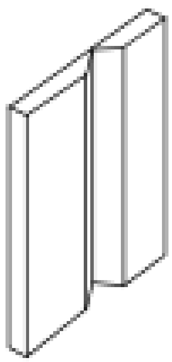
a) Butt Welds for Plates



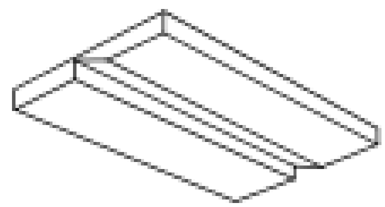
(A) Test Position 1G



(B) Test Position 2G

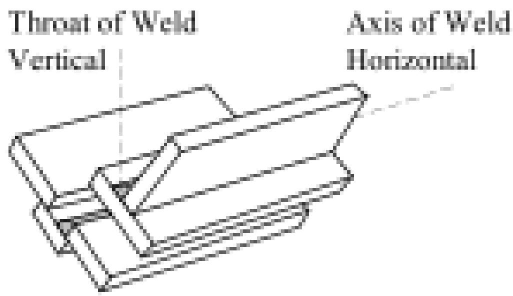


(C) Test Position 3G

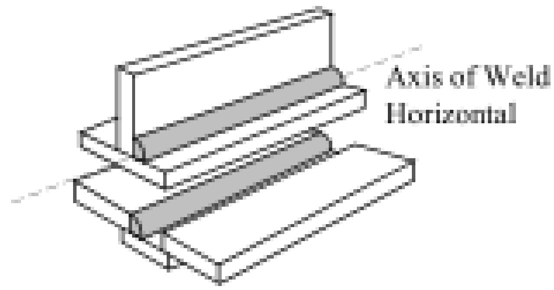


(D) Test Position 4G

b) Fillet Welds for Plates

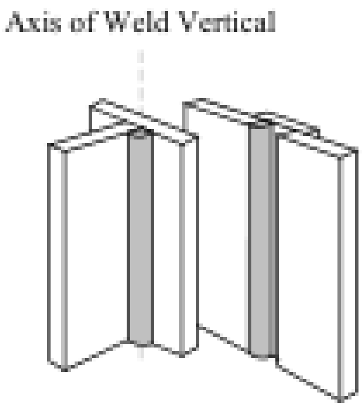


(A) Flat Position 1F

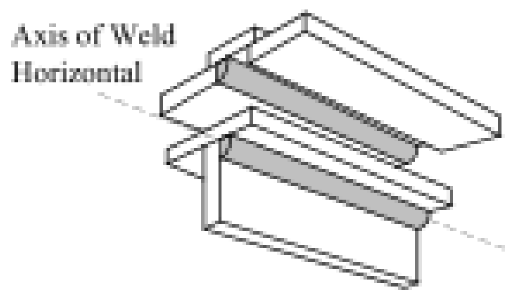


Note: One plate must be horizontal

(B) Horizontal Position 2F



(C) Vertical Position 3F



Note: One plate must be horizontal

(D) Overhead Position 4F