Rules for

Materials and Welding

Part 2

July 2024

RULES FOR

MATERIALS AND WELDING
JULY 2024

PART 2

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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PART 2

Foreword *(2024)*

The Rules in Part 2 incorporate the International Association of Classification Societies (IACS) Unified Requirements (UR) W – Materials and Welding. Also refer to Technical Backgrounds (TB) (development histories) for unified requirements which are available on the IACS website (iacs.org.uk).

The title *"Rule Requirements for Materials and Welding (Part 2)"* is intended to emphasize the common applicability of the material and welding requirements in "Part 2" to ABS classed vessels, other marine structures and their associated machinery, and thereby make "Part 2" more readily a common "Part" of the various ABS Rules and Guides, as appropriate.

Accordingly, the subject booklet, *Rules for Materials and Welding (Part 2),* is to be considered, for example, as being applicable and comprising a "Part" of the following ABS Rules and Guides:

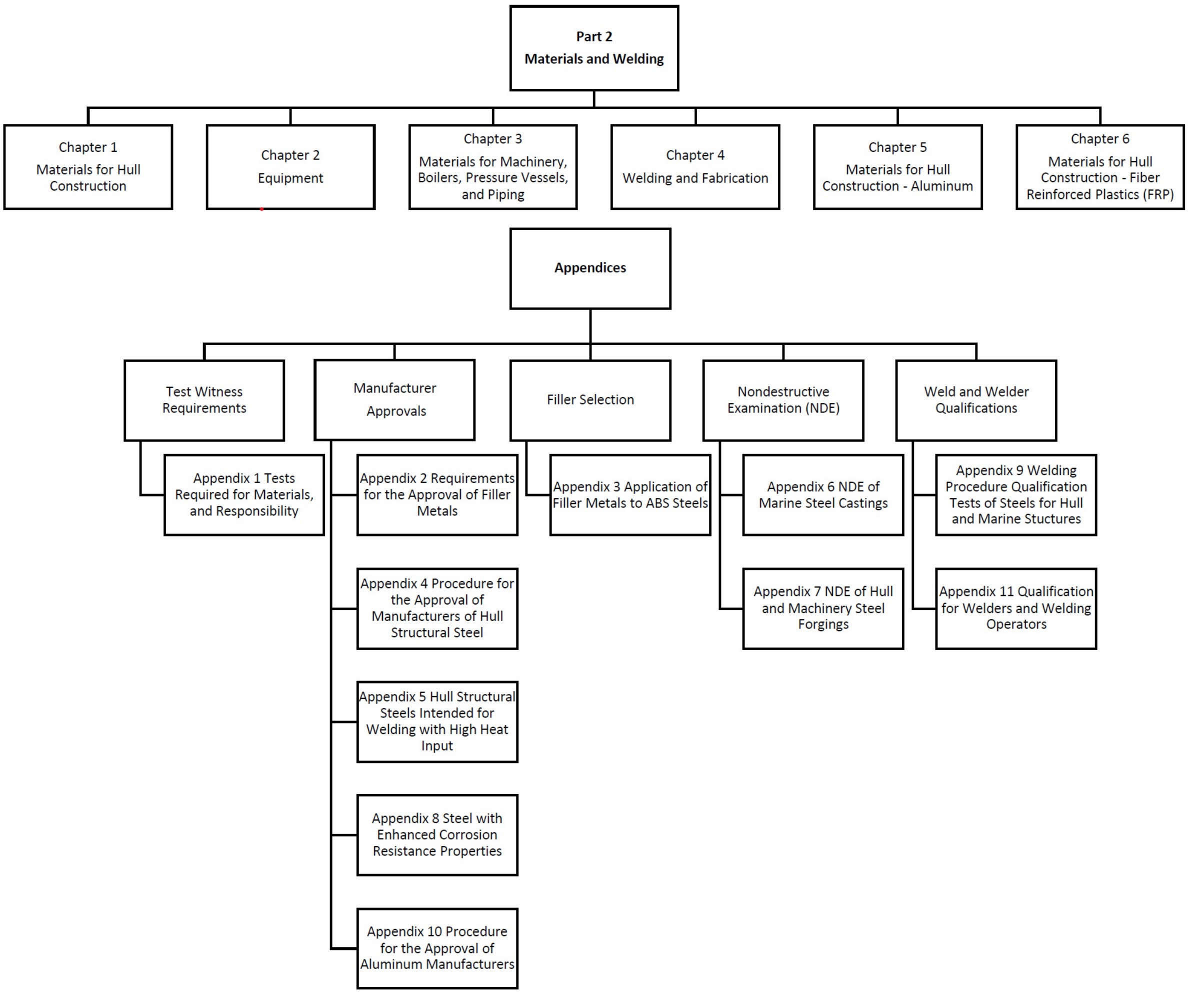
- *Rules for Building and Classing Marine Vessels*
- *Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways*
- *Rules for Building and Classing Mobile Offshore Units*
- *Rules for Building and Classing Steel Barges*
- *Rules for Building and Classing High-Speed Craft*
- *Rules for Building and Classing Floating Production Installations*
- *Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels*
- *Rules for Building and Classing Yachts*
- *Rules for Building and Classing Single Point Moorings*
- *Rules for Building and Classing Bulk Carriers for Service on the Great Lakes*
- *Rules for Building and Classing Steel Floating Dry Docks*
- *Rules for Building and Classing Offshore Installations*
- *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities*
- *Guide for Building and Classing Liftboats*
- *Guide for Building and Classing International Naval Ships*
- *Guide for Building and Classing Floating Offshore Liquefied Gas Terminals*
- *Guide for Building and Classing Drillships*
- *Guide for Building and Classing LNG Regasification Vessels*
- *Guide for Building and Classing SWATH Vessels*
- *Guide for the Certification of Offshore Mooring Chain*
- *Guide for Vessels Intended to Carry Compressed Natural Gases in Bulk*

In the 2018 edition, Part 2 was consolidated to include both the ABS *Rules for Materials and Welding (Part 2)* and the ABS *Rules for Materials and Welding (Part 2) – Aluminum and Fiber Reinforced Plastics (FRP).*

In the 2024 edition, goals and functional requirements are included. When alternative arrangements are proposed for classification, refer to Part 1D, Chapter 2 of the ABS *Rules for Alternative Arrangements, Novel Concepts and New Technologies (Part 1D).*

Part 2 is organized as follows:

Organization of Part 2 *(2024)*



PART 2

Materials and Welding

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CHAPTER 1

Materials for Hull Construction

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PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 1

General Requirements

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i) In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii) Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii) Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv) Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Testing and Inspection

1.2.1 General *(2024)*

All materials subject to test and inspection, intended for use in the construction of hulls and equipment of vessels classed or proposed for classification, are to be to the satisfaction of the ABS Surveyor and in accordance with the following requirements or equivalent.

Materials, test specimens and testing procedures having characteristics differing from those prescribed herein may be approved upon application, due regard being given to established practices in the country in which the material is produced and the purpose for which the material is intended, such as the parts for which it is to be used, the type of vessel and intended service, and the nature of the construction of the vessel.

Commentary:

Applicable ABS Rules indicate when testing and inspection is required in accordance with Part 2, under witness by ABS Surveyor.

For example,

i) *Marine Vessel Rules* Part 3 (specifically Section 3-1-2) or Part 4 or Part 5 or Part 6 will identify when certification is required in accordance with Part 2.

ii) *MOU Rules* Part 3 (specifically Section 3-1-4) or Part 4 or Part 6 will identify when certification is required in accordance with Part 2.

End of Commentary

1.2.2 Manufacturer Approval *(2024)*

i) All products for hull construction are to be manufactured at steel works approved by ABS for the type and grade of steel contemplated. The suitability of the products for welding and assumed forming is to be demonstrated during the initial approval test at the steel works. Approval of the steel works for rolled products is to be in accordance with Part 2, Appendix 4.

Refer to 1.11 for structural pipe. Structural pipe for hull construction refers to stanchions, pillars and truss members integral to the hull.

ii) It is the manufacturer's responsibility to confirm that effective procedures and production controls are implemented during the production, and that the manufacturing specifications are adhered to. In case of any deviation from the procedures and controls that could produce an inferior product, the manufacturer is to carry out a thorough investigation to determine the cause of the mishap and establish countermeasures to prevent its recurrence. The complete investigation report is to be submitted to the Surveyor. ABS reserves the right to request a closer survey until the cause is resolved to the satisfaction of the Surveyor. Each affected piece is to be tested to the satisfaction of the attending Surveyor prior to distribution from the steel works. In addition, the frequency of testing for subsequent products may be increased to gain confidence in the quality.

iii) Where the steel is not produced at the rolling mill, the procedures in 7.3 are to be followed.

iv) It is the manufacturer's responsibility to confirm that raw materials used/semi-finished/finished cast or wrought steel products produced are within radioactive contamination limits as permitted by an appropriate regulatory body/agency, as applicable to the place of manufacture. Radiation level and reference to the allowed limits are to be specified and documented in manufacturer's QA/QC procedures.

1.3 Tests and Data *(2024)*

1.3.1 Witnessed Tests

The designation (W) indicates that a Surveyor is to witness the testing unless the plant is enrolled and product is manufactured under ABS's Quality Assurance Program.

1.3.2 Manufacturer's Data

The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

1.3.3 Other Tests *(2024)*

The designation (A) indicates 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 Rule requirements.

See Part 2, Appendix 1 for complete listing of indicated designations for the various tests called out by Chapter 1, Chapter 2, and Chapter 3 of this Part.

1.4 Terminology *(2024)*

i) Sections are intended to cover bars, shapes.

ii) Structural Tubulars are intended to cover hollow structural sections (round, square and rectangular, etc.)

1.5 Certification on the Basis of the ABS Quality Assurance Program for Rolled Products *(2023)*

Mills approved by ABS have the option to enroll in the ABS Quality Assurance (QA) Program. The manufacturer is to have in place an effective quality assurance system certified by an internationally recognized certification body as complying with a recognized quality standard at least equivalent to the ISO 9000 series. Equivalency will be determined on a case-by-case basis. Such certification is to be valid during the validity of the ABS QA Certificate.

A QA Certificate will be issued to a manufacturer who has requested that Rule-required surveys and tests be conducted without an ABS Surveyor in attendance. For that purpose, the manufacturer is to meet the requirements of the ABS Quality Assurance Program. The intent is to have a quality assurance system in operation that is at least as effective as the Surveyor's attendance at those surveys and tests. Enrollment in the ABS QA Program will include a confirmatory evaluation, including at least initial, preiodic, annual, and renewal audits of the quality system, in accordance with the provisions of the applicable quality assurance standard and ABS's own criteria. When requested by the manufacturer, consideration will be given to crediting a periodic audit based on a Surveyor's recommendation after attendance for Material Certification or a surveillance visit on or about the due date of the periodic audit. The periodic audit will have a window of 45 days before and 45 days after the midpoint between annual audits.

The issuance of a Quality Assurance Certificate is contingent upon the recommendation by the attending Surveyor, seconded by the Surveyor in Charge, and final approval by the ABS Materials Department. During the manufacturing of the material, the Quality Assurance certification will provide an alternative to the requirements for witnessed testing by a Surveyor. This is not a relaxation of the Rule requirement for material testing, but rather allows such testing to be conducted without an ABS Surveyor being present. For continued compliance with the Rules, Guides or standards, a batch inspection verification system is to be agreed between the Surveyors and the manufacturer that will allow a random material certification of production.

Where conditions justify the need for increased surveillance, the QA does not preclude the Surveyor in Charge from expanding the scope of surveillance. Where the situation (e.g., frequency of ABS material certification, batch test results, etc.) warrants such action, ABS may require a closer interval of periodic quality audits. In such instances, the requirement for a renewal audit will be specially considered. ABS also reserves the right to conduct unscheduled quality audits.

Manufacturers enrolled in the optional ABS QA Program will be listed on the ABS website.

1.7 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

1.9 Calibrated Testing Machines *(2005)*

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition. Additionally, the Surveyor is to keep a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out to a recognized national or international Standard by competent personnel.

1.11 Structural Tubulars *(2024)*

Unless otherwise indicated (e.g., 3-1-4/1.1 of the ABS *Rules for Building and Classing Mobile Offshore Units*), tubulars intended for structural use are to be tested to the applicable specification as agreed with ABS.

1.13 References *(2024)*

Frequent references will be found within Part 2 to various American Society for Testing and Materials (ASTM) specification designations or other recognized national standards without year notations. Unless otherwise noted, the current issue of the ASTM specification or other recognized national standards is to be used.

3 Surface Quality *(1 July 2018)*

3.1 General

The steel is to be free from cracks, injurious surface flaws, injurious laminations and similar defects prejudicial to the use of the material for the intended application.

The finished material is to have a surface quality in accordance with a recognized standard such as EN 10163 Parts 1 (General), 2 (Plates), or ASTM A6 or an equivalent standard accepted by ABS, unless otherwise specified in this Section. In case there is conflict between the requirements, the more stringent requirements are to be followed.

3.3 Manufacturer Responsibility

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

3.3.1

The surface quality inspection method is to be in accordance with recognized national or international standard agreed between purchaser and manufacturer, accepted by ABS.

3.3.2

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

3.5 Acceptance Criteria

3.5.1 Imperfections *(2024)*

i) Imperfections of a harmless nature, for example pitting, rolled-in scale, indentations, roll marks, scratches and grooves, regarded as being inherent to the manufacturing process, are permissible irrespective of their number, provided the maximum permissible limits of Class A of EN 10163-2 or limits specified in a recognized equivalent standard accepted by ABS, are not exceeded and the remaining plate or wide flat thickness remains within the average allowable minus thickness tolerances specified in 2-1-1/15.

ii) Total affected area with imperfections not exceeding the specified limits is not to exceed 15% of the total surface on each side.

3.5.2 Defects

i) Affected areas with imperfections with a depth exceeding the limits of Class A of EN10163-2 or the maximum permissible limits specified in a recognized equivalent standard accepted by ABS, are to be repaired irrespective of their number.

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

3.7 Repair

3.7.1 Grinding Repair

i) Unless otherwise agreed, grinding may be applied provided all the conditions below are adhered to:

a) The nominal product thickness will not be reduced by more than 7% or 3 mm (0.12 in.), whichever is the less.

b) Each single ground area below the minimum thickness does not exceed 0.25 m^2 (2.7 ft^2).

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

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

e) Ground areas lying opposite each other on both surface is to not decrease the product thickness by values exceeding the limits as stated under i.

ii) Defects or unacceptable imperfections are to be completely removed by grinding and the remaining plate or wide flat thickness is to remain within the average allowable thickness tolerance specified in 2-1-1/15. The ground areas are to have a smooth transition to the surrounding surface of the product. Complete elimination of the defect can be verified by visual inspection, Magnetic particle (MT) or liquid penetrant (LT) testing.

Note: The NDE technique initially used to detect a defect is to be applied after grinding to verify defect removal. NDE operators are to be qualified to the satisfaction of the attending Surveyor.

3.7.2 Welding Repair

Weld repair procedures and the method for repair are to be reported and be approved by ABS. To confirm defects have been removed prior to weld repair, MP or LP may be required. Repair of defects such as unacceptable imperfections, cracks, shells or seams is to be followed by MP or LP inspection.

Local defects which cannot be repaired by grinding as stated in 2-1-1/3.7.1 may be repaired by welding with the agreement of ABS subject to the following conditions:

i) Any single welded area is not to exceed 0.125 m^2 (1.35 ft^2) and the sum of all areas is not to exceed 2% of the surface side in question.

ii) The distance between two welded areas is not to be less than their average width.

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

iv) If weld repair depth exceeds 3 mm, UT may be requested by ABS. If required, UT is to be carried out in accordance with an approved procedure.

v) The repair is to be carried out by qualified welders using an approved procedure for the appropriate steel grade. The electrodes is to be of low hydrogen type and is to be dried in accordance with the manufacturer's requirements and protected against re-humidification before and during welding.

3.9 Bars, Shapes and Tubulars

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

5 Identification of Materials

The manufacturer is to adopt a system for the identification of ingots, slabs, finished plates, shapes, castings and forgings which will enable the material to be traced to its original heat and the Surveyor is to be given every facility for so tracing the material.

7 Manufacturer's Certificates

7.1 Form of Certificate

Unless requested otherwise, four 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 are to be furnished to the Surveyor. 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 ABS. Before the certified mill tests reports and shipping information are distributed to the local ABS office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been made by an approved process and that it has satisfactorily withstood the prescribed tests. 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 American Bureau of Shipping Rules or state other specification) with satisfactory results."

At the request of manufacturers, consideration may be given to modifications in the form of the certificate, provided it correspondingly indicates compliance with the requirements of the Rules to no less degree than indicated in the foregoing statement.

7.2 Electronic Certification System *(1 July 2022)*

An electronic certification system may be used to issue certified mill test reports, which may be electronically signed and stamped by the attending Surveyor, subject to the following conditions:

i) Mills under the ABS QA Program may implement an electronic certification system provided its effectiveness is verified during the scheduled ABS quality audits.

ii) Mills approved by ABS but not enrolled in the ABS QA Program may request electronic certification system provided the following is complied with:

- ***a)*** Periodic and annual audits are conducted to verify the effectiveness of the electronic certification system.
- ***b)*** All material certification Rule requirements for survey attendance are met.

iii) A request is to be made to ABS Materials Department for approval to implement electronic certification system.

iv) All relevant information regarding the customer order is to be provided to the attending Surveyor by the manufacturer.

v) Procedures are to be established to control handling and distribution of certified mill test reports among the manufacturer, ABS, and the purchaser.

vi) Electronic Certification System is only allowed where the Surveyor has access to the results of the relevant tests and inspections and is able to authorize by access to the electronic system, the application of the ABS office stamp, and Surveyor's name on the test certificate. The name of the authorizing Surveyor is to be the name included on the certificate. The authorization may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor. It is recognized that there may be various quality control systems that govern issuance of material test reports. Proposals to meet the intent of this section are to be submitted for review and acceptance.

vii) The mills under the electronic certification system are to implement security provisions that appropriately control electronic storage and protect unauthorized use of all electronic signatures provided by ABS.The provisions are to be reviewed by ABS for approval to implement the electronic certification system.

viii) These provisions and effectiveness of the electronic certification system are to be assessed at the time of ABS audits at the mill by the attending Surveyor.

ix) A copy of the electronic certificate is supplied to ABS. This copy will be deemed to be the original of the test certificate.

x) An Annual Report is to be issued by the mill for ABS certified material products and is to be made available to the attending Surveyor for review.

xi) *Withdrawal of the Approval.* The approval may be withdrawn in the following cases:

a) Any findings during the audits which may affect the effectiveness of security controls based on which the electronic system has been granted.

b) Discovery of any cases of misuse of approved electronic certification without authorization by the Surveyor.

c) Not informing ABS immediately of any known issues in the approved electronic certification system which may affect the security of the system.

d) Discovery of failure of the manufacturer's electronic certification system.

e) Changes, made by the manufacturer without prior agreement of ABS, impact the approval.

7.3 Other Certificates *(2024)*

Where steel is not produced in the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor, for the semi-finished prodcuts, stating the following:

i) Process by which it was manufactured

ii) Name of the manufacturer who supplied it

iii) Number of the heat from which it was made and the ladle analysis

iv) Number of the heat is to be marked on each ingot, bloom, slab or billet for the purpose of identification.

Where the product is not heat treated in the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor by the works at which it is finally heat treated, stating the following:

i) Process by which it was rolled or forged

ii) Name of the manufacturer who supplied it

iii) Heat number from which it was made and the ladle analysis

All heat treatment facilities are to be ABS approved, in association with qualification testing being carried out on the final product after final heat treatment. The heat treatment works is also required to supply the record of heat treatment, including heat treatment curves, soaking time and temperature, and heating and cooling rates.

9 Marking and Retests

9.1 Identification of Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark, nor are they to be detached until the material has received its final treatment.

9.3 Defects in Specimens

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that for forgings a retest is not allowed if a defect develops during testing which is caused by rupture, cracks or flakes in the steel.

9.5 Retests

If the percentage of elongation of any tension test specimen is less than that specified and 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, a retest is to be allowed.

9.7 Rejected Material

In the event that any set of test specimens fails to meet the requirements, the material from which such specimens have been taken is to be rejected and the required markings withheld or obliterated.

11 Standard Test Specimens

11.1 General *(2024)*

i) The tension test specimens are to be of the full thickness or section of material as rolled, except as otherwise specified.

ii) Test specimens are to have undergone the same treatment as the material from which they have been taken (e.g., heat treatment).

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

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

v) The accuracy of the tensile test machines is to be within ±1% of the load.

vi) Testing machines are to be calibrated in accordance recognized standards at approximately annual interval

11.3 Tensile Test Specimens Orientation and Location *(2024)*

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

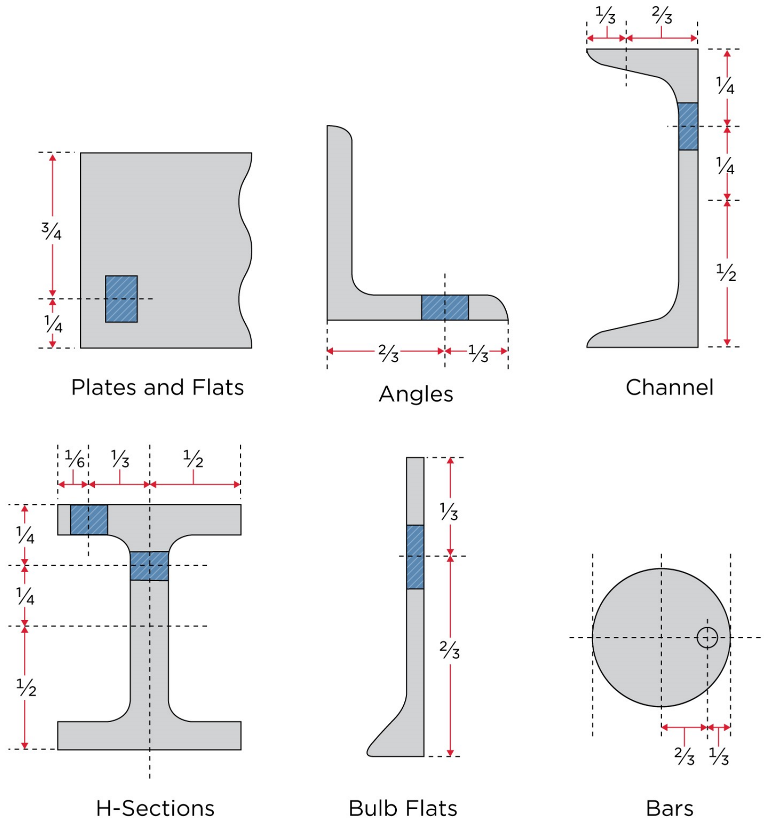
ii) Unless otherwise agreed the test samples are to be taken from the following positions:

	Plates and Flats, Width < 600 mm (24")	*Plates and Flats, Width ≥ 600 mm (24")*	*Shapes*[(1)]	*Bars*
Location of Test Specimen	⅓ from the outer edge	¼ width	⅓ from the outer edge	⅓ Radius
Direction of Tensile Test Specimen to the Final Direction of Rolling	Longitudinal or Transverse	Transverse	Longitudinal or Transverse	Longitudinal

Note:

1 In case of small sections, test specimen can be as near as possible to this position.

FIGURE 1A
Test Specimen Locations for Plates, Flats, Shapes and Bars *(2024)*



11.5 Tension Test Specimens for Plates and Shapes *(1996)*

11.5.1 Flat Specimens

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to the form and dimensions referred to in 2-1-1/16 FIGURE 2 or tension test specimens of dimensions other than described may be approved at the request of the manufacturer.

11.5.2 Round Specimens

For material over 19 mm (0.75 in.) in thickness or diameter, tension test specimens may be machined to dimensions referred to in 2-1-1/16 FIGURE 2. The axis of each round specimen is to be located as nearly as practicable midway between the center and the surface of the material. Tension test specimens of dimensions other than described above may be approved at the request of the manufacturer.

11.7 Tension Test Specimens for Castings (other than Gray Cast Iron) and Forgings *(2024)*

Tension test specimens for castings and forgings are to be machined to the dimensions as round specimen alternative C in 2-1-1/16 FIGURE 2 or in accordance with 2-1-1/16 FIGURE 3.

11.9 Bend Test Specimens, Castings and Forgings *(2005)*

When required, bend test specimens for castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. The length is unimportant provided it is enough 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.).

11.11 Impact Test Specimens *(2024)*

i) A set of impact tests is to consist of three specimens taken from a single test coupon or test location.

ii) Impact test specimens are to be machined to the form, dimensions and tolerances shown in 2-1-1/16 FIGURE 4.

iii) Full size standard specimens are to be used unless the section thickness of the product is less than 11 mm ($^{7}/_{16}$ in.) or the absorbed energy is expected to exceed 80% of the test machine full scale capacity.

iv) The length of the notch is to be perpendicular to the original rolled surface.

v) For plates, flats and bars.

	Thickness, t ≤ 40 mm (1.57 in.)	*Thickness, t > 40mm (1.57 in.)*
Test Specimen Location	Specimen longitudinal edges within 2mm (0.08 in.) from the surface	Specimen longitudinal axis at ¼t
Test Specimen Direction to Final Direction of Rolling	Option at steel manufacturer, unless specific orientation is specified	

Also see 2-1-2/11.1, as applicable.

11.13 Tolerances *(2024)*

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

13 Definition and Determination of Yield Point and Yield Strength

13.1 Yield Point *(2005)*

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

The test is to be carried out with an elastic stress within the following limits:

Modulus of Elasticity of the Material (E), N/mm²	*Rate of Stressing, N/mm²-s⁻¹*	
	Min.	*Max.*
< 150,000	2	20
≥ 150,000	6	60

13.3 Yield Strength (Proof Strength) *(2024)*

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% (*Rp 0.2*) offset method. Alternatively, for material whose stress-strain characteristics are established from previous tests in which stress-strain diagrams were plotted, the 0.5% extension under load method may be used.

For austenitic and duplex stainless steel products, the 1% proof stress (*Rp 1*) may be determined in addition to *Rp 0.2*.

The rate of loading is to be as stated in the limits in the table in 2-1-1/13.1 above.

13.5 Tensile Strength (R_m) *(2024)*

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

14 Elongation (A) *(2024)*

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

Generally, the elongation, A_5, is determined 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 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, A_0, on that gauge length, L_0, may after agreement be calculated from the following formula:

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

For tables and graphs, see ISO/DIS 2566.

15 Permissible Variations in Dimensions *(1994)*

15.1 Scope *(2002)*

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

The responsibility for meeting the tolerances rests with the manufacturer who is to maintain a procedure acceptable to the Surveyor. Where any tolerance (including over thickness tolerance) to be used is more stringent than the normal commercial tolerance, ABS is to be advised before the steel is presented for acceptance to confirm that the thickness measuring procedure is appropriate.

In all cases, the thickness of the steel is to comply with the under tolerance specified below. The steel mill is to consider the effect of mill scale on the resulting measurement.

For classification purposes, including the assessment of deterioration at future thickness gaugings, the thickness indicated on the approved plan is to be used.

15.3 Plates and Wide Flats *(1 July 2019)*

These requirements apply to the tolerance on thickness of steel plates and wide flats with widths of 600 mm (24 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:

i) Normal and higher strength hull structural steel.

ii) Extra high strength steel for welded structure according to Section 2-1-8.

The thickness tolerances for products below 5 mm (0.2 in.) are to be in accordance with a national or international standard such as ASTM A6 or Class B of ISO 7452. However, the minus tolerance is not to exceed 0.3 mm (0.012 in.).

Note:

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

Class C of ISO 7452 latest version, or equivalent recognized national or international standards, may be applied in lieu of 15.3.2, in which case the requirements in 15.3.3 and 15.3.4 need not be applied.

Additionally, if Class C ISO 7452 latest version is applied, it is required that the steel mill demonstrate to the satisfaction of ABS 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.

15.3.1 Responsibility

The responsibility for verification and maintenance of the production within the required tolerances rests with the manufacturer. The Surveyor may require that he witness some measurements. The responsibility for storage and maintenance of the delivered product(s) with acceptable level of surface conditions rests with the shipyard before the products are used in fabrication.

15.3.2 Thickness Tolerances

15.3.2(a) Thickness tolerances of a given products are defined as:

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

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

Note:

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

15.3.2(b) The minus tolerance on nominal thickness of products in the scope of 2-1-1/15.3 is 0.3 mm (0.012 in.) irrespective of nominal thickness.

15.3.2(c) Thickness tolerances are not applicable to areas repaired by grinding in accordance with 2-1-1/3.7.1, unless more stringent requirements are specified by the purchaser and agreed by ABS Materials Department.

15.3.2(d) Plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard such as ASTM A6, unless otherwise specified by the purchaser and agreed by ABS Materials Department.

15.3.2(e) Weight tolerance may be specified by purchaser.

15.3.3 Average Thickness

15.3.3(a) The average thickness of a product is defined as the arithmetic mean of the measurements made in accordance with the requirements of 2-1-1/15.3.4.

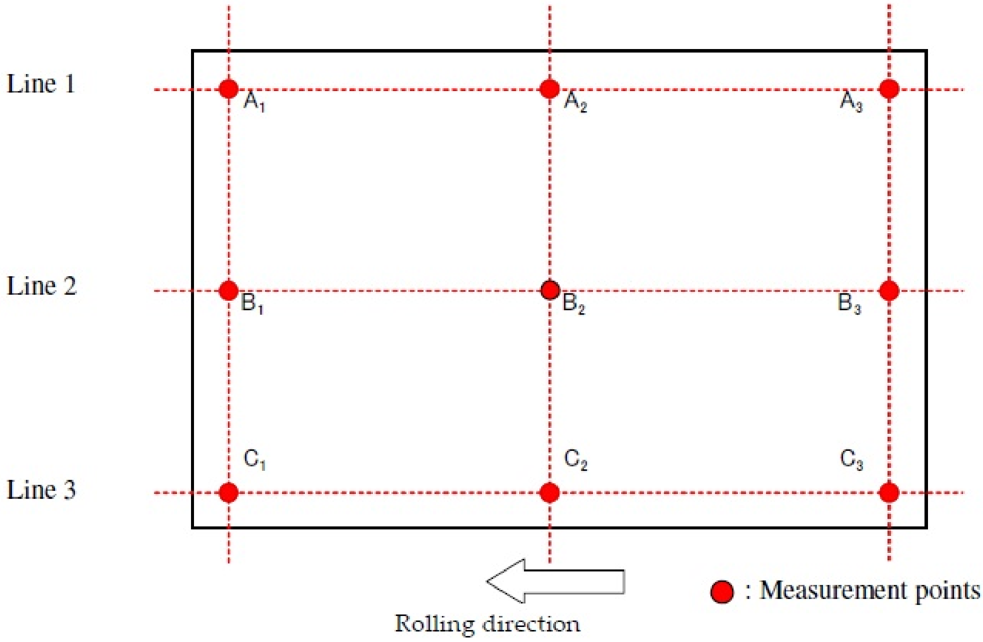
15.3.3(b) The average thickness of the product is not to be less than the nominal thickness.

15.3.4 Thickness Measurements

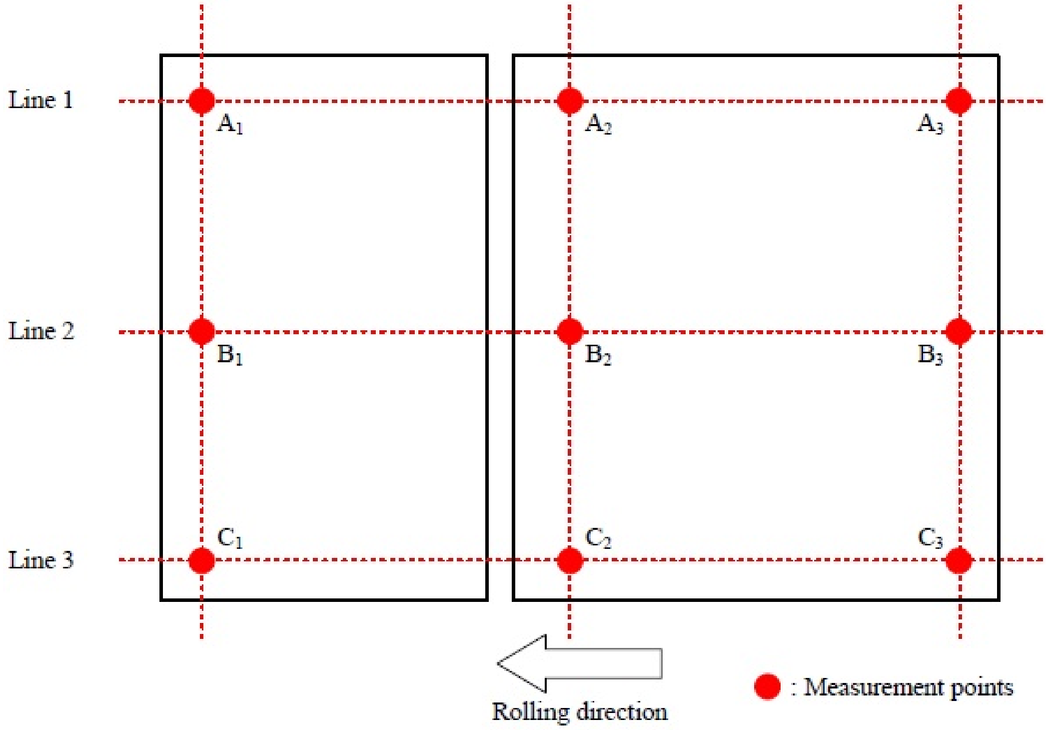
15.3.4(a) Thickness is to be measured at locations as defined in 2-1-1/15.3.4 FIGURE 1B. Automated or manual measurement methods may be used.

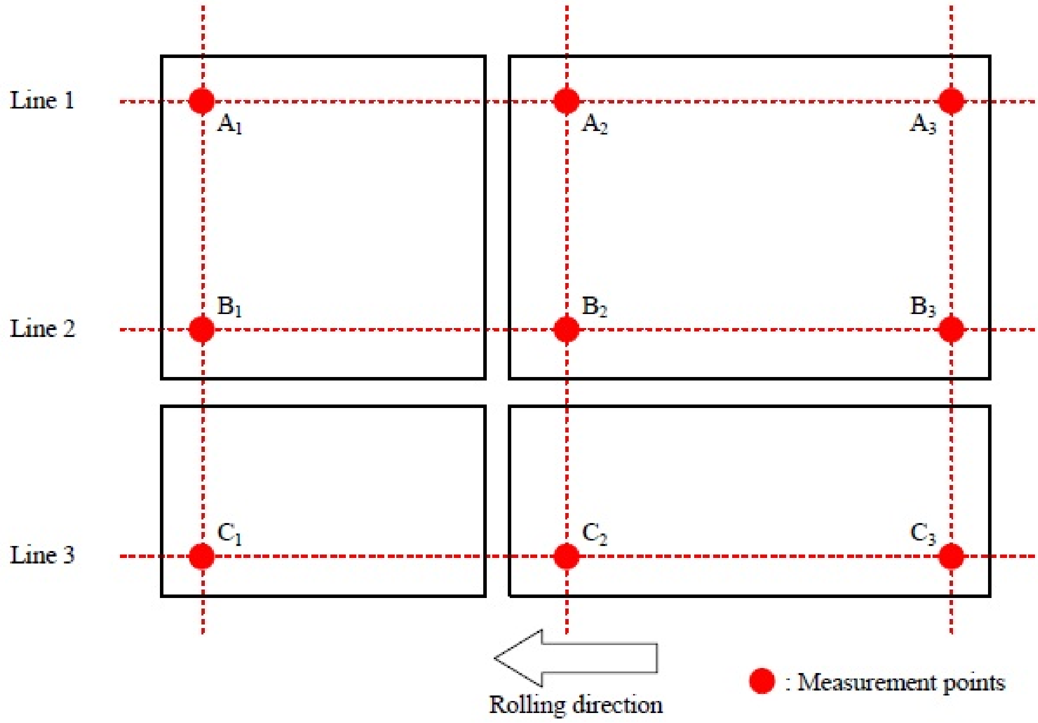
15.3.4(b) The procedure and records of measurements are to be made available to the Surveyor and copies provided on request.

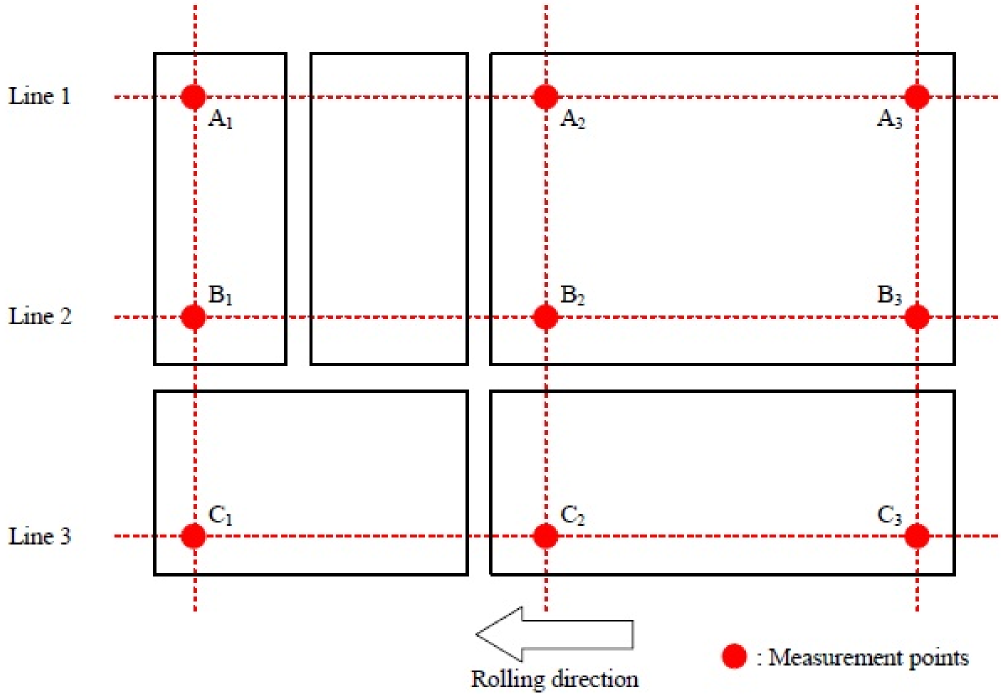
FIGURE 1B *(1 July 2013)*



a) Locations of Thickness Measuring Points for the Original Steel Plates


Line 1
Line 2
Line 3
A1
A2
A3
B1
B2
B3
C1
C2
C3
Rolling direction
: Measurement points


Line 1
Line 2
Line 3
A1
A2
A3
B1
B2
B3
C1
C2
C3
Rolling direction
: Measurement points



b) Locations of Thickness Measuring Points for the Cut Steel Products

Notes:

1 *(1 July 2013)* At least two lines are to be selected from Lines 1, 2, or 3 as shown, and at least three points on each selected line are to be selected for thickness measurement. 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. Examples of the original measurements relative to later cut products are shown in 2-1-1/15.3.4 FIGURE 1B b). It is to be noted that the examples shown are not representative of all possible cutting scenarios.

2 For automated measuring, peripheral points are to be located 10-300 mm (0.375-12.0 in.) from the edge.

3 For manual measuring, peripheral points are to be located 10-100 mm (0.375-4.0 in.) from the edge.

15.5 Shapes and Bars

The under tolerance of cross sectional dimensions for shapes and bars are based on the ordered dimensions and are to conform to those given in ASTM A6 or other recognized standards as may be specified in the purchase order.

16 Rolled Plates over 100 mm (4 in.) Thick

When ABS and non-ABS grade rolled plates of over 100 mm (4 in.) thickness are used for vessel hull structural application, in addition to chemical analysis the following test data is to be obtained at onequarter and mid thickness locations:

i) Tensile properties, and

ii) Impact properties in the longitudinal or transverse directions

Also, each plate is to be UT inspected in accordance with either ASTM A578 Level B or another equivalent recognized standard to evaluate the internal soundness.

FIGURE 2
Standard Tension Test Specimen[1] *(1995)*

d = diameter in mm

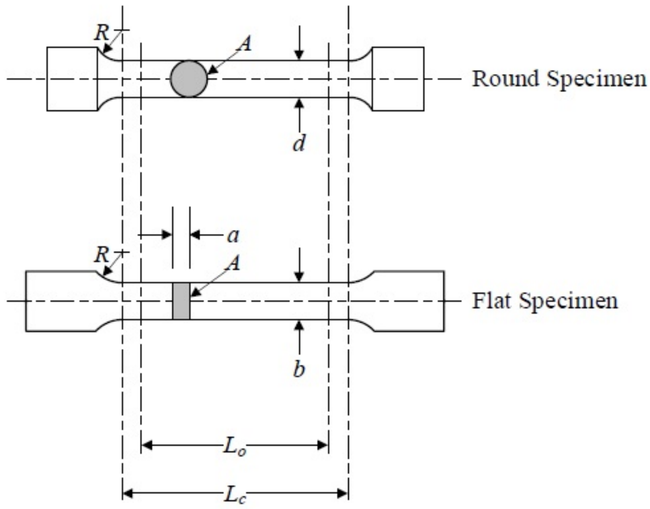
a = thickness in mm

b = width in mm

L_o = *(2005)* original gauge length in mm

L_c = *(2005)* parallel length in mm

A = *(2005)* original cross sectional area in mm^2



R = transition radius in mm

	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

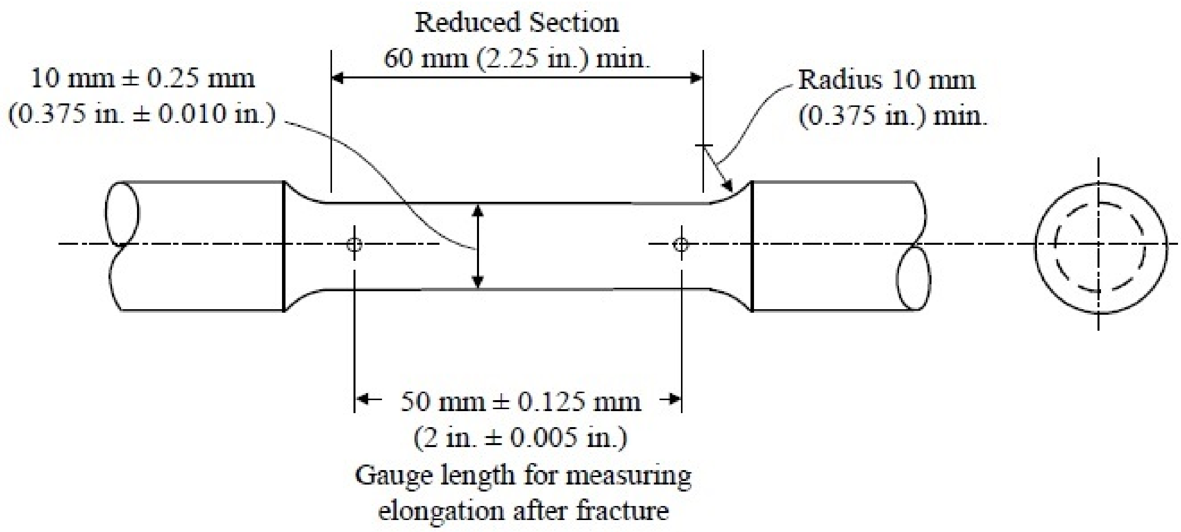
Notes:

1 Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in 2-1-2/15.9 TABLE 2 or 2-1-3/7.3 TABLE 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 *(2005)* L_o , the proportional gauge length, is to be greater than 20 mm.

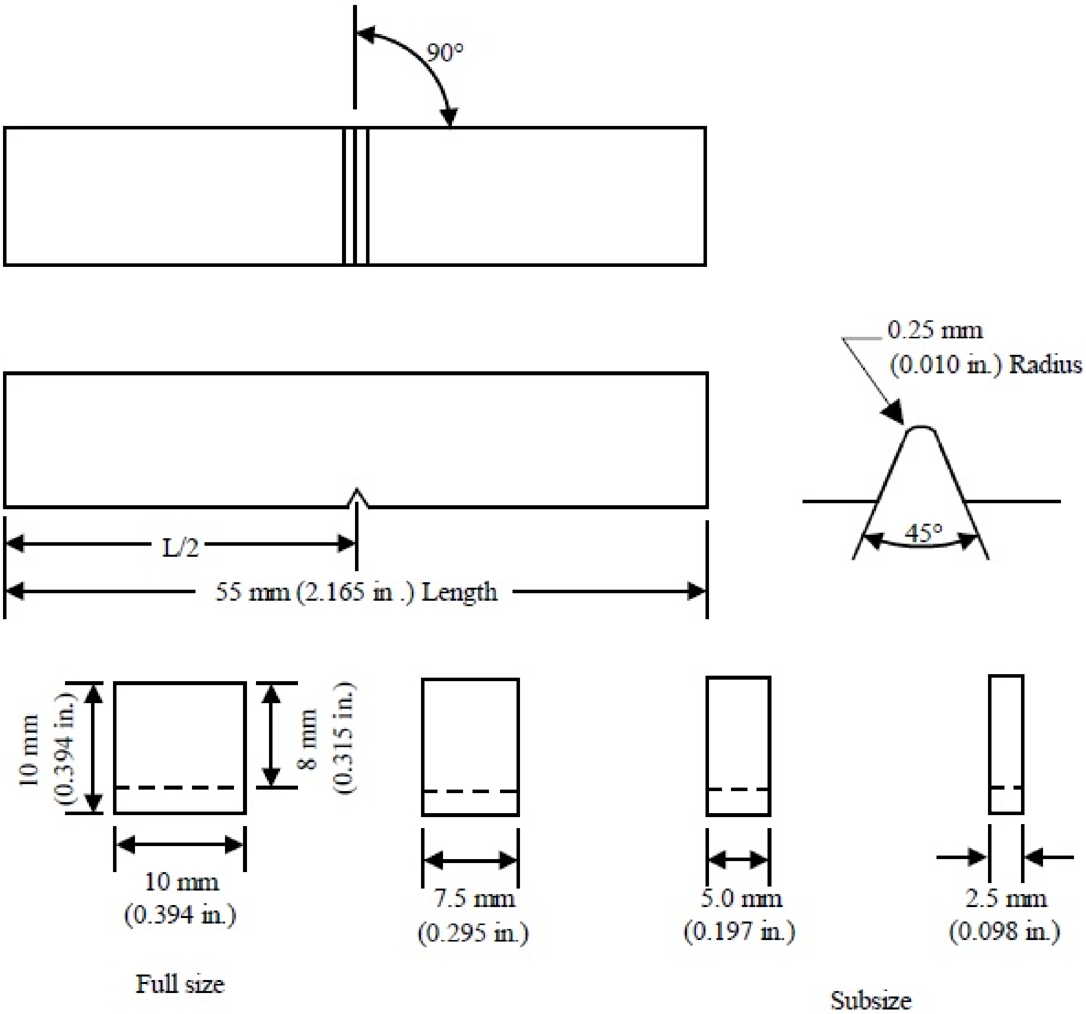
FIGURE 3
Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length *(2008)*



Note:

(2008) 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 way 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 4
Charpy V-notch Impact Test Specimens *(2024)*



Notes:

<table>
<tr><th colspan="2">Dimensions</th><th>Nominal</th><th>Tolerances</th></tr>
<tr><td colspan="2">Adjacent Sides</td><td>90º</td><td>± 10 min.</td></tr>
<tr><td colspan="2">Centering of notch (L/2)</td><td>27.5 mm (1.082 in.)</td><td>± 1 mm (0.039 in.)</td></tr>
<tr><td colspan="2">Length</td><td>55 mm (2.165 in.)</td><td>± 0.06 mm (0.0024 in.)</td></tr>
<tr><td colspan="2">Thickness</td><td>10 mm (0.394 in.)</td><td>± 0.06 mm (0.0024 in.)</td></tr>
<tr><td rowspan="4">Width</td><td>Standard Specimen</td><td>10 mm (0.394 in.)</td><td>± 0.11 mm (0.004 in.)</td></tr>
<tr><td>Subsize Specimen</td><td>7.5 mm (0.295 in.)</td><td>± 0.11 mm (0.004 in.)</td></tr>
<tr><td>Subsize Specimen</td><td>5 mm (0.197 in.)</td><td>± 0.06 mm (0.0024 in.)</td></tr>
<tr><td>Subsize Specimen</td><td>2.5 mm (0.098 in.)</td><td>± 0.06 mm (0.0024 in.)</td></tr>
<tr><td colspan="2">Angle of Notch</td><td>45º</td><td>± 2º</td></tr>
<tr><td colspan="2">Depth Below Notch</td><td>8 mm (0.315 in.)</td><td>± 0.06 mm (0.024 in.)</td></tr>
<tr><td colspan="2">Root Radius/Radius of Notch</td><td>0.25 mm (0.010 in.)</td><td>± 0.025 mm (0.001 in.)</td></tr>
<tr><td colspan="2">Angle between plane of symmetry of notch and longitudinal axis of test specimen</td><td>90º</td><td>± 2º</td></tr>
<tr><td rowspan="2">Surface Finish Requirements</td><td>Notched surface and opposite face</td><td colspan="2">2 µm (63 µin.)</td></tr>
<tr><td>Other surfaces</td><td colspan="2">4 µm (125 µin.)</td></tr>
</table>

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

ii (2015) Where the test temperature is other than ambient, the temperature of the test specimen at the moment of breaking is to be the specified temperature within ± 2°C (± 3.6°F).

17 Steel Plates and Wide Flats with Specified Minimum Through Thickness Properties ("Z" Quality) *(2013)*

"Z" quality steel is employed in those structural details subject to strains in the through thickness direction in order to minimize the possibility of lamellar tearing during fabrication.

These requirements are intended for material with a thickness greater than or equal to 15 mm (0.60 in.) where 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 specified:

i) **Z25** for normal ship applications

ii) **Z35** for more severe applications.

Through thickness properties are characterized by specified values for reduction of area in a through thickness tension test.

The steel works are to be approved by ABS for the manufacture of "Z" quality steels, in accordance with Part 2, Appendix 4. In addition, the maximum sulfur content is to be 0.008%, determined by ladle analysis.

When steels with improved through thickness properties are specified, special steel-making processes are to be used. The following processes used either singly or in combination would be considered to meet this requirement.

i) Low sulfur practices

ii) Additions of elements known to control the shape of nonmetallic inclusions.

iii) Electroslag or vacuum arc remelting.

iv) Control of centerline segregation during continuous casting

17.1 Sampling *(2024)*

For plates and wide flats, one test sample is to be taken close to the longitudinal centerline of one end of each rolled piece representing the batch. See 2-1-1/17.1 TABLE 1 and 2-1-1/Figure 5A and Figure B.

TABLE 1
Batch Size Depending Upon Product and Sulfur Content *(2005)*

Product	*Sulfur > 0.005%*	*Sulfur ≤ 0.005%*
Plate	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm (1.0 in.)	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm (1.0 in.)	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

FIGURE 5A
Schematic of Testing Direction *(2024)*

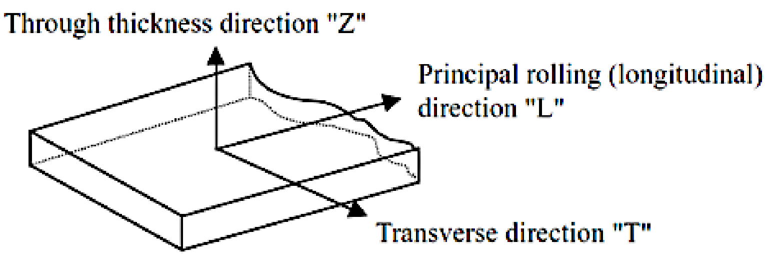
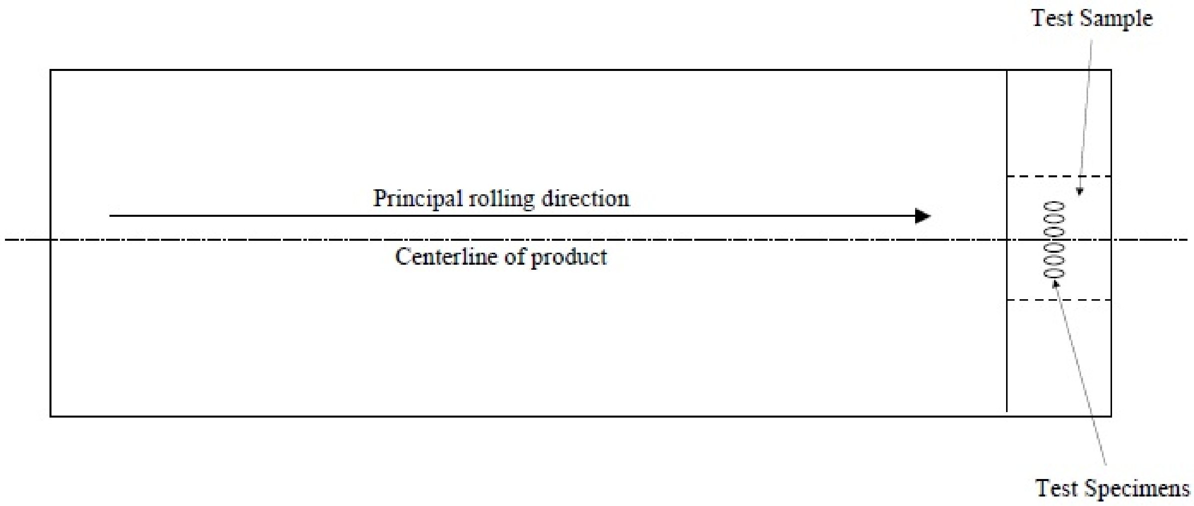


FIGURE 5B
Plate and Wide Flat Sampling Position *(2005)*



17.3 Number of Tensile Test Specimens

The test sample is to be large enough to accommodate the preparation of six (6) specimens. Three (3) test specimens are to be prepared while the remaining samples are set aside for possible retest.

17.5 Tensile Test Specimen Dimensions

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

17.7 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 is to be that shown for the appropriate grade given in 2-1-1/17.7 TABLE 2. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See 2-1-1/17.9 FIGURE 6.

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

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

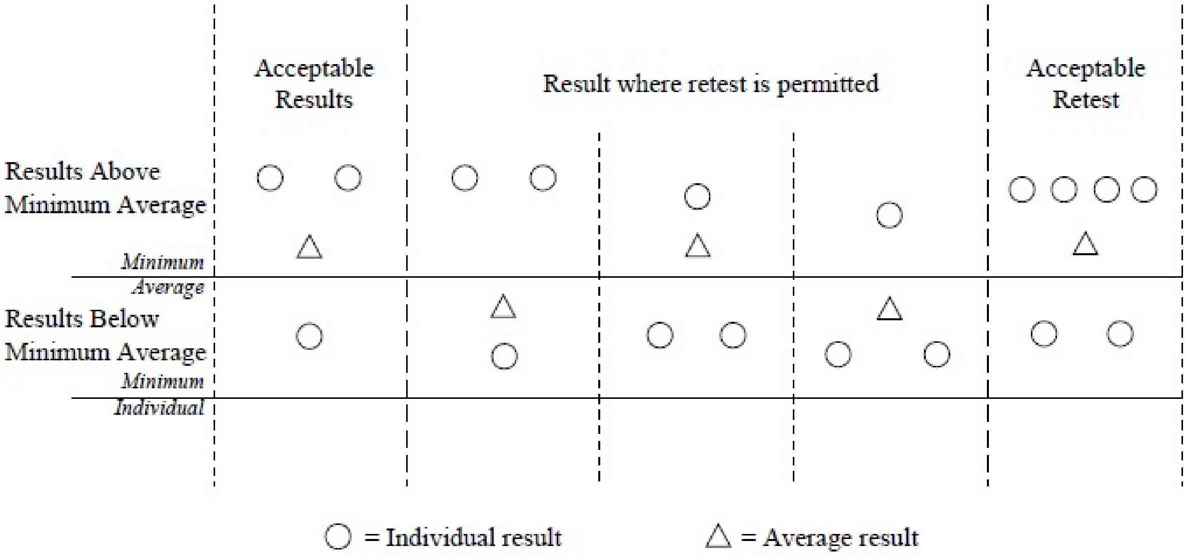
TABLE 2
Reduction of Area Acceptance Values *(2005)*

Grade	*Z25*	*Z35*
Minimum Average	25%	35%
Minimum Individual	15%	25%

17.9 Retests

2-1-1/17.9 FIGURE 6 shows the three cases where retest is permitted. In these instances, 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 no greater than two results below the minimum average. In the case of failure after retest, either the batch represented by the piece is rejected or each piece within the batch is required to be tested.

FIGURE 6
Diagram Showing Acceptance/Rejection and Retest Criteria *(2005)*



17.11 Ultrasonic Inspection *(2007)*

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

Ultrasonic testing is to be carried out on each piece in the final supply condition and with a probe frequency of 2.0 or 2.25 MHz. When carrying out UT on material less than 20 mm ($^3/_4$") thick, frequency up to 5 MHz may be considered acceptable if satisfactorily documented and qualified.

17.13 Marking

Products complying with 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).

17.15 Certification *(2023)*

The 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

When "Z" quality steels are required by the ABS approved drawings, certification of the plate as "Z" quality is to be performed at the mill. Only the mill is able to confirm compliance with the requirements of 2-1-1/17.

Alternatives are required to be agreed with ABS Materials Department on a case-by-case basis.

i) Under certain conditions, non-Z grade plate may be tested to "Z" quality through thickness requirement. A deviation request is to be submitted confirming at least one of the processes in 2-1-1/17 is followed and noted in the mill test report. In such cases, ABS can confirm the plate to have met "Z" quality through thickness tensile requirements, however, the plate is not certified as "Z" quality. Ultrasonic testing is required to be performed in accordance with 17.11 before and after welding.

19 Formed Materials

When material is hot or cold formed, confirmatory mechanical tests are to be conducted when required by 2-4-1/3.13.

21 Ultrasonic Examination of Plate and Wide Flats *(1 July 2018)*

21.1 *(1 July 2018)*

If plates and wide flats are ordered with ultrasonic inspection this is to be made in accordance with an accepted standard such as EN10160, ASTM A435 or equivalent, at the discretion of ABS. Acceptance criteria is to be agreed between the purchaser and manufacturer, and accepted by ABS. The products will be specially marked in accordance with 2-1-2/13.13.

Refer to 2-1-8/11.1 for requirements extra high strength steels.

21.3 *(1 July 2018)*

Verification of internal soundness is the responsibility of the manufacturer. The acceptance of internal soundness by the ABS Surveyor is not be absolve the manufacturer from this responsibility.

23 Fracture Toughness Testing

When specified, fracture toughness testing of materials and weldments is to be carried out. Fracture toughness testing 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. Tests are to be carried out as per BS 7448 Parts 1 & 2 or ASTM E1820 specification or any other recognized standard. The test is deemed to be valid and acceptable provided post-test data analyses meets all validity criteria of BS 7448 Parts 1 & 2 or 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 ABS approved specification. Specific aspects that are to be taken into considerations before testing is initiated are listed below:

23.1

Specimen geometry, notch orientation and load type (bend or tension) are to be selected as per the specification and are to be in conformity with BS 7448 Parts 1 & 2 or ASTM E 1823 or any other recognized standard.

23.3

Cut samples for machining test specimens are to be extracted from test coupons or locations with proper orientation identified as specified in the material specification for plates, and for welds, as given in the manufacturing procedure specification. Orientation mark, heat number, plate number, etc., based on the manufacturer's evolved traceability system are to be transferred onto the samples using a template and paint, local chemical etching or appropriate mechanical means. No plastic deformation or distortions are permitted during this process. This process is to be repeated on the finished, inspected and accepted specimens before the testing program is initiated. A mix-up of specimens without proper identification will call for rejection of the test results.

23.5

If straightening of the samples is needed, then 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 strength of the material. It is the responsibility of the manufacturer during this operation to confirm complete safety to personnel and the witnessing Surveyor.

23.6 *(2009)*

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

23.7

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

23.9

Calibration certificates for servo-mechanical/hydraulic universal testing machines, load cells, transducers, 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 verified by the Surveyor prior to the beginning of a test.

23.11

Crack opening displacement (COD) gauges are to be calibrated once per batch of testing in the presence of the Surveyor.

23.13

Fatigue pre-cracking loads and cyclic loading rates (applied stress intensity level/time) are to be as per BS7448 or ASTM E1820 or any other recognized standards, and the Surveyor is to witness at least one specimen in a batch of specimens being tested. For the rest, the test lab has to provide the loading history and certify that these were done in accordance with BS 7448 or ASTM E1820 or any other recognized standard requirements.

23.15

Crack length measurement can be made by compliance or 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 or ASTM E1820 or to any other recognized standard. Heat tinting/etching or any other suitable method(s) used to reveal the crack front to estimate the final crack length in post-test analysis is to be to the satisfaction of the Surveyor. Photo-macrographs of the broken samples are to be captured and documented along with the valid test report for each specimen tested.

23.17

The following acceptance criteria for CTOD tests are to be applied whenever CTOD tests are specified and performed.

i) If the scatter in CTOD (δ_c, δ_u or δ_m) data from a set of three tests is such that the minimum value is greater than or equal to 70% of the average value of the set, then the minimum value of the three specimens 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 location.

ii) If the minimum value is less than 70% of the average value of the set, or if the minimum value of the three specimens 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. The second lowest of all six values is to be reported as the characteristic CTOD value, and this is to be equal to or greater than the specified minimum CTOD value as stipulated in the ABS-approved material and fabrication specifications for the specified location.

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 2

Ordinary-strength Hull Structural Steel

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i) In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii) Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii) Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv) Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Ordinary-Strength Hull Structural Steel *(2024)*

The requirements in this subsection are intended for normal strength hull steels of the following thickness.

Product	*Maximum Thickness[(1)]*
Plates and Wide Flats	≤ 150 mm (6.0 in.)
Tubulars (seamless or welded)	≤ 70 mm (2.75 in.)
Sections and Bars	≤ 50 mm (2.0 in.)

Note:

1 Approval for steels with thickness greater than indicated in the above is to be agreed with the ABS Materials Department at the time of approval.

3 Process of Manufacture *(2024)*

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen, electricfurnace, vacuum-arc remelt, electro-slag remelt, or such other process as may be specifically 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 to 1 unless specifically approved.

3.1 Plates Produced from Coils *(2024)*

For coiled plate, the coil manufacturer and the processor (uncoiling facility) are to be approved by ABS. Data is to be submitted for review and approval to indicate that the manufacturing, processing, and testing will provide material which is in compliance with the Rules.

5 Chemical Composition

5.1 Ladle Analysis

The chemical composition is to be determined by the steel manufacturer on samples taken from each ladle of each heat and is to conform to the applicable chemical requirements of the grades of steel listed in 2-1-2/15.9 TABLE 1.

5.3 Product Analysis

When product (check) analysis is required, the chemical tolerances of ASTM A6 or of other nationally recognized standards may be applied.

5.5 Fine Grain Practice

Where steel is required to be made using fine grain practice, the requirement is to be met by adding aluminum, unless some other method is specifically approved. The fine grain requirement may be determined by one of the following methods.

5.5.1

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

5.5.2

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

7 Condition of Supply *(2024)*

The conditions of supply are to be in accordance with the requirements in 2-1-2/15.9 TABLE 5 and the following:

Controlled manufacturing processes require approval for each plant and combination of grade and thickness limit.

The conditions of supply are defined as follows. Reference can also be made to ASTM A941, for cooling definitions.

7.1 As Rolled – AR *(2024)*

This procedure involves steel being hot rolled then cooled in air, with no further heat treatment. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalizing temperature.

Commentary:

The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

End of Commentary

7.3 Heat Treatment

7.3.1 Normalizing Heat Treatment *(2024)*

Normalizing involves heating rolled steels above the critical temperature, Ac3, and in the lower end of the austenite recrystallization region for a specific period of time, followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the austenitic grain size and homogenizing the microstructure, provided that the steel is produced to fine austenitic grain size practice.

Commentary:

i Normalizing is usually conducted at the steel manufacturer's plant

ii In a situation where it needs to be carried out at shipyard or fabricator's plant, the Surveyor is to be satisfied with the heat-treating facilities and procedures.

iii When shipyard or fabricator's purchase order indicated that the mill tests are to be made on normalized coupons and it failed to do so, tests on normalized materials will be required at shipyard or fabricator's plant.

End of Commentary

7.3.2 Special Heat Treatment *(2024)*

Other types of heat treatment processes are to be specifically approved.

7.5 Controlled Manufacturing Process

7.5.1 Controlled Rolling - CR (Normalized Rolling - NR) *(2024)*

Controlled rolling is a procedure in which the final rolling temperature is generally controlled within the range used for normalizing heat treatments so that the austenite grains completely recrystallizes, allowed to cool in air, resulting in a material condition generally equivalent to that obtained by normalizing.

7.5.2 Thermo-mechanical Rolling (Thermo-mechanical Controlled Processing (TMCP)) *(2024)*

This procedure involves the strict control of the steel temperature and the rolling reduction. Generally, a high proportion of the rolling reduction is carried out close to or below the Ar3 transformation temperature and may involve rolling in the dual phase temperature region (recrystallization and non-recrystallization region of austenite), thus permitting little if any recrystallization of the austenite. Unlike controlled rolling, the properties produced by TMR cannot be reproduced by subsequent normalizing or other heat treatment.

7.5.3 Thermo-mechanical Controlled Processing (TMCP) + Accelerated Cooling (AcC) *(2024)*

Accelerated cooling (AcC) is a process to improve the mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TMCP operation. Direct quenching is excluded from accelerated cooling.

Commentary:

i Where CR (NR) and TMCP with/without AcC are applied, the programmed rolling schedules are to be verified by ABS at the time of the steel works approval and are to be made available when required by the attending Surveyor.

ii On the manufacturer's responsibility, the programmed rolling schedules are to adhered to during the rolling operation. Refer to 2-1-1/1.2.2. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

iii When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer is to take further measures required in 2-1-1/1.2.2 to the Surveyor's satisfaction.

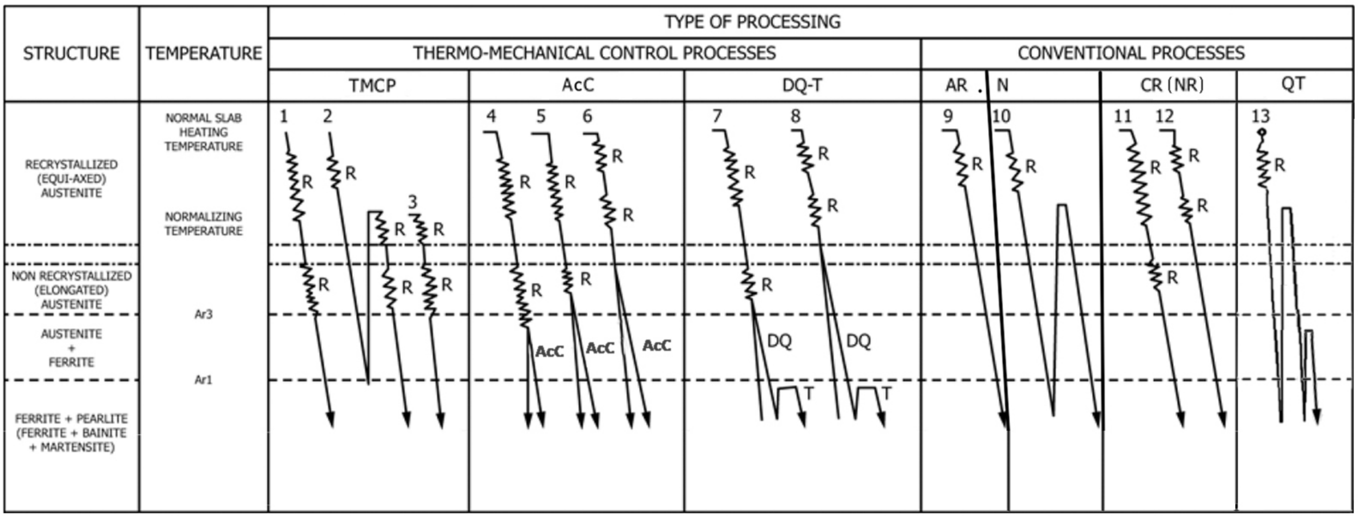
End of Commentary

7.7 Quenching and Tempering – QT *(2024)*

Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac3, held for a specific period of time, and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the Ac1, maintained at that temperature for a specific period of time to restore toughness properties by improving the microstructure and reduce the residual stress caused by the quenching process.

The selection of the above method is made by the manufacturer depending upon the chemical composition, thickness, and required properties.

FIGURE 1
Schematic Diagrams of Thermo-Mechanical and Conventional Processes
(2024)



Note:

TMCP: Thermo-Mechanical Controlled Process (Thermo-Mechanical Rolling)

AcC: Accelerated Cooling

DQ-T: Direct Quenching with Tempering

AR: As Rolled

N: Normalizing

CR (NR): Controlled Rolling (Normalizing Rolling)

QT: Quenching and Tempering

R: Reduction

9 Tensile Properties

9.1 Required Tensile Properties

The material, except as specified in 2-1-2/9.5, is to conform to the requirements of 2-1-2/15.9 TABLE 2 as to tensile properties.

9.3 Tension Test Specimens

9.3.1 *(1 July 2021)*

One tension test is to be made on two different plates, tubulars, shapes or bars from each heat of steel, unless the finished material from a heat is less than 50 tons, when one tension test will be sufficient. If, however, material from one heat differs 9.5 mm (0.375 in.) or more in thickness or diameter, one tension test is to be made from both the thickest and the thinnest material rolled, regardless of the weight represented.

9.3.2

One tension test is to be made on each plate as quenched and tempered.

9.3.3

For plates from coils, tension tests are to be made from not less than two coils from each heat, except where a single coil is to be certified, in which case, tension test specimens from that coil only need be tested. Two tension tests are to be made 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 obtained 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 obtained from both the thinnest and the thickest material rolled.

9.5 Exceptions *(2024)*

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 subject to tension test, but chemistry consistent with the required tensile properties is to be in compliance with the Rules or pertinent specification.

9.7 *<No Text> (2007)*

9.9 Omission of Elongation Requirements *(2024)*

For raised-pattern walkways not exceeding 12.5 mm (0.50 in.) in thickness, the requirement for elongation is waived.

9.11 Retests *(1996)*

9.11.1 *(2024)*

When the results of the tension test do not comply with the requirements, two further tests are to be carried out on specimens taken from the same sample. For plates from coils the retest specimens are to be taken adjacent to the original specimen.

9.11.2

For elongation retest, 2-1-1/9.5 is to be complied with.

9.11.3

If the results of both additional tests meet the requirements, the material tested or represented by the test is to be accepted.

9.11.4 *(2024)*

When the result of one or both additional tests do not meet the requirements, the sample is to be rejected. The remainder of the material in the batch may be accepted provided that two additional test specimens are selected and tested with satisfactory results. If one or both tests failed to meet the requirements, the batch is to be rejected.

9.11.5 *(2024)*

When a batch of material is rejected, at the option of the manufacturer to resubmit each piece individually, or to resubmit the lot after heat treatment, or reheat treatment, or as another grade.

Commentary:

Reheat treatment is defined as heating above the recrystallisation temperature. Full reheat treatment is limited to a maximum of three times unless otherwise agreed by ABS Materials Department.

End of Commentary

11 Impact Properties

11.1 Impact Tests *(2024)*

Charpy V-notch impact tests are to be carried out in accordance with 15.9 TABLE 4. These same requirements apply for tubulars, flats, bars, and shapes when specially ordered in these grades unless agreed otherwise.

11.1.1 *(2024)*

For rolled sections impact tests specimens are to be taken from the flanges of beams, channels, and tees, and from the legs of angles and bulb angles. One set of three impact specimens is to be obtained 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. See 2-1-1/11.11.

11.1.2

For plates produced from coils, impact test coupons are to be obtained adjacent to both tension test coupons and a third impact test coupon is to be obtained 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.

11.3 Impact Test Frequency

The frequency of impact testing is to be in accordance with 2-1-2/15.9 TABLE 5.

11.5 Initial Test Requirements *(2015)*

The average value of three specimens is to equal or exceed the required average value indicated in the applicable Rule Tables. Only one individual value may be below the required average, provided it is not less than 70% of the required average value.

Where the subsize specimens in 2-1-1/16 FIGURE 4 are to be used, the modified energy values will apply as follows:

Subsize Specimen Impact Requirements

Specimen Size	10 x 7.5 mm (0.394 x 0.295 in.)	10 x 5.0 mm (0.394 x 0.197 in.)	10 x 2.5 (0.394 x 0.098 in.)
Required Energy	5E/6	2E/3	E/2

E = energy required for 10 x 10 mm (0.394 x 0.394 in.) specimen

11.7 Retests

When the results fail to meet the above requirements but conditions ii) and iii) below are complied with, three additional specimens may be taken from the location as close to the initial specimens as possible and their test results added to those previously obtained to form a new average. The material represented may be accepted if for the six specimens all of the following conditions are met:

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

ii) No more than two individual values are below the required average.

iii) No more than one individual value is below 70% of the required average.

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

11.9 Unsatisfactory Tests *(1 July 2021)*

The remaining material from the heat may be accepted, provided satisfactory impact results are obtained on both of two further plates or tubulars of the same thickness as the rejected plate or tubular in the heat. Alternatively, the manufacturer may qualify material of the same thickness by impact testing each plate or tubular. Plates or tubulars of a lesser thickness in the same heat may be accepted, provided that satisfactory results are obtained on impact specimens taken from the next lower thickness than the rejected plate or tubular.

11.11 Thin Plates or Tubulars *(1 July 2021)*

Generally, impact tests are not required for plates or tubulars less than 6 mm (0.24 in.) in thickness.

12 Special Considerations *(2024)*

In case of special considerations such as:

i) For approval of new or special steels

ii) New production methods are proposed

iii) When new steel mills or pipe mills begin production

iv) When the reduction ratio is less than 3 to 1, the mills are to provide

v) Alternative chemical composition or deoxidation or fine grain practice

vi) Special heat treatment procedure

vii) Alternative Mechanical Properties

The mills are to provide:

i) Manufacturing procedures, as applicable

ii) Qualification tests are to be performed in accordance with Part 2, Appendix 4, as applicable.

iii) Statistical data in support chemical and mechanical properties

iv) Establish weldability

13 Marking

13.1 Stamped or Stenciled Material *(1 July 2021)*

The ABS markings **AB** and the applicable grades listed in 2-1-2/15.9 TABLE 1 indicating satisfactory compliance with the Rules are to be clearly steel-die-stamped or stenciled by the manufacturer on each finished plate, tubular, shape and bar to signify that the material has satisfactorily complied with the tests prescribed and that certificates for the material will be furnished to the Surveyor in accordance with 2-1-1/7.

Coiled steel which is certified for chemical analysis only, is to be marked **AB** without the grade designation.

13.3 Coils, Lifts and Bundles

In special cases, upon application, coils intended for light plate and secured lifts or bundles of light plates, shapes or bars 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 shown on a tag attached to each coil, lift or bundle.

13.5 Flanging-quality Identification *(2015)*

All material intended for cold flanging, when specially approved in accordance with 3-1-2/1.3.3 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)* is to be additionally marked **F** to signify that it is of such quality. Cold flanging is to be carried out in accordance with ASTM A6.

13.7 Special Stamping and Marking *(1 July 2021)*

Material other than those grades listed in 2-1-2/15.9 TABLE 1, is to be marked with both the initials **AB/S** and with either the applicable specification number, or such other markings as may be required for ready identification, to signify that the material has been produced and satisfactorily tested in accordance with the specification.

When a specification does not specifically require normalizing but the material is so ordered and so produced, then the plates or tubular are also to be marked with the initial **N** to indicate that the material has been normalized. A shipyard or fabricator who carries out a normalizing heat treatment in accordance with 2-1-2/7 is to also mark such material with the initial **N**.

13.9 Special Impact Testing

When steel is impact tested at temperatures other than those specified in 2-1-2/15.9 TABLE 4, the grade marking is to be followed by the test temperature in degrees Celsius. A prefix "0" to the test temperature is to indicate a temperature colder than zero degrees Celsius.

13.11 Steel with Improved Through Thickness Properties *(1 July 2021)*

Steel plates or tubulars meeting the requirements of 2-1-1/17 are to have the letter **Z** marked after the grade designation.

13.13 Steel with Ultrasonic Examination

Steels meeting the requirements of 2-1-1/21 are to have the letter **U** marked after the grade designation as a final letter.

13.15 Shipping Procedure

No material bearing these markings is to be forwarded from the steel works until the prescribed tests have been satisfactorily carried out in accordance with the Rules.

13.17 Steel at Secondary Sources

Secondary sources for ABS Grade Steel are required to provide traceability of steel intended for ABS certification. To retain proper identification, steel may be marked with the information indicated by the manufacturer's markings to the satisfaction of the Surveyor.

15 Surface Finish

15.1 Surface Examination *(2008)*

The material surfaces will be examined 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 in the following subparagraphs.

15.3 Treatment of Surface Defects -Plates *(1 July 2018)*

Refer to 2-1-1/3.

15.4 Treatment of Surface Defects - Tubulars *(1 July 2021)*

Treatment of surface defects in tubulars is to be in accordance with a recognized standard and agreed with ABS during qualification of the mill.

15.5 Treatment of Surface Defects -Shapes

Shapes may be conditioned by the manufacturer for the removal of surface defects by grinding or by chipping to sound metal and depositing weld metal, in accordance with the following limitations.

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

For material less than 9.5 mm (0.375 in.) thickness, in which the 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.

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

For material 9.5 mm (0.375 in.) and over in thickness, in which the defects are 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.

15.5.3 Welding Repairs

Surface defects which are greater in depth than the limits shown above may be removed by chipping or grinding and then depositing weld metal, subject to the following limiting conditions.

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

15.5.3(b) After removal of any defect in preparation for welding, the thickness of the shape is not to be reduced by more than 30% of the nominal thickness, nor is the depth of depression prior to welding to exceed 12.5 mm (0.50 in.) in any case.

15.5.3(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. Prior to welding, the depth of depression, measured from the toe inward, is to be limited to the thickness of the material at the base of the depression, with a maximum depth limit of 12.5 mm (0.50 in.).

15.5.3(d) An experienced mill inspector is to inspect and the welding is to be done in accordance with the requirements of 2-1-1/3.7.2.

15.7 Bar-stock Repairs

Bars may be conditioned by the manufacturer for the removal of surface defects by grinding, chipping or some other means, provided 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%.

15.9 Rivet Steel and Rivets *(2024)*

Rivet steel and rivets are to comply with the material requirements of Section 25 of the 1969 *Rules for Building and Classing Steel Vessels*.

TABLE 1
Chemical Properties of Ordinary Strength Hull Structural Steel 150 mm (6.0 in.) and Under *(2024)*

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 or semi-killed (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, 10]				
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	See Note 6	See Note 6	See Note 6	See Note 6
Cr	See Note 6	See Note 6	See Note 6	See Note 6
Mo	See Note 6	See Note 6	See Note 6	See Note 6
Cu	See Note 6	See Note 6	See Note 6	See Note 6
C + Mn/6	0.40	0.40	0.40	0.40
Marking	AB/A	AB/B	AB/D [7]	AB/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. (See 2-1-2/5.5.)

3 A maximum carbon content of 0.23% is acceptable for Grade A sections and bars.

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 AB/DN.

8 Intentionally added elements are to be determined and reported.

9 *(2015)* For steels of cold flanging quality, the maximum sulfur content is 0.020%.

10 Alternative chemical analysis requirements can be specifically agreed with ABS at the time of mill qualification

TABLE 2
Tensile Properties of Ordinary Strength Hull Structural Steel 150 mm (6.0 in.) and Under *(2024)*

Grade [5]	*Tensile Strength* *N/mm² (kgf/mm², ksi)*	*Yield Point min.* *N/mm² (kgf/mm², 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 2-1-1/16 FIGURE 2.

2 For Grade A sections, the upper limit of tensile strength may be 550N/mm² (56 kgf/mm², 80 ksi).

3 Minimum elongation for alternative B flat specimen in 2-1-1/16 FIGURE 2 is to be in accordance with 2-1-2/15.9 TABLE 3.

4 *(2008)* Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-2/15.9 TABLE 3 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 380-450 N/mm² (39-46 kgf/mm², 55-65 ksi) and a yield point of 205 N/mm² (21 kgf/mm², 30 ksi) minimum. See also 2-1-2/13.5 and 3-1-2/1.3.3 of the *Marine Vessel Rules*.

TABLE 3
Elongation Requirements for Tension Alternative B Specimen *(2024)*

	Thickness in mm (in.)							
exceeding		5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)
not exceeding	5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)	50 (2.0)
elongation (min. %)	14	16	17	18	19	20	21	22

TABLE 4
Impact Properties of Ordinary-Strength Hull Structural Steel 150 mm (6.0 in.) and Under *(2024)*

Average Absorbed Energy [1] *J (kgf-m, ft-lbf)*									
		t ≤ 50 mm (2.0 in.)		*50 mm (2.0 in.) < t ≤ 70 mm (2.8 in.)*		*70 mm (2.8 in.) < t ≤ 100 mm (4.0 in.)*		*100 mm (4 in.) < t ≤ 150 mm (6.0 in.)*	
Grade	*Temperature °C (°F)*	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]
A	20 (68)	[3]	[3]	34 (3.5, 25) [3]	24 (2.4, 17) [3]	41 (4.2, 30) [3]	27 (2.8, 20) [3]	48 (4.9, 35)	32 (3.3, 24)
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)	48 (4.9, 35)	32 (3.3, 24)
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)	48 (4.9, 35)	32 (3.3, 24)
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)	48 (4.9, 35)	32 (3.3, 24)

Notes:

1. The energy shown is minimum required for full size specimen. See 2-1-2/11.5 for subsize specimen requirements.
2. CVN Impact tests may be performed in either direction
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 2-1-2/15.9 TABLE 5.

TABLE 5
Condition of Supply and Frequency of Impact Tests
Ordinary Strength Hull Structural Steel *(2024)*

<table>
<tr><th rowspan="4">Grade</th><th rowspan="4">Deoxidation</th><th rowspan="4">Products</th><th colspan="6">Condition of Supply (Impact Test Lot Size in Tons)</th></tr>
<tr><th colspan="6">Thickness in mm (in.)</th></tr>
<tr><th>exceeding:</th><th></th><th>12.5 (0.5)</th><th>25 (1.0)</th><th>35 (1.375)</th><th>50 (2.0)</th></tr>
<tr><th>not exceeding:</th><th>12.5 (0.5)</th><th>25 (1.0)</th><th>35 (1.375)</th><th>50 (2.0)</th><th>150 (6.0)</th></tr>
<tr><td rowspan="4">A</td><td>Rimmed</td><td>All</td><td rowspan="13"></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 (25) AR (25)</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 or tubular	S = sections
2	Conditions of Supply:	A = Any Condition	N = normalized
		AR = As Rolled	TM = thermomechanical 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.

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 3

Higher-strength Hull Structural Steel

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Higher-strength Hull Structural Steel *(2024)*

The requirements in this subsection are intended for products for the following thicknesses:

Product	*Maximum Thickness*[(1)]
Plates and Wide Flats	≤ 150 mm (6.0 in.)
Tubulars (seamless or welded)	≤ 70 mm (2.75 in.)
Sections and Bars	≤ 50 mm (2.0 in.)

Note:

1 Approval for steels with thickness greater than indicated in the above is to be agreed with the ABS Materials Department at the time of approval.

3 Process of Manufacture, Chemical Composition, Condition of Supply, Tensile Properties, Impact Properties, Special Consideration, Marking and Surface Finish *(2024)*

The requirements in 2-1-2/3 through 2-1-2/15 are also applicable to higher-strength hull structural steels with the following paragraphs and Tables replaced by the higher-strength requirements as indicated below.

2-1-2/15.9 TABLE 1 replaced by 2-1-3/7.3 TABLE 1

2-1-2/15.9 TABLE 2 replaced by 2-1-3/7.3 TABLE 2

2-1-2/15.9 TABLE 3	replaced by 2-1-3/7.3 TABLE 3
2-1-2/15.9 TABLE 4	replaced by 2-1-3/7.3 TABLE 4
2-1-2/15.9 TABLE 5	replaced by 2-1-3/7.3 TABLE 5
2-1-2/5.7	replaced by 2-1-3/5

5 Fine Grain Practice *(2024)*

Where steel is required to be made using fine grain practice, it is to be in accordance with one of the following procedures.

5.1

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

5.3

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

5.5

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

5.7

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%.

5.9

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%.

7 Additional Requirements of TMCP Steel

7.1 Carbon Equivalent *(2024)*

The carbon equivalent C_{eq} as determined from the ladle analysis in accordance with the following equation is to meet the requirements in 2-1-3/7.3 TABLE 6:

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

Commentary:

i The formula is also applicable to other supply conditions, to provide a general indication of the weldability of the steel.

ii Selection of the alternative values of carbon equivalent may be agreed between the fabricator and steel mill when the steel is ordered.

End of Commentary

7.3 Cold Cracking Susceptibility, P_{cm} *(2024)*

The cold cracking susceptibility Pcm for evaluating weldability may be used instead of carbon equivalent Ceq if agreed by ABS

The cold cracking susceptibility P_{cm} can be calculated in accordance with the following equation from ladle analysis:

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

If this alternative is applied, the maximum allowable P_{cm} is to be included in the manufacturing specification and reported in the mill test report.

TABLE 1
Chemical Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under *(2024)*

Grades	*AH/DH/EH 32, AH/DH/EH 36 and AH/DH/EH 40*	*FH 32/36/40*
Deoxidation Practice	*Killed, Fine Grain Practice* (1)	
Chemical Composition (2, 9)	*(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)	0.02-0.05	0.02-0.05
V (6)	0.05-0.10	0.05-0.10
Ti	0.02	0.02
Cu (7)	0.35	0.35
Cr (7)	0.20	0.20
Ni (7)	0.40	0.80
Mo (7)	0.08	0.08
Ca	0.005	0.005
N	-	0.009 (0.012 if Al present)
Marking (8)	AB/XHYY (X = A, D, E or F YY = 32, 36 or 40)	

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 (See 2-1-3/5). Additionally, the fine grain elements are to be in accordance with the specification approved during manufacturer qualification.

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 2-1-3/5.

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 2-1-3/5 will apply.

7 These elements may be reported as ≤ 0.02% where the amount present does not exceed 0.02%.

8 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.

9 Alternative chemical analysis requirements can be specially agreed with ABS at the time of mill qualification.

TABLE 2
Tensile Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under *(1 July 2021)*

Grade	*Tensile Strength* N/mm^2 *(kgf/mm^2, ksi)*	*Yield Point min.* N/mm^2 *(kgf/mm^2, ksi)*	*Elongation* [1, 2, 3] *min. %*
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 2-1-1/16 FIGURE 2.

2 Minimum elongation for alternative B flat specimen in 2-1-1/16 FIGURE 2 is to be in accordance with 2-1-3/7.3 TABLE 3.

3 *(2008)* Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-3/7.3 TABLE 3 for 200 mm (8 in.) specimen and 20% for 50 mm (2 in.) specimen.

TABLE 3
Elongation Requirements for Tension Alternative B Specimen *(2024)*

Thickness in mm (in.)								
exceeding:		*5 (.20)*	*10 (.40)*	*15 (.60)*	*20 (.80)*	*25 (1.00)*	*30 (1.20)*	*40 (1.60)*
not exceeding:	*5 (.20)*	*10 (.40)*	*15 (.60)*	*20 (.80)*	*25 (1.00)*	*30 (1.20)*	*40 (1.60)*	*50 (2.00)*

Thickness in mm (in.)								
Grade Steel	elongation (%)							
XH 32	14	16	17	18	19	20	21	22
XH 36	13	15	16	17	18	19	20	21
XH 40	12	14	15	16	17	18	19	20

Note:
"X" denotes the various material grades, A, D, E and F.

TABLE 4
Impact Properties of Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under *(2024)*

Grade	*Temp °C (°F)*	*Average Absorbed Energy (1) J (kgf-m, ft-lbf)*							
		t ≤ 50 mm (2.0 in.)		*50 mm (2.0 in.) < t ≤ 70 mm (2.8 in.)*		*70 mm (2.8 in.) < t ≤ 100 mm (4.0 in.)*		*100 mm (4 in.) < t ≤ 150 mm (6.0 in.)*	
		Long'l (2)	*Transv (2)*	*Long'l (2)*	*Transv (2)*	*Long'l (2)*	*Transv (2)*	*Long'l (2)*	*Transv (2)*
AH 32 AH 36 AH 40	0 (32)	31 (3.2, 23) 34 (3.5, 25) 39 (4.0, 29)	22 (2.3, 16) 24 (2.4, 17) 26 (2.7, 19)	38 (3.9, 28) 41 (4.2, 30) 46 (4.7, 34)	26 (2.7, 19) 27 (2.8, 20) 31 (3.2, 23)	46 (4.7, 34) 50 (5.1, 37) 55 (5.6, 41)	31 (3.2, 23) 34 (3.5, 25) 37 (3.8, 27)	50 (5.1, 37) 54 (5.5, 40) 58 (5.9, 43)	33 (3.4, 25) 36 (3.7, 27) 39 (3.9, 29)
DH 32 DH 36 DH 40	-20 (-4)	31 (3.2, 23) 34 (3.5, 25) 39 (4.0, 29)	22 (2.3, 16) 24 (2.4, 17) 26 (2.7, 19)	38 (3.9, 28) 41 (4.2, 30) 46 (4.7, 34)	26 (2.7, 19) 27 (2.8, 20) 31 (3.2, 23)	46 (4.7, 34) 50 (5.1, 37) 55 (5.6, 41)	31 (3.2, 23) 34 (3.5, 25) 37 (3.8, 27)	50 (5.1, 37) 54 (5.5, 40) 58 (5.9, 43)	33 (3.4, 25) 36 (3.7, 27) 39 (3.9, 29)
EH 32 EH 36 EH 40	-40 (-40)	31 (3.2, 23) 34 (3.5, 25) 39 (4.0, 29)	22 (2.3, 16) 24 (2.4, 17) 26 (2.7, 19)	38 (3.9, 28) 41 (4.2, 30) 46 (4.7, 34)	26 (2.7, 19) 27 (2.8, 20) 31 (3.2, 23)	46 (4.7, 34) 50 (5.1, 37) 55 (5.6, 41)	31 (3.2, 23) 34 (3.5, 25) 37 (3.8, 27)	50 (5.1, 37) 54 (5.5, 40) 58 (5.9, 43)	33 (3.4, 25) 36 (3.7, 27) 39 (3.9, 29)
FH 32 FH 36 FH 40	-60 (-76)	31 (3.2, 23) 34 (3.5, 25) 39 (4.0, 29)	22 (2.3, 16) 24 (2.4, 17) 26 (2.7, 19)	38 (3.9, 28) 41 (4.2, 30) 46 (4.7, 34)	26 (2.7, 19) 27 (2.8, 20) 31 (3.2, 23)	46 (4.7, 34) 50 (5.1, 37) 55 (5.6, 41)	31 (3.2, 23) 34 (3.5, 25) 37 (3.8, 27)	50 (5.1, 37) 54 (5.5, 40) 58 (5.9, 43)	33 (3.4, 25) 36 (3.7, 27) 39 (3.9, 29)

Notes:

1 The energy shown is minimum required for full size specimen. See 2-1-2/11.5 for sub size specimen requirement.

2 Impact tests may be performed in either direction.

TABLE 5
Condition of Supply and Frequency of Impact Tests Higher-strength Hull Structural Steel *(2024)*

Grade	Deoxidation	Grain Refining Element	Products	Condition of Supply impact Test lot Size in Tons — Thickness in mm (in.): Exceeding: → not exceeding: →	12.5 (0.5)	12.5 (0.5) 20 (0.80)	20 (0.80) 25 (1.0)	25 (1.0) 35 (1.375)	35 (1.375) 50 (2.0)	50 (2.0) 150 (6.0)
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) QT (P)
			S		N (25) TM (25) QT (25) CR*(15)					N/A

Grade	Deoxidation	Grain Refining Element	Products	*Condition of Supply impact Test lot Size in Tons*						
				Thickness in mm (in.)						
				Exceeding: → *not exceeding:* →	*12.5 (0.5)*	*12.5 (0.5) 20 (0.80)*	*20 (0.80) 25 (1.0)*	*25 (1.0) 35 (1.375)*	*35 (1.375) 50 (2.0)*	*50 (2.0) 150 (6.0)*
AH 40	Killed, Fine Grain Practice	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)** QT (P)					N (P) TM (P) QT (P)
			S		N (25) TM (25) QT (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) QT (25) CR (25)**					N/A

Notes

1	Products:	P = plate or tubular	S = sections
2	Conditions of Supply:	A = Any Condition (AR, N, NR, TM)	N = normalized
		AR = As Rolled	TM = thermo-mechanically controlled processing
		CR = Control Rolled	QT = quenched and tempered
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

(**) = Upon application, CR delivery condition is to be specifically agreed

TABLE 6
Carbon Equivalent for Higher-strength Hull Structural Steel 150 mm (6.0 in.) and Under Produced by TMCP *(2024)*

Grade	*Carbon Equivalent, Max. (%)* [1]		
	$t \leq$ 50 mm (2.0 in.)	*50 mm (2.0 in.) < $t \leq$ 100 mm (4.0 in.)*	*100 mm (4.0 in.) < $t \leq$ 150 mm (6.0 in.)* [2]
AH 32, DH 32, EH 32, FH 32	0.36	0.38	0.40
AH 36, DH 36, EH 36, FH 36	0.38	0.40	0.42
AH 40, DH 40, EH 40, FH 40	0.40	0.42	0.45

Notes:

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

2 For thicknesses over 150 mm, carbon equivalent is to be agreed with ABS at the time of mill qualification.

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 4

Materials for Low Temperature Applications (2024)

1 General (2024)

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Manufacturer Approval

All rolled products intended for low temperature applications are to be manufactured at works approved by ABS for the type and grade. The suitability of the plates for welding and assumed forming is to be demonstrated during the initial approval test at the mill.

Approval of steel mills is to be in accordance with Part 2, Appendix 4.

Approval of stainless steel mills is to be in accordance with Chapter 2, Appendix 1 of the ABS *Guide for Materials and Welding for Stainless Steels*.

Approval of Aluminum mills is to be in accordance with Part 2, Appendix 10.

3 Materials for Low Temperature Applications *(2024)*

3.1 *(2024)*

Materials for ice class are to comply with the applicable requirements of Part 6, Chapter 1 the *Marine Vessel Rules*.

3.2 *(2024)*

Materials for vessels intended to carry refrigerated cargoes are to comply with the applicable requirements of Part 6, Chapter 2 of the *Marine Vessel Rules*.

3.3

Materials for Liquefied Gas Carriers are also to comply with the requirements of Section 5C-8-6 of the *Marine Vessel Rules*.

3.4 *(2024)*

Materials for vessels using Gases or other Low-Flashpoint Fuels are to comply with the applicable requirements of Section 5C-13-7 of the *Marine Vessel Rules*.

3.5 *(2024)*

The ABS *Guide for Vessels Operating in Low Temperature Environments* includes optional notations and additional requirements for materials intended for low temperature applications.

Commentary:

Materials for the following vessels are to be manufactured in accordance with Section 2-1-1, 2-1-2 and 2-1-3, as applicable,

i. Ships Exposed to Low Air Temperatures, MVR 3-1-2/3.5

ii. Cold Cargo for Ships Other Than Liquefied Gas Carriers, MVR 3-1-2/3.9

iii. Craft Exposed to Low Air Temperatures, HSC 3-1-2/1.5

iv. Vessels Exposed to Low Air Temperatures, HSNC 3-1-2/1.7

End of Commentary

5 Chemical Composition *(2024)*

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported and is to conform to the requirements of the applicable standard or proprietary specification.

7 Condition of Supply and Heat Treatment *(2024)*

Refer to 2-1-2/7.

9 Mechanical Properties *(2024)*

9.1 Tensile Properties

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area and are to meet the requirements of applicable Rules identified in 3 or designated standard or proprietary specification.

9.2 Impact Properties

Charpy V-notch impact tests are to be carried out to meet requirements of applicable Rules identified 3 or designated standard or proprietary specification.

9.3 Other Special Properties

Other properties, such as hardness, elevated or low temperature properties, fatigue properties, corrosion or wear resistance are to be established if required by the design criteria.

11 Service Temperature from 0°C (32°F) Down to -165°C (-265°F) *(2024)*

2-1-4/Table 1 lists ASTM grades and equivalent EN grades that may be used for a given service temperature. Alternatively, other recognized national or international standards may be agreed with ABS to meet the pertinent design requirements.

TABLE 1
Grades of Steel that May be Used for a Given Service Temperature *(2024)*

Specification/Grade		*Design Service Temperature*
Carbon Manganese or Low Alloy Steels[1]		
Refer to MVR 5C-8-6/4 TABLE 2 (ABS)	AB/V-OXX or AB/VH32-OXX or AB/VH36-OXX[2]	Below 0°C (32°F) and down to -55°C (-67°F)
Nickel Alloy Steels		
2.25% Ni Alloy Steel	ASTM A203 Grade A	-62°C (-80°F)
	ASTM A203 Grade B	-59°C (-75°F)
3.5% Ni Alloy Steel	ASTM A203 Grade D or EN 10028-4 12Ni14	-90°C (-130°F)
	ASTM A203 Grade E or EN 10028-4 12Ni14	-79°C (-110°F)
5% Ni Alloy Steel	ASTM A645 Grade A or EN 10028-4 X12Ni5	-105°C (-155°F)
5.5% Ni Alloy Steel	ASTM A645 Grade B	-165°C (-265°F)
7% Ni Alloy Steel	ASTM A553 Type III or ASTM A841 Grade G	-165°C (-265°F)
8% Ni Alloy Steel	ASTM A553 Type II	-165°C (-265°F)
9% Ni Alloy Steel	ASTM A353 or ASTM A553 Type I or EN 10228-4 X7Ni9 or EN 10228-4 X8Ni9	-165°C (-265°F)
Other Low Temperature Materials		
Austenitic Stainless Steel[3]	304, 304L, 316, 316L, 321 and 347	-165°C (-265°F)
36% Ni[4]	-	-165°C (-265°F)
Aluminum Alloy ASTM B209	5083	-165°C (-265°F)
High Manganese Austenitic Stainless Steel[5, 6]	ASTM A1106	-165°C (-265°F)

Notes:

1 Carbon manganese and low alloy steels for service temperature below 0°C (32°F) and down to -55°C (-67°F) are to be fully killed, fine grain steels.

2 'XX' indicates the CVN impact test temperature in Celsius below zero.

3 Refer to the ABS *Guide for Materials and Welding for Stainless Steel* for chemical properties, mechanical properties, and applicable manufacturing and approval requirements.

4 Applicable standard or proprietary specification for 36% Ni can be agreed on a case-by-case basis. In addition, chemistry will be specially considered for lowering the coefficient of expansion.

5 Corrosion tests are to be performed to qualify the use of this material grade for exposure to the intended cargo in liquid and gaseous form, except for methane (LNG).

6 Fabrication procedures are to include mitigation of fumes from welding, such as installation of extractor fans.

13 Service Temperatures below 165°C (-265°F) *(2024)*

Austenitic low carbon (less than 0.10%) stainless steels and aluminum alloys are to be used for these temperatures. The chemical composition, heat treatment, and tensile properties are to conform to the requirements of the approved specification. Stainless steels types 304, 304L, 316, 316L, and 347 and type 5083 aluminum alloy do not require toughness testing for service temperatures above -254°C (-425°F).

Commentary:

i Toughness tests for -254°C (-425°F) service temperature and below will be subject to special consideration.

ii Test data and successful past experiences are to be submitted to ABS for consideration.

End of Commentary

15 Marking *(2024)*

In addition to the ABS marking requirements detailed in Part 2, the manufacturer's name, trade mark, lot number, and heat numbers is to be legibly marked on the finished products. In addition, the following requirements are to be met, as applicable:

i) ABS grade materials for structural application with service temperature at or above -55ºC up to 0ºC as in MVR 5C-8-6/4 TABLE 2 (ABS) is to be marked with AB/V-OXX or AB/VH32-OXX or AB/VH36-OXX. Denote "XX" referring the test temperature in Celsius below zero.

ii) Materials with pressure vessel quality and intended for pressure vessel application are to have the letter **PV** marked after the grade.

iii) For aluminum sheet and plate, the applicable alloy and temper designation and the specification number is to be marked.

17 Inspection and Repair *(2024)*

17.1 General

The steels are to have a workmanlike finish and are to be free from cracks, injurious surface flaws, injurious laminations and similar defects harmful to the use of the material for the intended application.

17.3 Surface Quality

Refer to 2-1-2/15.

17.5 Internal Soundness

Verification of internal soundness is the responsibility of the manufacturer. The inspection methods and acceptance criteria are to be in accordance with the applicable design codes or recognized national or international standard agreed between purchaser and manufacturer, accepted by ABS.

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 5

Hull Steel Castings

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

The following requirements cover steel castings intended to be used in hull construction and equipment at ambient temperature, such as stern frames and rudder frames.

Requirements for ABS grade steel castings are in 2-1-5/11. Alternatively, casting which comply with national or proprietary specification may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

Commentary:

Ambient temperature is defined at -10°C for vessels and 0°C for offshore structures.

End of Commentary

1.5 Manufacturer Approval and Process of Manufacture *(2024)*

Castings are to be made by a manufacturer approved by ABS. ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of casting production, that may influence the final product properties:

i) Mold preparation and chaplet positioning

ii) Pouring times and temperatures

iii) Mold breakout

iv) Heat treatment and heat treatment recording

v) Coupon preparation

vi) Testing and inspection

vii) Rectification of Defective Castings

viii) Any of the above can be included in a Survey patrol.

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

When two or more castings are joined by welding 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.

3 Chemical Composition *(2024)*

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

To maintain weldability, carbon content is not to exceed 0.23% or carbon equivalent (Ceq) is not to exceed 0.41%, unless specially approved.

Castings that are intended to be welded (or cladded) are to be of weldable quality.

Commentary:

i Weldability of a casting can be established through weld procedure qualification tests in accordance with Part 2, Chapter 4.

ii Weldability of steels with carbon content greater than 0.23% is reduced.

End of Commentary

3.1 Ladle Analysis *(2024)*

A ladle analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. 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 is to be carried out.

The chemical composition thus determined is to be reported and is to conform to the requirements of the applicable ABS grade in 2-1-5/11 or recognized national standard or proprietary specification.

3.3 Product (Check) Analysis *(2024)*

When required by the specification, the product (check) analysis is to be performed in accordance with ASTM A751 or of other nationally recognized standards may be applied. The chemical composition determined by check analysis is to meet requirements of the applicable ABS grade in 2-1-5/11 or recognized national standard or proprietary specification.

5 Heat Treatment *(2024)*

Heat treatment facilities used in producing ABS certified castings are to be approved by ABS.

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

A heat treatment facility (independent or sub-contracted) can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

The ABS Surveyor is to attend the heat treatment facility (independent or sub-contracted) 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 heat treated using one of the following procedures in a furnace of ample proportions to bring the castings to a uniform temperature above the transformation range on the annealing or normalizing cycle, unless otherwise approved.

i) Fully annealed

ii) Normalized

iii) Normalized and tempered

iv) Quenched and tempered

For all types of steel the tempering temperature is to be not less than 550°C (1022°F), unless specifically agreed with ABS Materials Department.

The furnaces are to be maintained and have means for control and recording temperature. Castings are to be held "soaking" at the proper temperature for at least a length of time equivalent to one 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.

No annealed casting is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C (850°F). Thermocouples are to be connected to the furnace charge to measure and record that its temperature is uniform unless the temperature uniformity of the furnace can be verified at regular intervals.

Local heating or cooling and bending and straightening of annealed castings are not permitted, except with the express sanction of the Surveyor.

Commentary:

If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses. The stress relief temperature should be established in conjunction with the final heat treatment temperature and must not negatively affect the physical properties of the casting.

End of Commentary

The foundry 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.

7 Mechanical Properties

7.1 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet the requirements of the applicable ABS grade in 2-1-5/11 or a recognized national standard or proprietary specification. The alternative recognized standard or proprietary specification is to at least meet the minimum tensile properties for ABS ordinary grade steel casting unless lower tensile properties is approved to meet the design requirements.

7.3 Impact Properties *(2024)*

Charpy V-notch impact tests are to be carried out as noted below,

Minimum Specified Yield Strength, N/mm^2 (kgf/mm^2, ksi)	*Minimum Average Absorbed Energy, J (kgf-mm, ft-lbf)*	*CVN Test Temperature*
205-690 (21-70, 30-100)	27 (2.8, 20)	At 0°C or at design service temperature (when design service temperature <-10°C)

Commentary:

Ambient temperature is defined at -10°C for vessels and 0°C for offshore structures.

End of Commentary

9 Test Specimens

9.1 Material Coupons *(2016)*

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

Test material sufficient for the required number of tests and for possible retest purposes is to be provided for each casting. The physical properties are to be determined from test specimens prepared from coupons which, except as specified in 2-1-5/9.3, 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 detached until the heat treatment of the castings has been completed, nor until the coupons have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

Where the finished casting mass exceeds 10,000 kg (22,000 lb) or is of complex design, two test samples are to be provided. Where 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:

The controlling cross section thickness is the diameter of the largest theoretical sphere which can be inscribed within the critical section of the casting.

9.3 Separately Cast Coupons

In the case of small castings having an estimated weight of less than 908 kg (2000 lb) each, 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.

9.5 Number of Tests *(2005)*

At least one tension test is to be made from each heat in each heat-treatment charge, except where two or more samples are required, as indicated in 2-1-5/9.1 If the manufacturer's quality-control procedure includes satisfactory automatic chart recording of temperature and time, then 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.

9.7 Retests

If the results of the physical tests for any casting or any lot of castings do not conform to the requirements specified, the manufacturer may reheat-treat castings or a lot of castings that have failed to meet test requirements. Two additional test samples representative of the casting or casting batch are to be taken. If satisfactory results are obtained from both of the additional tests, the casting or batch of castings is acceptable. If one or both retests fail, the casting or batch of castings is to be rejected.

11 Requirement for ABS Grade Hull Steel Castings *(2024)*

Cast stern frames, rudder horns and shoe-pieces are to be manufactured from special grade material with the following chemical and mechanical requirements. Alternative grades with higher tensile properties, in accordance with recognized standards or proprietary specifications, can be considered based on design requirement provided CVN impact tests are performed in accordance with 2-1-5/7.3 at 0°C for vessels operating at ambient temperature.

11.1 Chemical Composition for ABS Ordinary and Special Grades *(2024)*

ABS ordinary and special grade steel castings for welded construction and where welded repair is anticipated, the chemical composition is to comply with the following limits or, where applicable, the requirements of the approved specification.

TABLE 1
Chemical Composition Limits ABS Ordinary and Special Grade Hull Steel Castings

ABS Grade	*Carbon (max.)*[2]	*Silicon (max.)*	*Manganese*	*Sulfur (max.)*	*Phosphorous (max.)*	*Aluminum*	*Residual Elements (max.)*				*Total Residual Elements (max)*
							Copper	*Chromium*	*Nickel*	*Molybdenum*	
Ordinary Grade	0.23	0.60	0.50 – 1.60	0.035	0.035	Note 1	0.30	0.30	0.40	0.15	0.80
Special Grade	0.23	0.60	0.70 – 1.60	0.035	0.035	$Al_{Acid\text{-}soluble}$: 0.015–0.08 Al_{total}: 0.02 – 0.10	0.30	0.30	0.40	0.15	0.80

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 For non-welded castings, the maximum carbon content can be 0.40%.

11.3 Mechanical Properties for ABS Ordinary and Special Grades

ABS ordinary and special grade steel castings are to conform to the following requirements.

TABLE 2
Mechanical Properties for ABS Ordinary and Special Hull Steel Castings

ABS Grade[1]	*Minimum Yield Strength, N/mm*^{2} *(kgf/mm*^{2}*, ksi)*	*Minimum Ultimate Tensile Strength, N/mm*^{2} *(kgf/mm*^{2}*, ksi)*	*Minimum % Elongation 50 mm (2 in.)*	*Minimum % Reduction of Area*	*Charpy V-Notch impact Test*	
					Test Temperature	*Minimum Average Absorbed Energy*
Ordinary Grade	205 (21, 30)	415 (42, 60)	25	40	20°C (68°F)	27 J (2.8 kgf-mm, 20 ft-lbs)
Special Grade	205 (21, 30)	415 (42, 60)	25	40	0°C (32°F)	27 J (2.8 kgf-mm, 20 ft-lbs)

Note:

1 In substantial agreement with ASTM A27 Grade 60-30 Class I. Additional requirements for chemistry (2-3-7/11.1 Table 1) and CVN impact properties (the table above) are applicable.

11.5 Other ABS Grade Hull Steel Castings

ABS grade steel castings may be manufactured in accordance with the requirements of the ASTM grade referenced in the table below to meet the design requirements and the additional requirements identified in this section.

TABLE 3
Tensile Properties for ABS Grade Hull Steel Castings

ABS Designation (1)	*ASTM Specification*	*Grade/Class*	*Minimum Yield Strength, N/mm*^{2} *(kgf/mm*^{2}*, ksi)*	*Minimum Ultimate Tensile Strength, N/mm*^{2} *(kgf/mm*^{2}*, ksi)*	*Minimum % Elongation 50 mm (2 in.)*
CA	ASTM A27	65-35 Class 1	240 (24, 35)	450 (46, 65)	24
CB	ASTM A27	70-40 Class 1	275 (28, 40)	485 (49, 70)	22
CC (2)	ASTM A148	80-40	345 (35, 40)	550 (56, 80)	22
CD (2)	ASTM A148	90-60	415 (42, 60)	620 (63, 90)	20
CE (2)	ASTM A148	105-85	585 (60, 85)	725 (74, 105)	17
CF (2)	ASTM A148	115-95	655 (67, 95)	795 (81, 115)	14

Notes:

1 Requirements for chemical composition (2-1-5/3), impact properties (2-1-5/7.3) and test specimens (2-1-5/9) are also required to be met.

2 In addition to the chemical composition requirements 2-1-5/3, the following is applicable. Alternative chemistry may be agreed with ABS Materials Department.

ABS Grade	*Carbon (max.)*	*Silicon (max.)*	*Manganese*	*Sulfur (max.)*	*Phosphorous (max.)*	*Aluminum*	*Alloy Elements*			
							Copper	*Chromium*	*Nickel*	*Molybdenum*
Alloy Steels	As agreed with ABS	0.60	0.70 – 1.60	0.035	0.035	$Al_{Acid\text{-}soluble}$: 0.015–0.08 Al_{total}: 0.02 – 0.10	0.30	0.30	0.40	0.15

13 Inspection and Repair *(2005)*

13.1 General *(1 July 2023)*

All castings are to be examined by the Surveyor after final heat treatment and thorough cleaning and they are to be found free from defects, in accordance with applicable acceptance criteria. Where applicable, internal surfaces are to be inspected. Surfaces are not to be hammered or peened or treated in any way which may obscure defects.

For welded composite cast 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 ABS.

Part 2, Appendix 6 is regarded as an example of an acceptable standard specifying suitable minimum inspection requirements for castings.

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

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

13.3 Minor Defects *(2006)*

Defects are to be considered minor when the cavity prepared for welding repair has a depth not greater than 20% of the actual wall thickness, 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 resulting from the removal of defects may be accepted, provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth, and complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing. Repairs of minor defects where welding is required are to be treated as weld repairs and repaired in accordance with an approved procedure. Minor defects in critical locations are to be treated as, and repaired in the same manner as, major defects.

13.5 Major Defects

Defects other than minor defects with dimensions greater than those given in 2-1-5/13.3 above, may, with the Surveyor's prior approval, be repaired by welding to the satisfaction of the Surveyor, using an approved procedure. Where major defects are considered numerous or excessive by the Surveyor, an evaluation of the casting is to be made to assess if weld repair is appropriate.

13.7 Welded Repair *(2018)*

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

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

Before 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 work intended.

Removal of defects and weld repair are to be carried out in accordance with Part 2, Appendix 6. The defects are to be removed to sound metal, and before 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 on large castings such as rudder horns, stern frames, shoe pieces and rudder stocks, welding is not permitted on unheat-treated castings. Corrective welding is to be associated with the use of preheat.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and by qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

13.7.1 Weld Procedure Qualification for Repair of Castings *(1 July 2023)*

i) Castings require to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs.

ii) Welding procedures are to be qualified and are to match the delivery condition of the casting. Qualification of welding procedures are to follow Appendix 2-A9-1.

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

iv) The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 2-1-5/7.1.

Commentary:

Recommendation for welding: For steels with C ≥ 0.23 or Ceq ≥ 0.45, the Procedure Qualification Record (PQR) on which the Weld Procedure Specification (WPS) is based, should be qualified on a base material having a Ceq as follows: the Ceq of the base material should not fall below more than 0.02 of the material to be welded. (Example: PQR for a material with actual Ceq = 0.50 may be qualified on a material with Ceq ≥ 0.48.)

End of Commentary

13.9 Post Weld Repair Heat Treatment *(2024)*

All welded repairs of defects are to be given a suitable post weld heat treatment, as indicated in 2-1-5/5, or subject to the prior approval of the ABS materials department, consideration may be given to the acceptance of local stress-relieving heat treatment at a temperature of not less than 550°C (1022°F), unless specifically agreed with ABS. The heat treatment employed is dependent on the chemical composition of the casting, the casting and defect dimensions, and the position of the repairs.

Commentary:

Subject to the prior agreement of ABS, special consideration may be given to the omission of post weld heat treatment or to the acceptance of local stress-relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.

End of Commentary

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

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

13.11 Nondestructive Testing

Hull castings, such as cast-steel stern frames and rudder horns, are to be subjected to surface inspection by magnetic particle, dye penetrant or other equivalent means. See Part 2, Appendix 6. Cast-steel stern frames are to be subjected to such inspection over the entire skeg portion of the casting, including the enlarged portion forming the junction to the propeller post, and at such 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 produce a satisfactory magnetic potential on the surfaces being tested.

In addition to surface inspection, cast-steel rudder horns are to be inspected by radiographic means or, at the discretion of the attending Surveyor, in accordance with an approved ultrasonic procedure at the area just below the connection to the shell, and at such other locations as may be indicated in Part 2, Appendix 6, and on the approved plan. Additional NDE is to be considered at chaplet locations and areas of expected defects. The radiographic acceptance standard for all categories of defects is to be at least equivalent 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.

14 Identification and Marking

14.1 Identification

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

14.3 Marking

The manufacturer's name or identification mark/pattern number is to be cast on all castings, except those of such small size as to make this type of marking impracticable. The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all castings accepted in such location as to be discernible after machining and installation. In addition, 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.

15 Certification *(2005)*

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

i) Purchaser's name and order number

ii) Description of castings, steel quality and weight

iii) Identification number

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

v) Results of mechanical tests

vi) Results of nondestructive tests, where applicable

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

viii) Where applicable, test pressure

ix) Specification

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 6

Hull Steel Forgings

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

The following requirements cover steel forgings intended to be used in hull construction and equipment at ambient temperature.

Requirements for ABS grade steel forgings are in 2-1-6/10. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

Commentary:

i Ambient temperature is defined at -10°C for vessels and 0°C for offshore structures.

ii Forgings may be used in lieu of steel castings provided the specifications are met.

iii In case forgings are proposed to be used in lieu of rolled products, qualification testing in accordance with Appendix 2-A4-2 may be needed.

End of Commentary

1.5 Manufacturer Approval and Process of Manufacture *(2024)*

Forgings are to be made by a manufacturer approved by ABS. Approval covers manufacture of ABS Grades or alternative grades manufactured in accordance with recognized national standards or proprietary specifications.

ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of forging production, that may influence the final product properties:

i) Closed die preparation and die maintenance

ii) Source of raw material

iii) Forging temperatures

iv) Forging reduction or upset (2-1-6/1.7)

v) Heat treatment and heat treatment recording (2-1-6/5)

vi) Coupon preparation (2-1-6/9)

vii) Testing and inspection (2-1-6/10, 2-1-6/11)

viii) Rectification of defective forgings (2-1-6/11.3)

Any of the above can be included in a Survey patrol.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

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 by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

1.7 Degree of Reduction *(2024)*

The plastic deformation is to be such as to achieve the specified internal quality requirements and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast or semi-finished 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:

Products		***Total Forging Ratio (Cross-section)***	
		Where L > D	***Where L ≤ D***
Forgings made from ingots, forged blooms, billets		Min. 3:1	Min. 1.5:1
Rolled products (Rolled rings)		Min. 4:1	Min. 2:1
Rolled bars (in lieu of forgings)		Min. 6:1	
Forgings made by upsetting	Starting stock is to have minimum forging reduction of 1.5:1	Minimum upsetting is to be 1.5 (L/L_u)	
	As cast starting material	Minimum upsetting is to be 3 (L/L_u)	

Note:
L – Length (Height) before forging
D – Diameter before forging
L_u – Length (Height) after upsetting

Commentary:

Refer to ASTM A788 to calculate reduction ratio.

End of Commentary

1.5 Discard

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

3 Chemical Composition *(2024)*

All forgings are to be made from killed steel. The chemical composition is to be reported. The chemical composition of each heat is to be determined by the steel maker on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis is to apply. Refer to 2-1-5/3 i) and ii) for ladle analysis and product (check) analysis.

The maximum sulfur and phosphorus contents are to be 0.035%.

Forgings that are intended to be welded (or cladded), including rudder stocks and pintles, are to be of weldable quality. To maintain weldability, carbon content is not to exceed 0.23% or carbon equivalent (Ceq) is not to exceed 0.41%, unless specially approved.

Weldability of steels with carbon content greater than 0.35% is reduced. Specially approved grades having more than 0.35% carbon are to have **S** marked after the grade number.

Commentary:

Weldability of a forging can be established through weld procedure qualification tests in accordance with Part 2 Chapter 4.

End of Commentary

5 Heat Treatment *(2024)*

Heat treatment facilities used in producing ABS certified forgings are to be approved by ABS.

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 uses.

A heat treatment facility (independent or sub-contracted) can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

The ABS Surveyor is to attend the heat treatment facility (independent or sub-contracted) 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 forgings are to be heat treated using one of the following procedures in a furnace of ample proportions to bring the forgings to a uniform temperature, unless otherwise approved,

i) Annealed

ii) Normalized

iii) Normalized and tempered

iv) Quenched and tempered

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

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. If for any reason, a forging is subsequently heated for further hot working, the forging is to be reheat-treated following the hot working. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, the manufacturer is to determine if a subsequent stress relieving heat treatment is necessary.

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.

Commentary:

If a forging is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses. The stress relief temperature should be established in conjunction with the final heat treatment temperature and must not negatively affect the physical properties of the forging.

End of Commentary

7 Mechanical Properties *(2024)*

7.1 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area and are to meet the requirements of the applicable ABS grade in 2-1-6/10 or a recognized national standard or proprietary specification.

7.3 Impact Properties *(2024)*

Charpy V-notch impact tests are to be carried out as noted below,

Minimum Specified Yield Strength, N/mm^2 (kgf/mm^2, ksi)	*Minimum Average Absorbed Energy (Longitudinal), J (kgf-mm ft-lbf)*	*CVN Test Temperature*
205-690 (21-70, 30-100)	27 J (2.8, 15)	At 0°C or at design service temperature, when design service temeprature is < -10°C

Commentary:

Ambient temperature is defined at -10°C for vessels and 0°C for offshore structures.

End of Commentary

7.5 Hardness Tests *(2024)*

Each forging, except those with weight at the time of heat treatment less than 114 kg (250 lb), is to be Brinell Hardness tested and is to meet the requirements of a designated standard or proprietary specification.

7.7 Other Properties *(2024)*

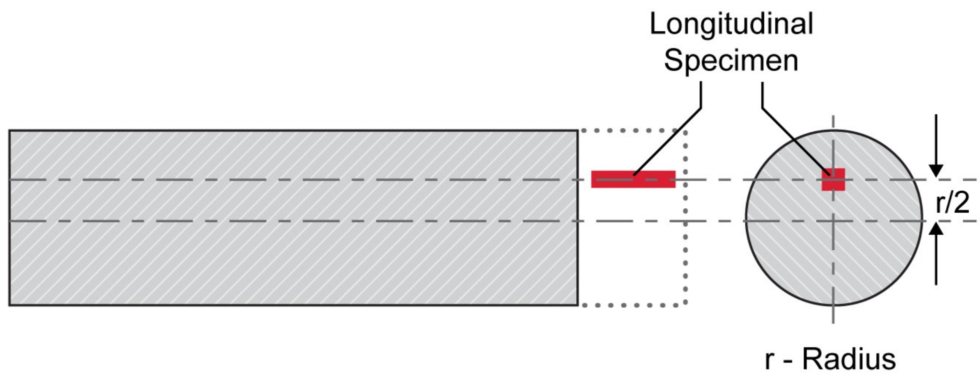
Other properties, such as elevated or low temperature properties, fatigue properties, corrosion or wear resistance are to be established if required by the design criteria.

9 Test Specimens

9.1 Location and Orientation of Specimens *(2024)*

The mechanical properties are to be determined from test specimens taken from prolongations having a sectional area not less than that of the body of the forging. Specimens may be taken in a direction parallel to the axis of the forgings in the direction in which the metal is most drawn out or may 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 (refer to the figure below). In the case of 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 location are in conformity with the specified tensile properties.

FIGURE 1
Hull Steel Forging – Example Representation of Test Specimen Location and Orientation *(2024)*



9.3 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.

9.5 Forgings Weighing less than 114 kg (250 lb) *(2024)*

In the cases of small forgings weighing less than 114 kg (250 lb) each, where the foregoing procedures are impracticable, 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 testing. In such cases, the special forgings are to be subjected to approximately the same amount of working and reduction as the forgings represented and are to be heat-treated with those forgings.

9.7 Specimen Identification *(2015)*

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

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed nor until the test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacture is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

9.9 Number of Tests

9.9.1 Large Forgings

In the case of large forgings with weight at the time of heat treatment of 3180 kg (7000 lb) or over, one tension test is to be made from each end of the forging.

9.9.2 Intermediate-sized Forgings

In the case of forgings with weight at the time of heat treatment less than 3180 kg (7000 lb), except as noted in the following paragraph, at least one tension test is to be made from each forging.

9.9.3 Small Forgings *(2024)*

In the case of small normalized forgings with weight at the time of heat treatment less than 1000 kg (2200 lb), and quenched and tempered forgings with weight at the time of heat treatment less than 500 kg (1100 lb), one tension test may to be taken from one forging as representative of a lot provided the forgings in each such lot are of 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 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.

Commentary:

Alternative criteria for testing can be considered for small forgings,

i If the total mass of the furnace charge exceeds 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings, one additional test specimen is to be taken for every 6000 kg (13200 lb) for normalized forgings and 3000 kg (6600 lb) for quenched and tempered forgings or part thereof.

End of commentary

9.11 Divided Forgings *(2024)*

In the cases of a number of pieces cut from a single forging, individual tests need not necessarily be made for each piece, but forgings are to be tested in accordance with whichever of the foregoing procedures is applicable to the primary forging involved.

9.13 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 physical 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. 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, but not more than three additional times.

10 Requirements for ABS Hull Steel Forgings *(2024)*

10.1 Chemical Composition for ABS Grade 2

Chemical composition for ABS Grade 2 forging is to comply with the following limits.

Carbon (max.)	*Managnese (max.)*	*Sulphur (max.)*	*Phosphorous (max.)*
0.23%	1.35%	0.035%	0.035%

Note: ABS Grade 2 is in substantial agreement with ASTM A668 Carbon-steel Forgings for General Industrial Use (Class B = Grade 2).

10.3 Tensile Properties for ABS Grade 2

ABS Grade 2 steel forgings are to conform to the following requirements as to tensile properties:

Size		*Tensile Strength min. N/mm² (kgf/ mm², psi)*	*Yield Point/ Yield Strength min. N/ mm² (kgf/ mm², psi)*	*Longitudinal Specimens*		*Transverse Specimens*		*Brinell Hardness Number Minimum 10 mm ball, 300 kg load*
Solid Diameter or Thickness				*Elongation in Gauging Length % 4d 5d*	*Reduction of Area, Min. %*	*Elongation in 50 mm (2 in.) Min. %*	*Reduction of Area, Min. %*	
Over	*Not Over*							
	305 mm (12 in.)	415 (42, 60000)	205 (21, 30000)	25 23	38	20	29	120
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 of the two specimens is not to exceed 70 N/mm² (7 kg/mm², 10000 psi).

10.5 Other ABS Grade Hull Steel Forgings

ABS grade steel forgings may be manufactured in accordance with the requirements of the ASTM grade referenced in the table below to meet the design requirements and the additional requirements identified in this section.

TABLE 1
Tensile Properties for ABS Grade Hull Steel Forgings

ABS Designation[1]	*ASTM Specification*	*Grade/Class*	*Yield Strength, N/mm² (kgf/mm², ksi)[2]*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)[2]*	*Minimum % Elongation 50 mm (2 in.)[2]*
FC	ASTM A668	C	230 (23, 30)	455 (46, 66)	23
FD	ASTM A668	D	260 (26.5, 37.5)	515 (52.5, 75)	24
FE	ASTM A668	E	305 (31, 44)	585 (60, 85)	25
FF	ASTM A668	F	380 (39, 55)	620 (63, 90)	20
FG	ASTM A668	G	345 (35, 50)	550 (56, 80)	24
FH	ASTM A668	H	415 (42, 60)	620 (63, 90)	22

Notes:

1 Requirements for chemical composition (2-1-6/3), impact properties (2-1-6/7.3) and test specimens (2-1-6/9) are also required to be met.

2 Refer to the applicable ASTM standard for the tensile properties for a given diameter. Tensile properties in this table are provided for reference.

11 Inspection and Repair *(2024)*

11.1 Examination *(2024)*

All forgings are to be examined by the Surveyor after final heat treatment and they are to be found free from defects. Where applicable, this is to include the examination of internal surfaces and bores.

It is the manufacturer's responsibility 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 ABS. Part 2, Appendix 7 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.

11.3 Rectification of Defective Forgings *(2018)*

11.3.1 Grinding *(2024)*

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

11.3.2 Weld Repair *(2024)*

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

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

Before undertaking 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.

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

Based on weldability and criticality of the forging, weld repair may not be permitted.

11.3.3 Temporary Welds *(2024)*

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and by qualified welders/operators. Temporary welds are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

12 Identification and Marking *(2024)*

12.1 Identification *(2024)*

The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast, and the Surveyor is to be given full access for tracing the forgings as requested.

12.3 Marking *(2024)*

Appropriate identification markings of the manufacturer are to be stamped on the forging along with the ABS markings indicating satisfactory compliance with the Rule requirements as furnished by the Surveyor. All forgings are to be stamped in a location that is discernible after machining and installation.

For example, Grade 2 forgings are to be stamped **AB/2**.

13 Certification *(2005)*

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

i) Purchaser's name and order number

ii) Description of forgings and steel quality

iii) Identification number

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

v) Results of mechanical tests

vi) Results of nondestructive tests, where applicable

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

viii) Specification

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 7

Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks *(2014)*

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR6	The materials used in the lower surface of the strength deck are to provide enhanced protection against chemicals common in crude oil and inert gas including hydrogen sulfide and sulfur dioxide.
MAT-FR7	The materials used in the upper surface of the lower tank regions are to provide enhanced protection against chemicals common in crude oil, sludge, and drain water.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope *(2024)*

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 Section 4 of the ABS *Guide for Performance Standard for Corrosion Protection* and the performance standard MSC 289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention (Corrosion protection of cargo oil tanks of crude oil tankers).

1.3

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

Product Type	*Maximum Thickness*
Plates and Wide Flats	50 mm (2.0 in)
Sections and Bars	50 mm (2.0 in)

1.5

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.

1.7

Since steels with enhanced corrosion resistance properties are similar to the ship steels as specified in Section 2-1-2 for Ordinary-strength Hull Structural Steel and Section 2-1-3 for Higher-strength Hull

Structural Steel, the basic requirements of Section 2-1-2 and Section 2-1-3 apply to these steels except where modified by this section.

1.9 *(2024)*

The weldability of steels with enhanced corrosion resistance properties is similar to those given in Section 2-4-1, therefore welding requirements specified in 2-4-3/3 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.

Commentary:

The brand name of welding consumables is to be specified by considering the corrosion resistant properties of the weld metal.

End of Commentary

3 Approval

3.1

All materials are to be manufactured at works which have been approved by ABS for steel in accordance with Part 2, Appendix 4.

3.3

Corrosion tests are to be carried out in accordance with Part 2, Appendix 8. Approval can be given for application to the following areas of a cargo oil tank:

i) Lower surface of strength deck and surrounding structures;

ii) Upper surface of inner bottom plating and surrounding structures;

iii) For both strength deck and inner bottom plating

3.5 *(2024)*

It is the manufacturer's responsibility to apply effective process and production controls within the manufacturing specifications. If the process or production controls are changed 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 ABS.

5 Method of Manufacture

5.1 *(2024)*

Method of manufacture, deoxidation practice and rolling practice is to be in accordance with Sections 2-1-2 and 2-1-3.

7 Chemical Composition

7.1

The chemical composition of samples taken from each ladle of each cast is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory and is to be in accordance with the requirements 2-1-2/5 for Ordinary-strength Hull Structural Steel and 2-1-3/3 for Higher-strength Hull Structural Steel.

7.3

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.

7.5

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

7.7

The carbon equivalent is to be in accordance with 2-1-3/7.1.

9 Condition of Supply

9.1

All materials are to be supplied in one of the supply conditions specified in 2-1-2/15.9 TABLE 5 for Ordinary-strength Hull Structural Steel and 2-1-3/7.3 TABLE 5 for Higher-strength Hull Structural steel.

11 Mechanical Properties

11.1

Tensile testing is to be carried out in accordance with 2-1-2/15.9 TABLE 2 for Ordinary-strength Hull Structural Steel and 2-1-3/7.3 TABLE 2 for Higher-strength Hull Structural steel. Charpy V-notch Impact Testing is to be carried out in accordance with 2-1-2/15.9 TABLE 4 for Ordinary-strength Hull Structural Steel and 2-1-3/7.3 TABLE 4 for Higher-strength Hull Structural steel.

13 Surface Quality *(1 July 2018)*

Please refer to 2-1-2/15.

15 Tolerances

15.1

Unless otherwise agreed or specially required the thickness tolerances in 2-1-1/15, “Permissible Variations in Dimensions” are applicable.

17 Identification of Materials

17.1

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

17.3

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

19 Testing and Inspection

19.1 Facilities for Inspection

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

19.3 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 2-1-1/11. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.

19.5 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 2-1-1/17 is to be carried out.

19.7 Ultrasonic Inspection

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

19.9 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.

21 Test Material

21.1

Definitions and requirements for test samples are to be in accordance with 2-1-1/11.

23 Test Specimens

23.1 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 2-1-1/11.

25 Number of Test Specimens

25.1

Number of Tensile and Charpy V-notch Impact test specimens are to be in accordance with 2-1-1/11.

27 Retest Procedures

27.1

To be in accordance with 2-1-1/9.5.

29 Marking

29.1 *(2024)*

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:

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

ii) 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**

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

Location where Steel is Effective	*Enhanced Corrosion Resistance Properties Designation*
Lower surface of strength deck and surrounding structures (ullage space)	**RCU**
Upper surface of inner bottom plating and surrounding structures	**RCB**
For both strength deck and inner bottom plating	**RCW**

Commentary:

i RCU, for the lower surface of strength deck and surrounding structures, defined as the deckhead with complete internal structure, including brackets connecting to longitudinal and transverse bulkheads. In addition:

a) In tanks with ring frame girder construction the underdeck transverse framing is to be protected down to level of the first tripping bracket below the upper faceplate;

b) Longitudinal and transverse bulkheads are to be protected to the uppermost means of access level. The uppermost means of access and it supporting brackets are to be fully protected.

c) On cargo tank bulkheads without an uppermost means of access the protection is to extend to 10 percent of the tank's height at centreline but need not extend more than 3 m down the deck.

ii RCB, for the upper surface of inner bottom plating and surrounding structures, defined as the flat inner bottom and all structure to a height of 0.3 m above inner bottom, is to be protected;

iii RCW, for both strength deck and inner bottom plating.

iv) As required by ABS, 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).

v) Name or initials to identify the steelworks.

vi) Cast or other number to identify the piece.

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

29.3

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.

29.5

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

29.7

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

31 Documentation

31.1

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

31.3

The number of copies required are to be specified by ABS.

31.5

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

31.7

ABS may require separate documents for each grade of steel.

31.9

The certificate is to contain, in addition to the description, dimensions, etc., of the material, at least the following particulars:

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

ii) Identification of the cast and piece including, where appropriate, the test specimen number.

iii) Identification of the steelworks.

iv) Identification of the grade of steel [and the manufacturer’s brand name].

v) Ladle analysis (for elements specified in 2-1-2/15.9 TABLE 1 for Ordinary-strength Hull structural steel and 2-1-3/7.3 TABLE 1 for Higher-strength Hull structural steel).

vi) If the steel is approved in accordance with 2-1-7/7.3, the weight percentage of each element added or intentionally controlled for improving corrosion resistance.

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

viii) Test Results

31.11

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 ABS 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 initialled for the makers by an authorized official:

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

31.13

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

PART 2

CHAPTER 1

Materials for Hull Construction

SECTION 8

Extra High Strength Steel *(2018)*

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope *(2024)*

The requirements in this Section are intended for product forms, which include plates, wide flats, sections, bars and tubulars.

Specific requirements described in this Section, together with the general requirements in Sections 2-1-1, 2-1-2 and 2-1-3, are applicable to ABS extra high strength steels. Manufacturers are to be ABS approved. Refer to 2-1-1/1.2 and 2-A4-3.

Steels are grouped in eight categories of 43, 47, 51, 56, 63, 70, 91 and 98 based on the level of specified minimum yield strength (see 2-1-8/1.2 TABLE 1). Each category is assigned with four different alphabetic indicators of AQ, DQ, EQ and FQ according to the Charpy V-notch impact test temperature (see 2-1-8/1.2 TABLE 2 and 5.11 TABLE 5A) to designate the steel grades, except for 91 and 98 grade for which FQ grades are specially considered by ABS. For example, Grade AQ43 indicates 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).

Commentary:

For Grades 91 and 98, Charpy V-notch impact test temperature is to be specifically considered and agreed upon by ABS Materials Department on a case-by-case basis.

End of Commentary

TABLE 1
Steel Category Based on Minimum Yield Strength *(2018)*

Yield Strength\ Category	*43*	*47*	*51*	*56*	*63*	*70*	*91*	*98*
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)	890 (91, 129)	960 (98, 139)

TABLE 2
Steel Grade Suffix Based on Test Temperature *(2018)*

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

2 Process of Manufacture *(2024)*

i) The steel is to be fully killed and manufactured by basic oxygen, electric arc furnace, vacuum-arc remelt, electro-slag remelt, or other process that are specifically approved by ABS.

ii) The steel mill is to have a documented process for control of raw materials. When the semi-finished products are not manufactured by an ABS approved plate manufacturer, the manufacturer of the semi-finished product is to be subject to approval by ABS.

iii) The steel is to be fine grain treated and have a fine grain structure. The fine grain practice is to be detailed in the manufacturing specification and submitted to ABS at the time of approval. All produced products are to have a fine grain structure greater than or equal to 6 determined by micrographic examination in accordance with ISO 643, ASTM E112 or an alternative test method. Refer to 2-1-2/5.5 and 2-1-3/5 for fine grain practice.

iv) The steels are to contain Nitrogen binding elements as detailed in the manufacturing specification. Also refer to note 4 in 2-1-8/4.1 TABLE 4A.

v) Processes used to control Hydrogen are to be applied. This includes Hydrogen out-gassing methods such as holding at suitable temperatures in controlled conditions. Details of holding environments are to be submitted.

vi) Vacuum degassing is mandatory for steel grades 70, 91 and 98, for all grades with a thickness greater than 50 mm, and for all steels with enhanced through-thickness properties.

3 Delivery Condition – Rolling Process and Heat Treatment *(2022)*

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

- Normalized (N)
- Normalized rolling (NR)/Controlled rolled (CR)
- Thermo-mechanical controlled rolled (TM)/with Accelerated cooling (TM+AcC)/with direct quenching followed by tempering (TM+DQ), or
- Quenched and Tempered condition (QT)

The definition of these delivery conditions are defined in 2-1-2/7.

Note:

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

3.1 Rolling Reduction Ratio

The rolling reduction ratio of slab, billet or bloom to the finished product (plate, section or bar) is to be at least 3:1 unless agreed at the time of approval. In such cases, additional information and qualification testing may be required.

The plastic deformation during rolling is to be such as to obtain a uniform wrought structure and satisfactory mechanical properties through the cross section.

When manufacturing rolled products from ingots, slabs, billets or blooms and it cannot be certain that a wrought microstructure can be achieved with a 3:1 reduction ratio, a higher reduction ratio than 3 to 1 will be required. The heat, pressure and rolling technique is to be sufficient to produce a uniform microstructure and close voids, particularly when rolling from ingots. The plastic deformation during rolling is to be such as to obtain a uniform wrought structure and satisfactory mechanical properties through the cross section.

3.3 Thickness Limits

Maximum thickness of plates, sections, bars and tubulars for which a specific delivery condition is applicable are shown in 2-1-8/3.3 TABLE 3.

TABLE 3
Maximum Thickness Limits *(2024)*

Delivery condition	*Maximum thickness (mm)* [(1)]			
	Plates	*Sections*	*Bars*	*Tubulars*
N	250	50	250	70
NR/CR	150	See Note 2		
TM	150	50	Not Applicable	Not Applicable
QT	250	50	Not Applicable	70

Notes:

1 Approval for steels with thickness greater than indicated in the above table are subject to the special consideration of ABS.

2 The maximum thickness limits of sections, bars and tubulars produced by NR/CR process are to be agreed with ABS. (NR/CR maximum thicknesses are generally less than N maximum thickness.)

4 Chemical Composition *(2024)*

Elements used for alloying, deoxidizing, fine grain treatment, nitrogen binding, inclusion shape control and modification, and any residual elements are to be included in the material or manufacturing specification.

4.1 Ladle Analysis *(2024)*

The chemical composition is to be determined by the steel manufacturer on samples taken from each heat and is to conform to the applicable requirements of the grade of steel listed in 2-1-8/4.1 TABLE 4A. The method of sampling is to be in accordance with that carried out for the initial qualification tests. The aim analysis is to be in accordance with the material specification. All elements listed in 2-1-8/4.1 TABLE 4A are to be reported.

i) For all steel grades, the carbon equivalent (C_{eq}) value is to be calculated from the ladle analysis. Maximum values are specified in 2-1-8/4.1 TABLE 4B in accordance with the following equation:

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

ii) For steel grades 47 and higher, carbon equivalent (CET) may be used instead of C_{eq} at the discretionof the manufacturer, and is to be calculated in accordance to the following equation:

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

Note:

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

iii) For TM and QT steels with carbon content no more than 0.12%, the cold cracking susceptibilityPcm for evaluating weldability may be used instead of carbon equivalent C_{eq} or CET atmanufacturer's discretion and is to be calculated using the following equation:

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

TABLE 4A
Chemical Composition *(2024)*

Delivery condition[1]	*N/NR/CR*[6]		*TM*[6]		*QT*	
Steel grade \ *Chemical Composition*[2,10]	AQ/DQ 43 AQ/DQ 47	EQ 43 EQ 47	AQ/DQ 43 AQ/DQ 47 AQ/DQ 51 AQ/DQ 56 AQ/DQ 63 AQ/DQ 70 AQ 91	EQ/FQ 43 EQ/FQ 47 EQ/FQ 51 EQ/FQ 56 EQ/FQ 63 EQ/FQ 70 DQ/EQ 91	AQ/DQ 43 AQ/DQ 47 AQ/DQ 51 AQ/DQ 56 AQ/DQ 63 AQ/DQ 70 AQ 91 AQ 98	EQ/FQ 43 EQ/FQ 47 EQ/FQ 51 EQ/FQ 56 EQ/FQ 63 EQ/FQ 70 DQ/EQ 91 DQ/EQ 98
Carbon % max	0.20	0.18	0.16	0.14	0.18[5]	
Manganese %	1.0~1.70		1.0~1.70		1.70 (max)	
Silicon % max	0.60		0.60		0.80	
Phosphorus %max[3]	0.030	0.025	0.025	0.020	0.025	0.020
Sulphur % max[3,12]	0.025	0.020	0.015	0.010	0.015	0.010
Aluminum total% min[4]	0.02		0.02		0.018	
Niobium % max	0.05		0.05		0.06	
Vanadium % max	0.20		0.12		0.12	
Titanium % max	0.05		0.05		0.05	
Nickel % max	0.80		3.50[7]		3.50[7]	
Copper % max[11]	0.55		0.55		0.50	
Chromium %max[11]	0.30		0.50		2.00	
Molybdenum %max[11]	0.10		0.50		0.70	
Nitrogen % max	0.025		0.025		0.015[8]	
Calcium % max	0.005		0.005		0.005	
Oxygen ppmmax[9]	Not applicable		Not applicable	50	Not applicable	30
Boron (max)	0.005		0.005		0.005	

Notes:

1 Refer to 2-1-8/3 for delivery conditions.

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

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

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

5 Higher carbon content may be agreed by ABS.

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

7 Nickel content to be agreed at time of qualification by ABS.

8 Higher nitrogen content may be agreed by ABS.

9 The requirement on maximum oxygen content is only applicable to DQ/EQ 91/98.

10 The contents of any other elements intentionally added is to be determined and reported.

11 Elements may be reported as ≤ 0.02% where the amount present does not exceed 0.02%.

12 The Sulphur content for Z-quality steels is to be less than or equal to 0.008%. Refer to 2-1-1/17.

TABLE 4B
Maximum C_{eq}, CET and P_{cm} Values[1,2] *(2024)*

<table>
<tr><th rowspan="4">Steel Grade</th><th rowspan="4">Delivery Condition</th><th colspan="8">Carbon Equivalent (%)</th></tr>
<tr><th colspan="6">Ceq</th><th>CET</th><th>Pcm</th></tr>
<tr><th colspan="3">Plates</th><th>Sections</th><th>Bars</th><th>Tubulars</th><th>All</th><th>All</th></tr>
<tr><th>t≤50 (mm)</th><th>50<t≤100 (mm)</th><th>100<t≤250 (mm)</th><th>t≤50 (mm)</th><th>t ≤ 250 or d ≤ 250 (mm)</th><th>t ≤65 (mm)</th><th>All</th><th>All</th></tr>
<tr><td rowspan="3">43</td><td>N/NR/CR</td><td>0.46</td><td>0.48</td><td>0.52</td><td>0.47</td><td>0.53</td><td>0.47</td><td colspan="2">N.A</td></tr>
<tr><td>TM</td><td>0.43</td><td>0.45</td><td>0.47</td><td>0.44</td><td colspan="4">N.A</td></tr>
<tr><td>QT</td><td>0.45</td><td>0.47</td><td>0.49</td><td colspan="2">N.A</td><td>0.46</td><td colspan="2">N.A</td></tr>
<tr><td rowspan="3">47</td><td>N/NR/CR</td><td>0.50</td><td>0.52</td><td>0.54</td><td>0.51</td><td>0.55</td><td>0.51</td><td>0.25</td><td>N.A</td></tr>
<tr><td>TM</td><td>0.45</td><td>0.47</td><td>0.48</td><td>0.46</td><td colspan="2">N.A</td><td>0.30</td><td>0.23</td></tr>
<tr><td>QT</td><td>0.47</td><td>0.48</td><td>0.50</td><td rowspan="12">N.A</td><td rowspan="12">N.A</td><td>0.48</td><td>0.32</td><td>0.24</td></tr>
<tr><td rowspan="2">51</td><td>TM</td><td>0.46</td><td>0.48</td><td>0.50</td><td>N.A</td><td>0.32</td><td>0.24</td></tr>
<tr><td>QT</td><td>0.48</td><td>0.50</td><td>0.54</td><td>0.50</td><td>0.34</td><td>0.25</td></tr>
<tr><td rowspan="2">56</td><td>TM</td><td>0.48</td><td>0.50</td><td>0.54</td><td>N.A</td><td>0.34</td><td>0.25</td></tr>
<tr><td>QT</td><td>0.56</td><td>0.60</td><td>0.64</td><td>0.56</td><td>0.36</td><td>0.28</td></tr>
<tr><td rowspan="2">63</td><td>TM</td><td>0.50</td><td>0.52</td><td>N.A</td><td>N.A</td><td>0.34</td><td>0.26</td></tr>
<tr><td>QT</td><td>0.56</td><td>0.60</td><td>0.64</td><td>0.58</td><td>0.38</td><td>0.30</td></tr>
<tr><td rowspan="2">70</td><td>TM</td><td>0.56</td><td colspan="2">N.A</td><td>N.A</td><td>0.36</td><td>0.30</td></tr>
<tr><td>QT</td><td>0.64</td><td>0.66</td><td>0.70</td><td>0.68</td><td>0.40</td><td>0.33</td></tr>
<tr><td rowspan="2">91</td><td>TM</td><td>0.60</td><td>N.A</td><td rowspan="3">N.A</td><td rowspan="3">N.A</td><td>0.38</td><td>0.28</td></tr>
<tr><td>QT</td><td>0.68</td><td>0.75</td><td>0.40</td><td rowspan="2">N.A</td></tr>
<tr><td>98</td><td>QT</td><td>0.75</td><td>N.A</td><td>0.40</td></tr>
</table>

Notes:
N.A = Not Applicable

1 Alternative limits can be specifically agreed upon by ABS and are subject to pre-qualification by the manufacturer.

2 Application of which formula is to be applied (Ceq, CET, Pcm) is subject to agreement between the manufacturer and purchaser.

5 Mechanical Properties

Test specimens and test procedures for mechanical properties are in accordance with Sections 2-1-1 and 2-1-2.

5.1 Tensile Test

5.1.1

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

5.1.2

Full thickness flat tensile specimens are to be prepared. When the capacity of the test machine is exceeded by the use of a full thickness specimen, sub-sized flat tensile specimens representing either the full thickness or half of the product thickness obtained by machining and retaining one of the original surfaces may be used. Alternatively, machined round test specimens as per 2-1-1/11.5.2 may be used. The round specimens are to be located at a position lying at a distance of *t/4* from the surface and additionally at *t/2* for thickness above 100 mm or as near as possible to these positions.

5.1.3

The results of the tests are to comply with the appropriate requirements of 2-1-8/5.11 TABLE 5A. In the case of product forms other than plates and wide flats where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those transverse requirements as listed in 2-1-8/5.11 TABLE 5B.

5.3 Impact Test

5.3.1

The Charpy V-notch impact test specimens are to be taken with their axes longitudinal or transverse to the final rolling direction and the results are to comply with the appropriate requirements of 2-1-8/5.11 TABLE 5A.

5.3.2

Sub-surface test specimens are to be located with their edges not more than 2 mm (0.08 in.) from the rolled surface. For thickness greater than 40 mm (1.57 in.) the impact test specimens are to be taken at quarter thickness (t/4) and for products with thickness in excess of 100 mm (4.0 in.), impact tests are to be taken at the quarter thickness (t/4) location and mid-thickness (t/2).

5.3.3 *(2024)*

Tests carried out at mid t and are to achieve at least $^{2}/_{3}$ of the required Joule value indicated in 5.11 TABLE 5A. Alternatively, the mid t test can be carried out at 10°C above the specified CVN test temperature to achieve the same Charpy value specified for the sub-surface specimen.

5.3.4

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

5.5 Through Thickness Tensile Test

For steels designated with improved through thickness properties, through thickness tensile tests are to be performed in accordance with 2-1-1/17.

5.7 Test Frequency

5.7.1 Tensile Test *(2024)*

i) Tension test specimens are to be taken from each heat treatment batch that is less than or equal to 25 tons, and are to be from the same cast, in the same delivery condition and of the same thickness.

ii) Tubulars supplied in QT condition, tensile test is to be verified from both ends of the product.

5.7.2 Impact Test *(2024)*

i) For steel products in N/NR/CR or TM condition, test specimens are to be taken from each piece.

ii) For steel products in QT condition, test specimens are to be taken from each individually heat treated part thereof.

iii) For sections and bars, impact test specimens are to be taken from each batch of 25 tons or fraction thereof, from each heat treatment batch of the same cast, delivery condition and thickness

Commentary:

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

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

End of Commentary

5.9 Traceability

Traceability of test material, specimen sampling and test procedures including test equipment with respect to mechanical properties testing, is to be in accordance with 2-1-1/5 and 2-1-1/9.

5.11 Re-test *(2024)*

Re-test procedures for tensile tests and Charpy impact tests are to be in accordance with 2-1-1/9.5, 2-1-2/9.11 and 2-1-2/11.7.

TABLE 5A
Mechanical Properties Requirements *(2024)*

	Tensile Properties (1,3, 8,10)			*Impact Test*	
Grade of Steel	*Yield Strength, ReH (4) N/mm² (kgf/mm², ksi)*	*Tensile Strength, RmN/mm² (kgf/ mm², ksi)*	*Elongation % (5,6) in $5.65\sqrt{A}$ (7) minimum*	*Test Temperature °C (°F)*	*Energy Average J (1,2) (kgf-m, ft-lb)*
AQ43 DQ43 EQ43	420 (43, 61)	530/680 (54/69, 77/98)	18	0 (32) -20 (-4) -40 (-40)	41 (4.2, 30) (2) L or 27 (2.8, 20) (1) T
FQ43				-60 (-76)	
AQ47 DQ47	460 (47, 67)	570/720 (58/73, 83/104)	17	0 (32) -20 (-4)	46 (4.7, 34) L or

	Tensile Properties (1,3, 8,10)			*Impact Test*	
Grade of Steel	*Yield Strength, ReH* (4) *N/mm^2 (kgf/mm^2, ksi)*	*Tensile Strength, RmN/mm^2 (kgf/ mm^2, ksi)*	*Elongation %* (5,6) *in* $5.65\sqrt{A}$(7) *minimum*	*Test Temperature °C (°F)*	*Energy Average J* (1,2) *(kgf-m, ft-lb)*
EQ47				-40 (-40)	31 (3.2, 23) T
FQ47				-60 (-76)	
AQ51 DQ51 EQ51	500 (51, 73)	610/770 (62/78, 88/112)	16	0 (32) -20 (-4) -40 (-40)	50 (5.1, 37) L or 33 (3.4, 24) T
FQ51				-60 (-76)	
AQ56 DQ56 EQ56	550 (56, 80)	670/835 (68/85, 97/120)	16	0 (32) -20 (-4) -40 (-40)	55 (5.6, 41) L or 37 (3.8, 27) T
FQ56				-60 (-76)	
AQ63 DQ63 EQ63	620 (63, 90)	720/890 (73/91, 104/129)	15	0 (32) -20 (-4) -40 (-40)	62 (6.3, 46) L or 41 (4.2, 30) T
FQ63				-60 (-76)	
AQ70 DQ70 EQ70	690 (70, 100)	770/940 (78/96, 112/136)	14	0 (32) -20 (-4) -40 (-40)	69 (7.0, 51) L or 46 (4.7, 34) T
FQ70				-60 (-76)	
AQ91 DQ91	890 (91, 129)	940/1100 (96/112, 136/160)	11	0 (32) -20 (-4)	69 (7.0, 51) L or
EQ91				-40 (-40)	46 (4.7, 34) T
AQ98(9) DQ98(9)	960 (98, 139)	980/1150 (100/117, 142/167)	10	0 (32) -20 (-4)	69 (7.0, 51) L or
EQ98(9)				-40 (-40)	46 (4.7, 34) T

Notes:

1 T = Transverse

2 L = Longitudinal

3 For plates and sections for applications, such as leg, rack and chord in Mobile Offshore Units (MOU), where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness. Materials intended for leg, racks and chords are to have a designation "R" after the Grade (i.e., EQ70-R).

4 For tensile test, either the upper yield stress (ReH) or where ReH cannot be determined, the 0,2 percent proof stress (Rp0.2) is to be determined and the material is considered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength.

5 The elongation for alternative B specimen in 2-1-1/16 FIGURE 2 is to be in accordance with 2-1-8/5.11 TABLE 5B.

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 2-1-8/5.11 TABLE 5A and 2-1-8/5.11 TABLE 5B.

7 *A* equals cross-sectional area of test specimen.

8 For thickness greater than 100 mm, except as indicated in Note 3, ABS will consider a reduction in tensile properties provided they are accounted for in the design phase. Refer to Note in 3-1-4/1.1 and 3-1-4/3.7 of the *MOU Rules*.

9 Maximum thickness for 98 grades is limited to 50 mm.

10 Tensile values that fall between the categories listed in the table will be considered.

TABLE 5B
Requirements for Alternative Specimen[(1)] *(2024)*

	Thickness, mm						
		>10	>15	>20	>25	>40	>50
Grade of Steel	≤10	≤15	≤20	≤25	≤40	≤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

Note:

1 91 and 98 grade specimens which are not included in this table are to be proportional specimens with a gauge length of $L_0 = 5.65\sqrt{S_0}$.

7 Tolerances

Unless otherwise agreed or specially required, the thickness tolerances are to be in accordance with 2-1-1/15.

9 Surface Quality

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. The surface quality inspection method are to be in accordance with EN 10163 Parts 1, 2 and 3 or equivalent standards agreed between purchaser and manufacturer and accepted by ABS.

Surface finish requirements are to be in accordance with the relevant requirements in 2-1-2/15.

Surface inspection is the responsibility of the manufacturer. The acceptance by ABS Surveyor of material later found to be defective are not to absolve the manufacturer of this responsibility.

9.1 Plate Edge Inspection

Edge of the plate is to be inspected. Any discontinuity greater than 25 mm in length is to be further investigated for depth and extent. Treatment of discontinuity is to be agreed with ABS.

11 Internal Soundness

Verification of internal soundness is the responsibility of the manufacturer. The acceptance by the ABS Surveyor is not to absolve the manufacturer of this responsibility.

11.1 Ultrasonic Examination

11.1.1 *(2022)*

All steel grades with thickness greater than or equal to 15 mm (0.60 in.) are to be inspected for internal quality at the mill in accordance with EN10160 or ASTM A578 or other recognized standard as agreed with ABS. Acceptance criteria is to be agreed between the purchaser and manufacturer, and accepted by ABS.

11.1.2

Acceptable standards are as follows:

For leg, rack and chord plates in Mobile Offshore Units (MOU), the acceptance criteria shall be a minimum of EN10160 Level S2/E3.

11.1.3

If chords are ordered with ultrasonic inspection in the final formed and heat treated condition, the specification and acceptance criteria is to be agreed between the purchaser and manufacturer, and accepted by ABS.

11.1.4 *(2024)*

For Z quality steels, ultrasonic examination is to be carried out on products of thickness 15 mm and above (refer to 2-1-1/17).

13 Stress Relieving Heat Treatment and Other Heat Treatments *(2024)*

Steels approved by the procedures given in 2-A4-3 are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming (refer to 2-A4-3/5.11.3(e)) for the purpose of reducing the risk of brittle fracture, increasing the fatigue lifetime and maintaining the dimensional stability for machining.

Commentary:

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

End of Commentary

15 Fabrication and Welding

Upon request from the fabricator, the steel mill may supply the parameters applied during the weldability tests (carried out in accordance with 2-A4-2/5.13) to develop fabrication procedures. Also ABS can populate this information on the ABS website with written consent from the steel mill.

17 Facilities for Inspection *(2024)*

Testing is to be witnessed by the ABS Surveyor to verify that the test results meet the specified requirements.

The manufacturer is to provide access to the steel works to enable the Surveyor to,

i) Verify that the approved manufacturing process is followed

ii) Select test materials

iii) Witness mechanical tests and to verify testing is in accordance with standards

iv) Witness/verify NDE inspection, calibration of inspection equipment.

19 Identification of Materials

The manufacturer is to adopt a system for the identification of ingots, slabs, billet or bloom and finished products, which will enable the material to be traced to its original cast.

The steel mill is to facilitate the Surveyor to verify traceability of the material.

21 Marking

Refer to requirements in 2-1-2/13.

Permanent marking of the grade and delivery condition is to be done on the product in the final delivery condition. Marking of the final designated grade is not permitted on semi-finished products.

Materials intended for leg, racks and chords are to have a designation "R" after the Grade (i.e., EQ70-R).

23 Documentation of Inspection Tests *(2024)*

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

i) Purchaser's order number

ii) Identification of the cast/heat, batch and plate number

iii) Manufacturer's identification

iv) Identification of the grade of steel

v) Chemical analysis and Ceq, CET or Pcm value

vi) Delivery condition with heat treatment temperatures

vii) Mechanical properties test results, including traceable test identification

viii) Surface quality and inspection results

ix) UT report

x) Manufacturer's Certificate refer to 2-1-1/7

ABS

PART 2

CHAPTER 2
Equipment

CONTENTS

PART 2

CHAPTER 2
Equipment

SECTION 1
Anchors

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties, when applicable.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements covered in the cross-referenced Rules (Sections 2-1-1, 2-1-5, 2-1-6, 2-4-1, 2-4-3 or Part 2, Appendix 9) are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope

The requirements of this section apply to 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.

These manufacturing requirements are applicable to ordinary anchors and superior holding power (SHP) anchors.

1.3 Types of Anchor

1.3.1 Ordinary Anchors *(2024)*

Ordinary stockless anchors are to be of an approved design. Any changes or alterations from the approved design are to be approved prior to manufacture.

The mass of the heads of stockless anchors including pins and fittings are not to be less than 60 % of the total mass of the anchor. Also refer to 3-5-1/7 of the *Marine Vessel Rules*.

1.3.2 Superior Holding Power (SHP) Anchors *(2024)*

SHP anchors are to be of an approved design and subject to special approval. Any changes or alterations to the approved design made during manufacture are to be approved. Also refer to 3-5-1/7 of the *Marine Vessel Rules*.

SHP anchors are to be suitable for ship use and are not to require prior adjustment or special placement on the seabed.

SHP anchors are to have at least twice the holding power of ordinary stockless anchors of the same weight.

When SHP anchors of proven superior holding ability are used as bower anchors, the mass of each bower anchor can be reduced by up to 25 % of the mass specified in 2-2-1/13 TABLE 6.

Approved manufacturers of SHP anchors are included in a specific directory maintained by ABS.

1.3.3 SHP Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs) *(2024)*

Superior holding power anchors with holding powers of at least 4 times the holding power of ordinary anchors are subject to ABS technical assessment and approval. The use of these SHP anchors is limited to restricted service ships and the SHP anchor mass is not to exceed 1500kg.

When SHP Anchors for restricted service of proven superior holding ability are used as bower anchors, the mass of each bower anchor can be reduced by up to 50% of the mass specified in 2-2-1/13 TABLE 6.

For approval and/or acceptance as a SHP anchor, satisfactory full scale tests according to 7.1.4 are to be performed to confirm that the anchor has a holding power of at least four times that of an ordinary stockless anchor or at least twice that of a previously approved SHP anchor of the same mass.

3 Materials for Anchors *(2024)*

All anchors are to be manufactured from materials meeting the requirements of the ABS *Rules for Materials and Welding (Part 2)* and produced by a manufacturer approved by ABS.

i) Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-5 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated.

Cast steel anchor flukes and shanks are to have integrally cast test coupons. The test coupons are not to be detached until the full heat treatment cycle has been completed. The method of detachment is not to physically or metallurgically damage the anchor component. Test coupons are not to be detached until they have been stamped by the Surveyor for identification and are to be traceable to the cast components they represent. Test reports are to be traceable to the test coupons.

ii) Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 2-1-6. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction in Section 2-1-6.

iii) Rolled plates and bars for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of Section 2-1-1. Rolled bars intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of Sections 2-1-1 or 2-3-8.

3.1 Superior Holding Power (SHP) Anchors for Restricted Service and to a Maximum Weight of 1500 kg (3306 lbs) *(2024)*

In addition to the above requirements, the steel for SHP Anchors is to be selected in accordance with 3-1-2/3.1 TABLE 1 Class II of the *Marine Vessel Rules*. The welding consumables are to meet the toughness for the base steel grades. 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).

5 Manufacture of Anchors *(2007)*

5.1 Tolerance

If not otherwise specified in standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerances are to be applied.

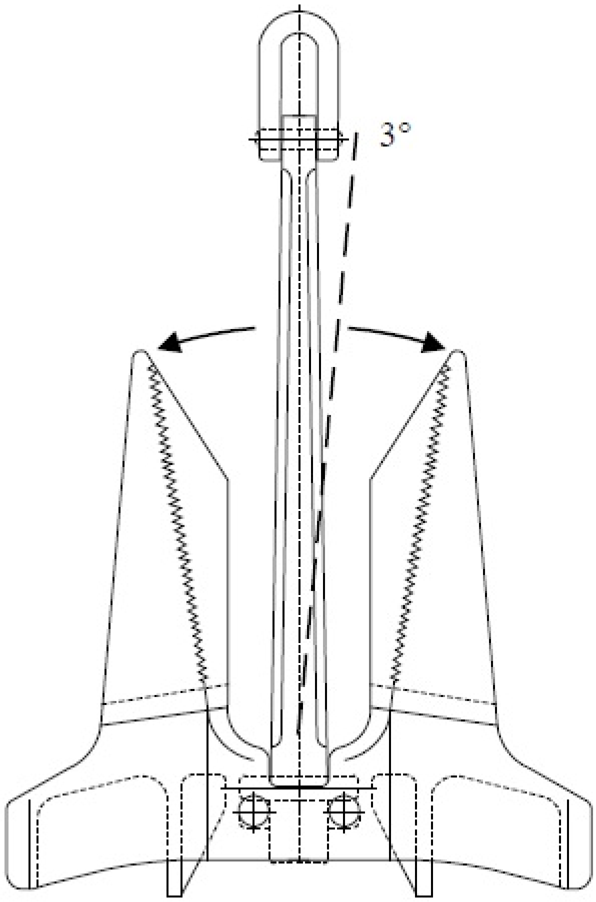
The clearance either side of the shank within the shackle jaws is to be no more than 3 mm (0.12 in.) for small anchors up to 3 tonnes (3.3 tons) weight, 4 mm (0.16 in.) for anchors up to 5 tonnes (5.5 tons) weight, 6 mm (0.24 in.) for anchors up to 7 tonnes (7.7 tons) weight and is not to exceed 12 mm (0.47 in.) 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 verify 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 in.) for pins up to 57 mm (2.24 in.) and 1.0 mm (0.04 in.) for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, see 2-2-1/5.1 FIGURE 1.

FIGURE 1
Allowable Lateral Movement of Shank *(2007)*



5.3 Welding of Anchors *(2024)*

Welded construction of fabricated anchors is to be carried out with approved procedures in accordance with Sections 2-4-1 and 2-4-3. NDE is to be carried in accordance with the requirements of 2-2-1/7.3.5 TABLE 3 or 2-2-1/7.3.5 TABLE 4 or 2-2-1/7.3.6 TABLE 5.

5.5 Heat Treatment *(2012)*

Components for cast or forged anchors are to be properly heat treated; fully annealed; normalized or normalized and tempered in accordance with 2-1-5/5 or 2-1-6/5. Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

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.

5.7 Surface Cleanliness

All parts are to have a clean surface consistent with the method of manufacture and intended method of inspection.

5.9 Repairs *(2010)*

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 2-1-5/13 and 2-1-6/11.3. The restrictions of 2-2-1/7.3.7 - Repair Criteria, also apply.

The manufacturer is to maintain full records detailing the extent and location of all weld repairs made to each casting or forging and details of weld procedures and heat treatments applied. These records are to be available to the Surveyor and copies 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.

5.11 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.

7 Testing and Certification *(2007)*

All anchors are to be inspected and tested in the presence of the Surveyor, the proof testing is to be done 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 inspected and calibrated.

7.1 Proof Load Testing of Anchors *(2024)*

Proof load testing for ordinary and SHP anchors is to be carried out by a testing facility agreed with ABS.

7.1.1 Proof Load Testing of Ordinary Anchors *(2014)*

Before application of proof test load, the anchors are to be visually examined, and all defects are to be removed, and if necessary repaired by welding, 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 2-2-1/13 TABLE 6 and are 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 2-2-1/7.1.1 FIGURE 2.

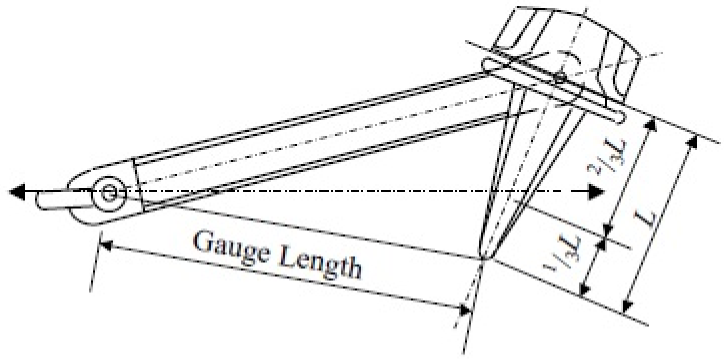
In the case of stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

After proof load testing the anchors are to be examined for cracks and other defects, and for excessive deformation due to seating.

Upon completion of the proof load tests, 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 (see 2-2-1/7.1.1 FIGURE 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
Proof Load Application



7.1.2 Proof Load Testing of SHP Anchors

SHP anchors are to be proof tested with loads required by 2-2-1/13 TABLE 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 2-2-1/7.1.

7.1.3 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 2-2-1/13 TABLE 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 2-2-1/7.1.

7.1.4 SHP Full Scale Anchor Holding Power Tests at Sea *(2024)*

In addition to proof tests SHP anchors are to undergo anchor holding power sea tests on various types of sea bottom, using anchors representative of the full range of anchor size proposed. The holding power test load is not to exceed the proof load of the anchor.

i) The anchors are to be tested in association with the size of chain required for that anchor mass. The length of the cable with each anchor is to be such that the pull on the shank remains horizontal. For this purpose, a scope of 10 is considered normal, but a scope of not less than 6 may be accepted subject to the holding power of the anchor is verified by testing or through an assessment of the uplifting forces to the anchor. Scope is defined as the ratio of length of cable to depth of water.

ii) Three tests are to be taken for each anchor design and each type of sea bottom. The stability of the anchor and ease of breaking out are to be noted where possible. Tests are to be carried out from a tug, but alternatively, shore-based tests may be accepted. The pull is to be measured by dynamometer. Measurements of pull, based on the RPM/bollard pull curve of the tug may be accepted as an alternative to a dynamometer.

iii) For approval and/or acceptance for a range of SHP anchor sizes, tests are to be carried out for at least two anchor sizes. The mass of the maximum size approved is not to be more than 10 times the mass of the largest size tested.

iv) For approval and/or acceptance for a range of SHP restricted service anchor sizes, at least three anchor sizes are to be tested, indicative of the bottom, middle and top of the mass range.

Commentary:

The holding power of the anchor depends on its construction, the seabed morphology, and the angle of chain with respect to the sea bottom which is related to the scope. The lower the scope, the higher the uplifting forces. Ordinary chain's holding power is based on its length and weight which is calculated by the ship's Equipment Number, EN, for a scope of 6 as standard, while for more severe conditions a scope of 10 is preferred.

SHP anchors achieve a higher holding by design of larger fluke area rather than weight and it is known by years of implementation that a scope of 10 will have no negative effect to the holding power of an SHP anchor. On the other hand, once the scope is reduced, uplifting forces will start acting on the large fluke area, and hence the holding power may be reduced. For that reason, a scope below 10 is to be verified accordingly.

End of Commentary

7.3 Anchor Tests *(2024)*

7.3.1 Testing Requirements *(2024)*

Anchors are to be tested in accordance with test program "A" or "B".

TABLE 1
Applicable Test Programs for Each Product Form *(2010)*

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
Product Test Requirements for Program A and B *(2010)*

Program A	*Program B*
Drop test	Drop test
Hammering test	---
Visual inspection	Visual inspection
General NDE	General NDE
---	Extended NDE

7.3.2 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.

7.3.3 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.

7.3.4 Visual Inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

7.3.5 General Nondestructive Examination *(2024)*

After proof loading, general NDE is to be carried out as indicated in 2-2-1/7.3.5 TABLE 3 and 2-2-1/7.3.5 TABLE 4.

The NDE may be carried out in accordance with Part 2, Appendix 6, "Nondestructive Examination of Marine Steel Castings" or other national or international standards.

TABLE 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

TABLE 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

7.3.6 Extended Nondestructive Examination *(2024)*

After proof loading extended NDE is to be carried out as indicated in 2-2-1/7.3.6 TABLE 5.

The NDT may be carried out in accordance with Part 2, Appendix 6, "Nondestructive Examination of Marine Steel Castings" or other national or international standard.

TABLE 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

Location	*Method of NDE*
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

7.3.7 Repair Criteria

If defects are detected by NDE, repairs are to be carried out in accordance with 2-2-1/5.9. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

7.5 Mass and Dimensional Inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is an integral component.

7.7 Retests

Mechanical retest is permitted in accordance with the requirements of 2-1-5/9.7 and 2-1-6/9.13.

9 Marking for Anchors

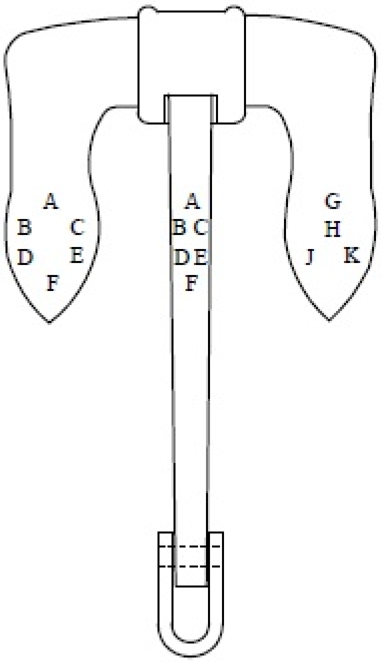
9.1 Markings

When anchors have satisfactorily passed the above test requirements, they are to be clearly stamped by the manufacturer as shown in 9.3 FIGURE 3.

9.3 Provisions for Marks *(2005) (2024)*

One side of the anchor is to be reserved solely for the above marks and the other side used for the marker's name or other trademarks that may be desired. If the design of the anchor does not admit of 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 initial, see the figure below.

FIGURE 3
Stockless Anchor *(2008)*



A	The number of Certificate. (Furnished by the Surveyor)	00-PA123
B	*(2005)* The Maltese Cross Stamp 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	34680
E	Signifying that the Testing Machine is recognized by the Committee of the American Bureau of Shipping	AB
F	The Weight of Anchor	1906
G	*(2008)* Signifying that Anchor Head has been verified by a Surveyor to the American Bureau of Shipping	AB
H	The Weight of Anchor Head	1140
J	*(2005)* The Maltese Cross Stamp and the Initials of the Surveyor who witnesses the Drop Test	✠ X.Y.X.
K	Month and Year of Drop Test	6-00

11 Certification *(2007)*

Anchors which meet the requirements of this section are to be certified by ABS. The following items are to be included in the certificate:

- Manufacturer's name
- Type
- Mass
- Fluke and Shank identification numbers

- Grade of materials
- Proof test loads
- Heat treatment
- Markings applied to anchor

13 Painting *(2007)*

All types of anchor are to remain unpainted until all tests and inspections have been completed.

TABLE 6
Proof Tests for Anchors

Note See also 3-5-1/7 of the Marine Vessel Rules

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		

Note See also 3-5-1/7 of the Marine Vessel Rules

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*
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		

Note See also 3-5-1/7 of the Marine Vessel Rules

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		

Note See also 3-5-1/7 of the Marine Vessel Rules

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*
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		

Note See also 3-5-1/7 of the Marine Vessel Rules

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		

Note See also 3-5-1/7 of the Marine Vessel Rules

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*
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		

PART 2

CHAPTER 2
Equipment

SECTION 2
Anchor Chain

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Goals*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties, wwhen applicable.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Scope *(2024)*

This section covers requirements for manufacture, fabrication, testing and inspection of anchor chain and chain accessories. Three grades of stud-link anchor chain are covered, and are described as follows:

Strength Level	*Grade*	*Method of Manufacture*
Normal Strength	1	Flash Butt-welded
High Strength	2a 2b	Flash Butt-welded or Drop-forged Cast Steel
Extra-high Strength	3a 3b	Flash Butt-welded or Drop-forged Cast Steel

3 General

All chain is to have a workmanlike finish and be free from injurious defects. There is to be an odd number of links in each shot of anchor chain cable to verify shackles leading over the windlass are in the same position.

5 Specially Approved Chain *(2024)*

Steel chain made by processes or to requirements differing from those shown in 2-2-2/25.5 TABLE 1 and certain types of drop-forged chain are subject to ABS technical assessment and approval.

7 Qualification of Manufacturers *(2020)*

7.1 General *(2020)*

Anchor chain and chain accessories are to be produced by manufacturers approved by ABS. For approval purposes, the manufacturer is to submit a manufacturing procedure specification, applicable material grades, and dimensional details of chain/accessories along with a test plan for ABS review. The approval tests, as a minimum, are to include:

i) Chemical analyses

ii) Proof load tests

iii) Break load tests

iv) Tensile tests

v) Impact tests

vi) Metallographic examinations

vii) Dimensional measurements

viii) Visual inspection

ix) Nondestructive examination

Qualification testing is to be carried out on the largest size chain or accessory. The approval tests are to be witnessed by an attending Surveyor and the test-data are to be submitted to ABS Materials Department for review and acceptance. The approval is valid for a maximum of 5 years and the renewal process is to be on similar lines as specified in 2-A4-2/11.

9 Chain Dimensions and Tolerances

9.1 Shape

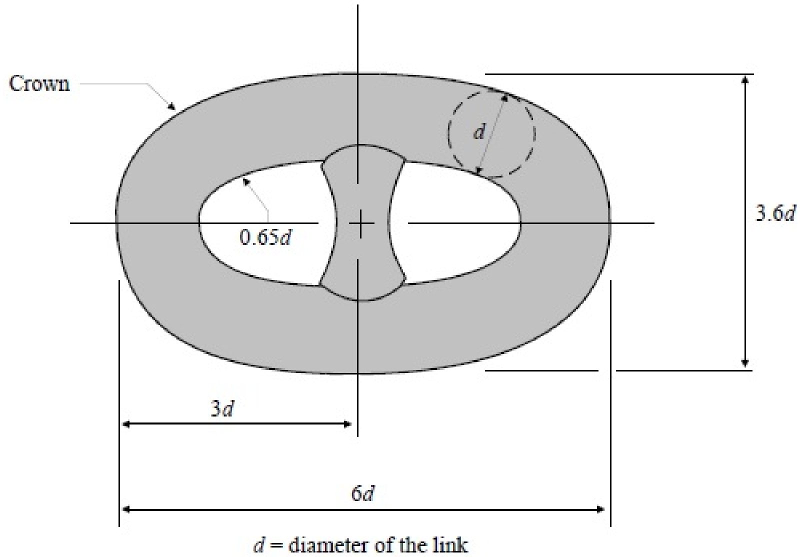
Each link is to be uniform and symmetrical, and is to have smooth internal radii that are to be at least 0.65 times the chain diameter.

9.3 Dimensions *(2024)*

The dimensions, shape and proportions of links and accessories are to conform to an approved recognized standard, such as ISO 1704, or the designs are subject to ABS technical assessment and approval.

After proof testing, measurements are to be taken on at least one link per each 27.5 m (15 fathoms) of chain tested and conform to the dimensions shown below.

Common Link



9.5 Tolerances *(1999)*

The minus tolerances on the diameter in the plane of the link at the crown are permitted to the extent shown below, provided the cross-sectional area of the link at that point is at least the theoretical area of the nominal diameter:

Chain Diameter in mm (in.)		*Crown Minus Tolerance in mm (in.)*
Over	*Up to*	
–	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 exceed 5% of the nominal diameter. The manufacturer's specification for plus tolerance in way of weld is to be submitted for approval.

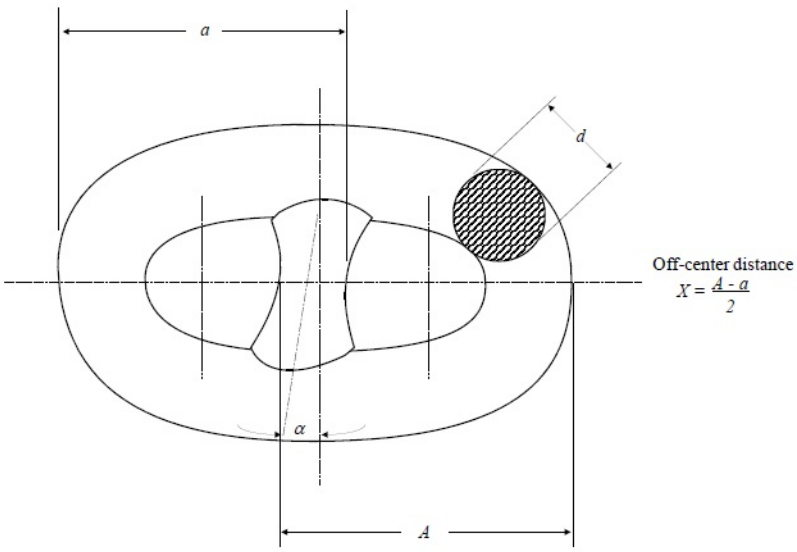
Subject to 2-2-2/9.7, the tolerances on other dimensions in 2-2-2/9.3 are not to exceed ±2.5%.

Studs are to be located 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 follows:

Final Link



9.7 Length Over Five Links

After completion of the proof testing, the length over five links is to be measured while applying a tension of approximately 10% of the applied proof load. The Surveyor is to verify the length over a five link measurement from at least three locations per each 27.5 m (15 fathoms) of chain tested. The allowable 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 2-2-2/27 TABLE 2.

11 Material and Fabrication of Anchor Chain and Chain Accessories *(2024)*

11.1 Process of Manufacture *(2024)*

Manufacturers of bar, plate, castings, and forgings are to be ABS approved as indicated in 2-2-3/1.2. The steel used for the manufacture of chain is to be made by the open-hearth, basic oxygen, electric-furnace or such other process as may be subject to ABS technical assessment and approval. Refer to 2-2-3/1.2.

Rimmed steel is not acceptable for any grade of chain.

11.3 Heat Treatment of Chain Lengths

11.3.1 Flash Butt-welded Chain

Grades 1 and 2a flash butt-welded chain may be supplied in either the as-welded or normalized condition.

11.3.2 Drop-forged, Cast-steel and Extra-high-strength Chain

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 in accordance with the manufacturer's approved specification.

11.3.3 Sequence of Heat Treatment

Heat treatment is to be completed prior to the proof and breaking tests.

11.5 Flash Butt-welding *(2024)*

Flash butt-welding of chain grades is to be performed in accordance with parameters shown to meet the minimum mechanical properties.

11.7 Stud Attachment *(2024)*

Studs are to be securely fastened by press fitting or welding with an approved weld 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. Any welding of chain subsequent to the approved manufacturing process is to be approved by the attending Surveyor.

Welding of studs is to be in accordance with an approved weld procedure, qualified in accordance with Section 2-4-3, subject to the following conditions:

i) The studs are to be of weldable steel.

ii) The studs are to be welded at one end only (i.e., opposite to the weldment of the link). The stud ends are to fit the inside of the link without appreciable gap.

iii) The welds, preferably with the links in the horizontal position, are to be performed by qualified welders using suitable welding consumables.

iv) All welds are to be carried out before the final heat treatment of the chain cable.

v) The welds are to be free from defects that may impair the proper use of the chain. Under-cuts, end craters and similar defects are to be ground off, where necessary.

ABS may request a procedure test for the welding of chain studs.

13 Material Testing of Bars, Castings or Forging Intended for Anchor Chain *(2024)*

13.1 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, 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.

13.2 Chemical Composition – Ladle Analysis *(2024)*

The chemical composition of the chain material is to be determined by the steelmaker using samples taken from each ladle of each heat and is to comply with the approved specification of the chain manufacturer.

13.3 Number of Tests

One set of tests consisting of one tension, and one bend or three impact test specimens as required in 2-2-2/25.5 TABLE 1 are to be taken from the largest casting or drop forging from each lot of 50 tons or fraction thereof from each heat.

13.5 Tension Test Specimens *(1996)*

For cast or drop-forged links, machined type specimens are to be used. They are to be cut and notched as shown in 2-2-2/13.13 FIGURE 1. The tension-test results for stud-link anchor chain materials are to meet the applicable requirements shown in 2-2-2/25.5 TABLE 1.

The required minimum percentage elongation values in 2-2-2/25.5 TABLE 1 are based on specimens having gauge lengths equal to 5 times the diameter. For specimens having other gauge lengths the equivalent elongation value is to be calculated by the following equation:

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

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.

13.7 Bend Test Specimens

For cast or drop-forged links, machined type specimens are to be used. Each specimen is to withstand, without fracture, cold bending around a mandril diameter and through the angle specified in 2-2-2/25.5 TABLE 1.

13.9 Impact Test Specimens

Impact test specimens are to be in accordance with 2-1-1/11.11. They are to be cut and notched as shown in 2-2-2/13.13 FIGURE 1. The average value of 3 specimens is to comply with the requirements of 2-2-2/25.5 TABLE 1.

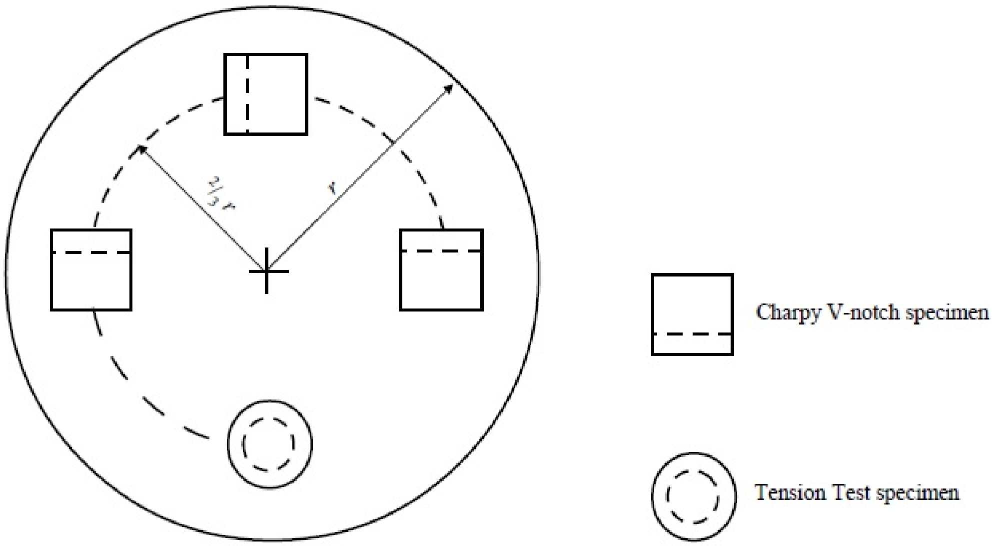
13.11 Retests *(2024)*

When a specimen fails to meet the requirements of 2-2-2/25.5 TABLE 1 retest in accordance with 2-1-2/9.11, 2-1-2/9.13, 2-1-2/11.7 and 2-1-2/11.9 may be permitted, as applicable.

13.13 Manufacturer's Option

At the option 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 2-2-2/13.3.

FIGURE 1
Location and Orientation of Test Specimens



13.15 Nondestructive Examination (NDE) *(2024)*

NDE is to be performed on proof loaded chain links in accordance with recognized standards accepted by ABS. NDE procedures, together with rejection/acceptance criteria are to be agreed upon by ABS.

NDE personnel are to be qualified and certified according to ISO 9712, ACCP or equivalent. Personnel qualification to an employer or a responsible agency-based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed by ABS and found acceptable, and the Level 3 is ASNT Level III, ISO 9712 Level III or ACCP Professional Level III, and certified in the applicable method. NDE operators are to be qualified to at least level II

15 <No Text> *(2024)*

17 Testing and Inspection of Chain Lengths

17.1 General *(1996)*

All anchor chain is to be subjected to breaking and proof tests in the presence of a Surveyor. The Surveyor is to verify that the testing machines are maintained in a satisfactory and accurate condition and is to keep a record of the dates and by whom the machines were rechecked or calibrated. Prior to test and inspection, the chain is to be free from paint or other coating which would tend to conceal defects. After proof testing, links are to be carefully examined 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 be subjected to magnetic particle or dye penetrant inspection.

17.3 Chain Identification

Each shot is to be stamped with a distinctive mark in order to identify it through the several processes of gauging, testing, measuring, examining, repairing and weighing. In the event of the Surveyor attending the works while forged chains are being fabricated, which are to be submitted for testing, the break test specimens are to be selected as far as possible during the process of fabrication.

17.5 Testing Precautions

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 as is equally applied to every link tested.

17.7 Weighing of Tested Chain

When chains have satisfactorily passed the requirements, they are to be weighed, together with the shackles forming the outfit, and this actual weight will be given on the certificate of test.

17.9 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 the original chain diameter. The certificate issued for such chain will include for descriptive purposes the original chain diameter as well as the mean diameter of the part most worn, and is to be marked, "This chain is not new, and has been previously used".

17.11 Breaking Test

A break-test specimen consisting of at least three links is to be taken from the chain or produced at the same time and the same way as the chain. Where produced separately, the specimen is to be securely attached 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 2-2-2/27 TABLE 2 (stud-link chain).

The breaking load test is to be carried out in the presence of the Surveyor and is to be maintained for a minimum of 30 seconds. A specimen is to be considered to have successfully passed the test if there is no sign of fracture after application of the required load. Special attention is to be given to the visual inspection of the flash butt weld. Where the first test is not satisfactory, one more specimen may be cut out and subjected to the breaking load. If this test fails, the shot is to be rejected, and additional specimens are to be cut from each of the three remaining shots of 27.5 m (15 fathoms) or less 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 required 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 is to be mechanically tested, according to 2-2-2/17.15.

17.13 Proof Test

Each shot of chain of 27.5 m (15 fathoms) length or less and the entire length of chain when produced in lengths longer than 27.5 m (15 fathoms) is to withstand the applicable proof load indicated in 2-2-2/27 TABLE 2 (stud-link chain). Upon special request and when approved by ABS, 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 applied and the chain re-examined. If one link breaks under the proof test, a joining link is to be inserted and the proof test again applied; if a second link breaks, the shot or length under test is to be rejected. For chain produced in long continuous lengths, if more than one link breaks under proof test, the entire length is to be rejected unless approved otherwise.

17.15 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 the 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 and, additionally, three impact specimens are to be taken with notches at the weld center. The results of the tests are to comply with the requirements given in 2-2-2/25.5 TABLE 1.

When the results of the original tests fail to meet the requirements, retests in accordance with 2-1-2/9.11 and 2-1-2/11.7 may be permitted, as applicable.

17.17 Mechanical and Breaking Tests on Chain Produced in Long Continuous Lengths

When chain is produced in lengths longer than 27.5 m (15 fathoms), the test frequency for the mechanical and breaking tests required in 2-2-2/17.11 and 2-2-2/17.15 are to be based on tests at regular intervals according to the following table. If an order or a fraction of an order is less than the specified length, that length is to be subject to all tests required for a full length.

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

17.19 Nondestructive Examination – After Proof Load Test *(2024)*

NDE is to be performed on proof loaded chain links in accordance with recognized standards. NDE procedures, together with rejection/acceptance criteria are to be agreed with ABS.

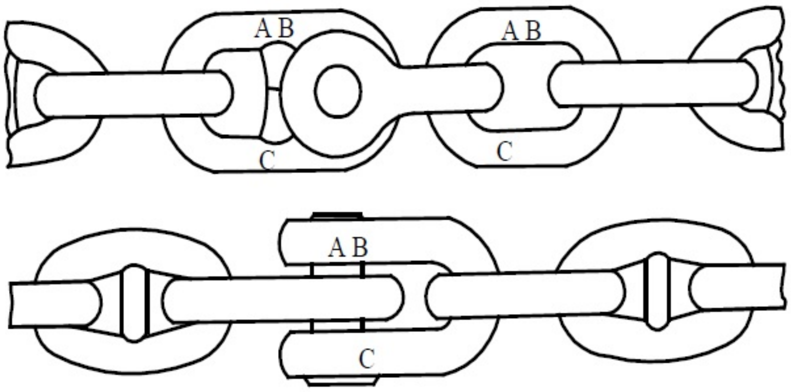
NDE personnel are to be qualified and certified according to ISO 9712, ACCP or equivalent. Personnel qualification to an employer or responsible agency-based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level 3 is ASNT Level III, ISO 9712 Level III or ACCP Professional Level III and certified in the applicable method. NDE operators are to be qualified to at least Level II.

19 <No Text> *(2024)*

21 Marking for Chain *(2001)*

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 2-2-2/21 FIGURE 2 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. Any accessory tested to a break load for a lower grade chain, as permitted in 2-2-2/23.13, is to be marked with the grade of the chain to which it is tested.

FIGURE 2
Marking for Chain



A	The Number of the Certificate (Furnished by the Surveyor)	78 PT1234
B	Signifying that the Chain has been satisfactorily tested to the ABS Requirements and the Grade as Applicable	AB/1, AB/2 or AB/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.)	

23 Anchor Chain Accessories

23.1 Dimensions and Dimensional Tolerances *(1996)*

The dimensions of anchor chain accessories are to be in accordance 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%

23.2 Locking Pins in Accessories *(2020)*

Locking pins in detachable connecting links are to have taper contact at both top and bottom in the link halves. Acceptable material is to be used for plugging the locking pin hole, which is to contain an appropriate undercut recess or equivalent arrangement to secure the plug.

23.3 Material Testing *(2024)*

Test specimens are to be taken either from finished accessories, or from special test bars indicated in 2-2-2/23.5 and 2-2-2/23.7. 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 comply with 2-2-2/25.5 TABLE 1 or such other specification is subject to ABS technical assessment and approval. When the results of original tests do not meet the requirements, retests in accordance with 2-1-2/9.11 and 2-1-2/11.7 may be permitted, as applicable.

In addition, refer to 2-2-2/13 for testing and NDE of bars, castings, and forgings intended for chain accessories.

23.5 Cast Accessories

Test specimens may be taken from integrally or separately cast test blocks, heat-treated together with the accessories represented.

23.7 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.

23.9 Inspection – After Proof Load Test *(2024)*

All accessories are to be inspected by magnetic particle or other suitable method to confirm freedom from injurious surface defects. Special attention is to be given to welds.

In addition, refer to 2-2-2/17.19 for inspection of finished chain accessories.

23.11 Hardness Test

All accessories are to be subjected to a Brinell hardness test to meet the following:

Grade	*Brinell Hardness Number Minimum 10 mm ball, 3000 kg load*
1	120
2	145
3	207

23.13 Break Test *(2001)*

Break tests are to be made 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 necessarily 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. For accessories from the same lot (see 2-2-2/23.3), the Surveyor may reduce the number of break tests 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 2-2-2/23.13.1 below.

23.13.1 Use of Break Tested Parts *(2001)*

Where it is demonstrated by either one of the following methods that the accessories can withstand at least 140% of the breaking test load prescribed in 2-2-2/27 TABLE 2 for the chain in which they are intended, such accessories may be used in service provided:

23.13.1(a) the materialof the accessories is of higher grade than the chain (e.g., grade 3 accessories of grade 2 size in grade 2 chain), or

23.13.1(b) where an accessory of increased dimension is specially approved for the particular application and a procedure test is completed at 140% of the 2-2-2/27 TABLE 2 break test load. All parts of the accessories used in this procedure test are to be subsequently discarded.

In either case, each accessory requiring a break test is to be tested to 100% of the 2-2-2/27 TABLE 2 break load for the chain in which it is intended to be used.

23.15 Proof Tests

Each accessory is to be subjected to a proof test in accordance with 2-2-2/17.3.

23.17 Markings

The certificate number, **AB/Chain Grade**, and nominal chain diameter are to be steel die stamped on each accessory. 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 located in such a manner as to be readily visible when completely assembled together with the chain.

25 Studless Short-link Chain *(2024)*

25.1 General *(2024)*

Studless short-link chain is to meet the requirements specified in 2-2-2/3 and 2-2-2/11. Material is to be in accordance with the manufacturer's specification which is to be the equivalent of normal strength Grade 1 requirements of 2-2-2/25.5 TABLE 1.

25.3 Testing

Breaking and proof testing are to be in accordance with 2-2-2/17 and subjected to the applicable testing loads as given in 2-2-2/27 TABLE 3.

25.5 Marking

One link including the end link in every 4.5 m 1(2.5 fathoms) is to be steel die stamped as prescribed in locations A, B and C by the manufacturer as shown in 2-2-2/13.13 FIGURE 1. In special cases, shots of comparatively 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 1
Chain Materials -Mechanical Properties *(1999)*

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 @ 0°C (32°F), J (kgf-m, ft-lbf)			
base metal *at weld center*	– –	27 (1) (2.8, 20) 27 (1) (2.8, 20)	60 (6, 43) 50 (5, 36)
Bend Test			
mandrel dia. (2) *Angle (degree)*	2T 180	3T 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.

27 Material Hardness for Windlass-Wildcats and Gypsy Wheels *(2024)*

All materials (castings, forgings, rolled bars or rolled plate) used for the construction of torque-transmitting and load-bearing parts of windlasses are to be tested in the presence of, inspected and certified by the Surveyor in accordance with Part 2, Chapter 3 as required per 4-5-1/3.1 of the *Marine Vessel Rules*.

27.1 Wear and Abrasion

For wear and abrasion considerations, the type of material used for windlass-wildcats and gypsy wheels is dependent 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.

27.3 Approximate Hardness Values for Wildcats and Gypsy Wheels

ASTM Type	*Steel Grade*	*Brinell Hardness (approx.)*
I and III	Medium Strength (ASTM A27)	150 HB
II and IV	High Strength (ASTM A148)	300 HB

Selection of the correct 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.

27.5 Cladding and Hardfacing

Weld cladding or hardfacing 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 influences 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 + 25HB
II and IV	300 + 50 HB

TABLE 2
Stud-link Anchor-chain Proof and Break Tests

SI Units

		Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kN*	*kN*	*kN*	*kN*	*kN*	*kN*	*kg*
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
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

		Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kN*	*kN*	*kN*	*kN*	*kN*	*kN*	*kg*
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
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

MKS Units

		Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kg*
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

		Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Diameter	*Length of Five Links*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass kilograms per 27.5 meters*
mm	*mm*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kgf*	*kg*
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
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

US Units

			Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Dia meter	*Length of Five Links*		*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass pounds per 15 fathoms*
in.	*ft*	*In*	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*	*lb*
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

			Normal Strength Grade 1		*High Strength Grade 2*		*Extra-high Strength Grade 3*		
Chain Dia meter	*Length of Five Links*		*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Proof Load*	*Breaking Load*	*Mass pounds per 15 fathoms*
in.	*ft*	*In*	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*	*lb*
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
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:

See also 2-2-2/9.

The weight of chain is not to be more than $2^{1}/_{2}$% under the weight specified.

TABLE 3
Unstudded Short-link Chain

SI Units (MKS Units)

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	125.0	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

US Units

Diameter of Common Links	*Breaking Test*	*Proof Test*
in.	*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

PART 2

CHAPTER 2
Equipment

SECTION 3
Rolled Steel Bars for Chain, Cast and Forged Materials for Accessories and Materials for Studs

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Rolled steel bars, casting and forged are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Process and Qualification of Manufacture *(2024)*

Semi-finished rolled steel bars Grades U1, U2 or U3 for Grade 1, 2 or 3 ship grade chains, cast and forged materials for accessories and materials for studs are to be in accordance with this section.

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

Commentary:

Bars for offshore mooring chains are to be in accordance with the ABS *Guide for the Certification of Offshore Mooring Chain*.

End of Commentary

The manufacturers of rolled bars for ship grade anchor chain and accessories are to be ABS approved. Approval is not required for U1 bars. The bar manufacturers are to submit the manufacturing specifications and the details of the manufacturing procedure include deoxidation practice, fine grain practice, chemical composition, heat treatment process, mechanical properties. The approval tests are to be carried out in accordance with Section 2-A4-2, the scope of which is to be agreed with ABS.

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

Unless otherwise stipulated, the steel bars are to be supplied in the as rolled condition.

1.3 Deoxidation Practice (2024)

Grade U1, U2 and U3 bars are to be fully killed and, in addition, Grade U2 or U3 bars are to be produced to a fine grain practice.

1.5 Chemical Composition and Heat Treatment (2024)

The chemical composition and heat treatment are to be in accordance with the manufacturer's specification that is to be submitted and approved by ABS. In general, they are to conform to 2-2-3/3 TABLE 1.

1.7 Mechanical Properties (1999)

Mechanical tests are to be carried out in accordance with 2-2-3/3 and the results are to meet the requirements in 2-2-2/25.5 TABLE 1.

1.9 Dimensional properties (1999)

Unless otherwise approved, the tolerances on diameter and roundness ($d_{max} - d_{min}$) are to be within the limits listed in 2-2-3/3 TABLE 2, where d_{max} and d_{min} are the maximum and minimum diameter measured at the section under consideration.

3 Material Testing

3.1 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.

3.3 Number of Tests (2024)

One tensile and three Charpy impact test specimens are to be taken from two different bars of steel from each heat unless the material from a heat is less than 50 metric tons (49.21 long tons), in which case, tests from one bar will be sufficient. For material from one heat that differs 9.5 mm (0.375 in.) or more in diameter, one set of tensile and Charpy tests is to be taken from the thinnest and thickest bar.

3.5 Tension Test Specimens (1996)

Tension test specimens for bar material are to be taken at $^{2}/_{3}r$ as shown in 2-2-2/13.13 FIGURE 1 or as close thereto as possible and machined to 2-1-1/16 FIGURE 2 or appropriate national standard specimen.

The required minimum percentage elongation values in 2-2-2/25.5 TABLE 1 are based on specimens having gauge lengths equal to 5 times the diameter. For specimens having other gauge lengths the equivalent elongation value is to be calculated by the following equation:

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

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 five (5) times the specimen diameter.

3.7 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 specified in 2-2-2/25.5 TABLE 1.

3.9 Impact Test Specimens

Impact test specimens are to be in accordance with 2-1-1/11.11. They are to be cut and notched as shown in 2-2-2/13.13 FIGURE 1. The average value of 3 specimens is to comply with the requirements of 2-2-2/25.5 TABLE 1.

3.11 Additional Tests before Rejection *(2024)*

When a specimen fails to meet the requirements of 2-2-2/25.5 TABLE 1 applicable retests in accordance with 2-1-2/9.11, 2-1-2/11.7 and 2-1-2/11.9 may be permitted.

3.13 Manufacturer's Option

At the option 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 2-2-2/13.3.

3.15 Free from Defects *(2024)*

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

3.17 Identification of Material

Manufacturers are to effectively operate an identification system verifying the traceability of the material to the original cast.

3.19 Marking *(2005)*

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

3.21 Material Certification *(2024)*

Bar material for Grade U2 or U3 is to be certified by ABS. For each consignment, manufacturers are to present the mill test report to ABS Surveyor containing at least the following data:

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

3.23 Forged Steels for Chain Cables and Accessories *(2024)*

Forged steels used for the manufacture of chain cables and accessories are to be in compliance with Section 2-1-6 "Hull Steel Forgings", unless otherwise specified in the following paragraphs.

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

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 as shown in 3 TABLE 1.

3.25 Cast Steels for Chain Cables and Accessories *(2024)*

Cast steels used for the manufacture of chain cables and accessories are to be in compliance with Section 2-1-5 "Hull Steel Castings", unless otherwise specified in the following paragraphs.

The chemical composition is to comply with the specification approved by ABS. 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 as shown in 3 TABLE 1.

3.27 Materials for Studs *(2024)*

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

TABLE 1
Rolled Bars for Chain – Chemical Composition and Intended Chain Condition *(2024)*

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 Si Mn P S Al [2] (total) min.	0.20 0.15 - 0.35 0.40 min. 0.040 0.040 -	0.24 0.15 - 0.55 1.00 - 1.60 0.035 0.035 0.020	0.36 0.15 - 0.55 1.00 - 1.90 0.035 0.035 0.020
Bar Stock Marking	AB/U1	AB/U2 [3], [4]	AB/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. See 2-1-3/5.
3. Bars impact tested in accordance with Note 1 to 2-2-2/25.5 TABLE 1 to be marked AB/U2AW.
4. Normalized (U2) bars for Grade 2 chains are to be marked AB/U2N.

TABLE 2
Rolled Bar for Chain – Dimensional Tolerances *(1999)*

Specified Bar Diameter, mm (in.) over	up to	*Tolerance on Diameter, mm (in.)*	*Tolerance on ($d_{max} - d_{min}$) mm (in.)*
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)

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

CONTENTS

PART 2

CHAPTER 3
Materials for Machinery, Boilers, Pressure Vessels, and Piping

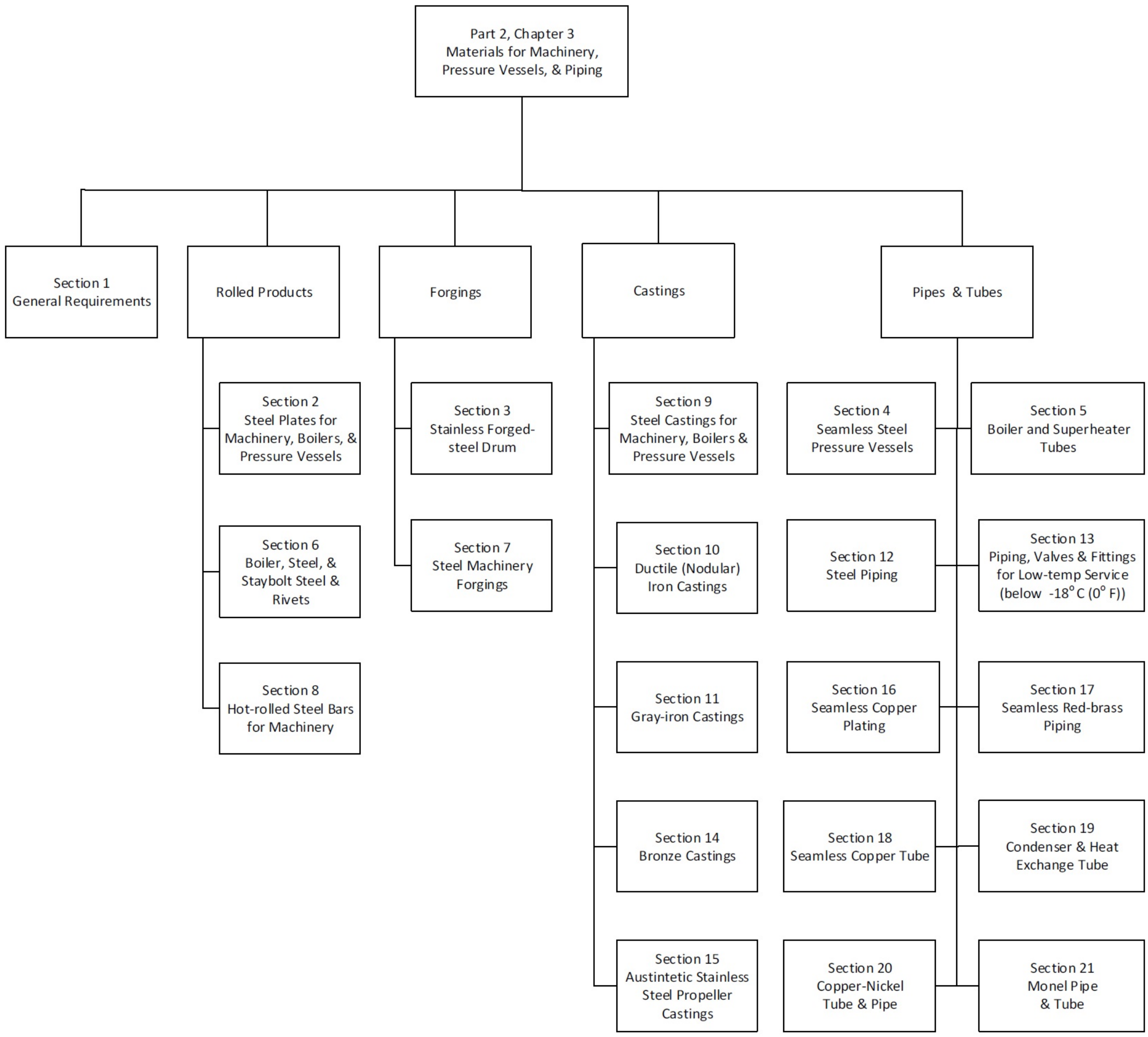
SECTION 1
General Requirements

1 General *(2024)*

1.1 Objective *(2024)*

The goals and functional requirements for the topics covered in this Chapter are included in the respective Sections.

The figure below shows the requirements in Part 2, Chapter 3:



1.1 Testing and Inspection *(2024)*

i) All materials subject to test and inspection, intended for use in boilers, pressure vessels, piping and machinery of vessels classed or proposed for classification, are to be verified by the Surveyor in accordance with the following requirements or their equivalent.

ii) Materials, test specimens, and testing procedures having characteristics differing from those prescribed herein require special approval for each application of such materials and the physical tests may be modified to suit conditions as approved in connection with the design.

1.3 Test and Test Data

1.3.1 Witnessed Tests

The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under ABS's Quality Assurance Program.

1.3.2 Manufacturer's Data

The designation (M) indicated that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

1.3.3 Other Tests

The designation (A) indicates 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 Rule requirements.

See Part 2, Appendix 1 for complete listing of indicated designations for the various tests called out by Part 2, Chapter 3.

1.5 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

1.7 Calibrated Testing Machines *(2005)*

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

1.9 References *(2024)*

For identification of references, see 2-1-1/1.13.

3 Defects

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. Except as indicated for specific materials, welding or dressing for the purpose of remedying defects is not permitted unless and until sanctioned by the Surveyor. In such cases, where sanction is required for materials to be so treated, the Surveyor may prescribe further probing and necessary heat treatment; then, if found satisfactory, the part treated is to be stamped with the Surveyor's identification mark and surrounded by a ring of paint.

5 Identification of Materials

The manufacturer is to adopt a system of marking ingots, slabs, finished plates, shapes, castings and forgings which will enable the material to be traced to its original heat; and the Surveyor is to be given every facility for so tracing material.

7 Manufacturer's Certificates

7.1 Form of Certificate *(2024)*

Refer to 2-1-1/7.

7.2 Electronic Certification System *(2024)*

Refer to 2-1-1/7.2.

7.3 Other Certificates *(2024)*

Refer to 2-1-1/7.3.

9 Marking and Retests

9.1 Identification of Test Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark; but in no case, except as otherwise specified, are they to be detached until the material has received its final treatment. Satisfactory ABS-tested material is to be stamped **AB**, or as specified for a particular material, to indicate compliance with the requirements.

9.3 Defects in Specimens

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that for forgings, a retest is not allowed if a defect develops during testing which is caused by rupture, cracks, or flakes in the steel.

9.5 Retests *(2024)*

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

Elongation, A_5, is determined 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 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, A_0, on that gauge length, L_0, may after agreement be calculated from the following formula:

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

9.7 Rejected Material

In the event that any set of test specimens fails to meet the requirements, the material from which such specimens have been taken are to be rejected and the required markings withheld or obliterated.

11 Standard Test Specimens

11.1 General

Test specimens are to be taken longitudinally and of the full thickness or section of material as rolled, except as otherwise specified.

11.3 Test Specimens *(2024)*

i) Test specimens are to receive no other preparation than that prescribed and are to similarly and simultaneously receive all of the treatment given the material from which they are cut, except as otherwise specified.

ii) Straightening of specimens distorted by shearing is to be carried out while the piece is cold.

iii) The accuracy of the tensile test machines is to be within ±1% of the load.

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

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

vi) Testing machines are to be calibrated in accordance recognized standards at approximately annual intervals.

11.5 Tension Test Specimens for Plates and Shapes

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 1, or they may be prepared with both edges parallel throughout their length. Alternatives to the foregoing are indicated under specific materials.

11.7 Tension Test Specimens for Castings (Other than Gray Cast Iron) and Forgings *(2024)*

Tension test specimens for castings (other than gray cast iron) and forgings are to be machined from the finished material and to the form and dimensions shown for the round specimen alternative C in 2-3-1/11.13 FIGURE 1 or in accordance with 2-3-1/11.13 FIGURE 2.

11.9 Tension Test Specimens for Gray Cast Iron *(2006)*

Tension test specimens for gray cast iron are, unless otherwise approved, to be machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 3 from test bars cast separately from the casting represented. Such test bars are to be poured from ladles of iron used to pour the castings and under the same sand conditions, and they are to receive the same thermal treatment as the castings they represent.

11.11 Transverse or Flexure Test Specimens for Gray Cast Iron *(2006)*

Transverse or flexure test specimens for gray cast iron are, unless otherwise approved, to be a test bar as cast with a 50 mm (2 in.) diameter and 700 mm (27 in.) length. Such test bars are to be cast under the same conditions as described in 2-3-1/11.9.

11.13 Bend Test Specimens for Steel Castings and Forgings *(2005)*

When required, bend test specimens for steel castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. The length is unimportant, provided that it is enough 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.).

FIGURE 1
Standard Tension Test Specimen (1) *(2006)*

d = diameter in mm

a = thickness in mm

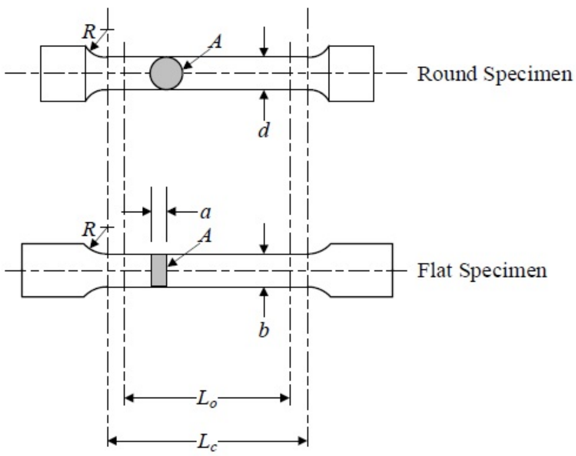
b = width in mm

L_o = original gauge length in mm

L_c = parallel length in mm

A = original cross-sectional area in mm^2

R = transition radius in mm



	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

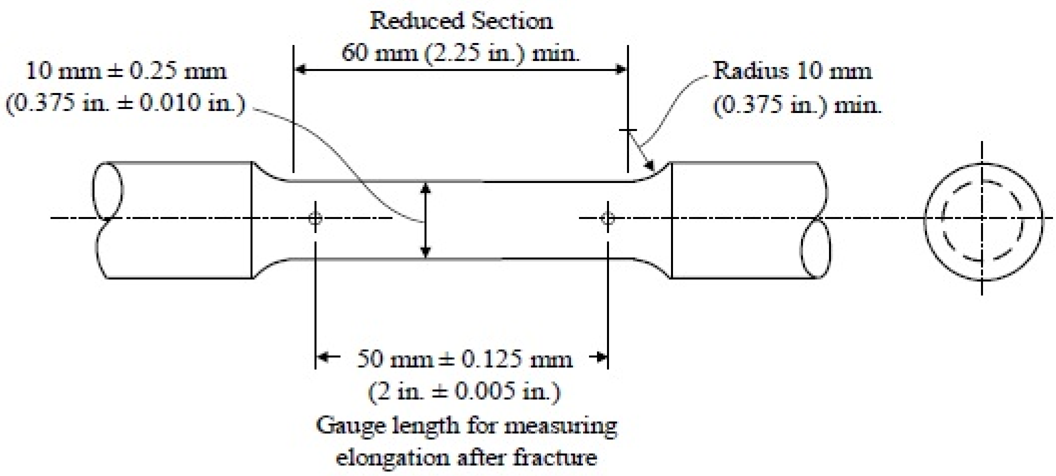
Notes:

1. Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in 2-1-2/15.9 TABLE 2 or 2-1-3/7.3 TABLE 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.

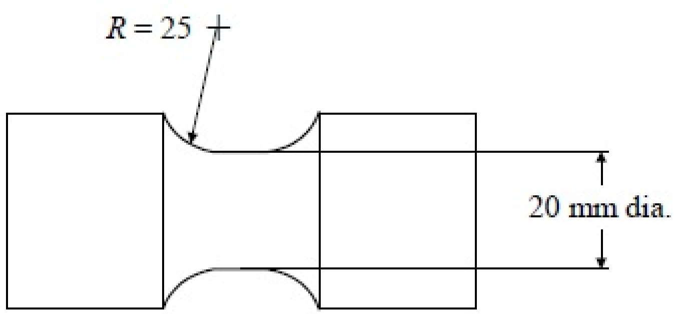
3. L_o, the proportional gauge length, is to be greater than 20 mm.

FIGURE 2
Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length *(2008)*



Note:
(2008) 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 way 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 3
Tension Test Specimen Machined from Transverse or Flexure Test Bars for Gray Cast Iron *(2006)*



13 Definition and Determination of Yield Point and Yield Strength *(2024)*

Refer to 2-1-1/13.

15 Permissible Variations in Dimensions

15.1 Scope

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

The responsibility for meeting the specified tolerances rests with the manufacturer who is to maintain a procedure acceptable to the Surveyor.

15.3 Plates *(1 July 2019)*

The maximum permissible under thickness tolerance for plates and wide flats for construction of machinery, excluding boilers, pressure vessels and independent tanks for liquefied gases and chemicals (see 2-3-2/1.15), is to be in accordance with the following:

These requirements apply to the tolerance on thickness of steel plates and wide flats with widths of 600 mm (24 in.) or greater (hereinafter referred to as products).

Note:

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

Class C of ISO 7452 latest version may be applied in lieu of 2-3-1/15.3.2, in which case the requirements in 2-3-1/15.3.3 and 2-3-1/15.3.4 need not be applied.

Additionally, if ISO 7452 is applied, it is required that the steel mill demonstrate to the satisfaction of ABS 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.

15.3.1 Responsibility

Responsibility for verification and maintenance of production within the required tolerances rests with the manufacturer. The Surveyor may require witnessing of some measurements. Responsibility for storage and maintenance of the delivered plates with acceptable level of surface conditions, before the products are used in fabrication, rests with the shipyard.

15.3.2 Thickness Tolerances *(1 July 2019)*

15.3.2(a)

Thickness tolerances of a given product are defined as:

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

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

Note:

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

15.3.2(b) (1 July 2019)

The minus tolerances are to be in accordance with the following table.

Nominal Thickness, t, mm (in.)	***Tolerance, mm (in.)***
$3 \le t < 5$ ($0.12 \le t < 0.20$)	0.3 (0.012)
$5 \le t < 8$ ($0.20 \le t < 0.32$)	0.4 (0.016)

Nominal Thickness, t, mm (in.)	*Tolerance, mm (in.)*
$8 \leq t < 15$ ($0.32 \leq t < 0.59$)	0.5 (0.02)
$15 \leq t < 25$ ($0.59 \leq t < 0.98$)	0.6 (0.024)
$25 \leq t < 40$ ($0.98 \leq t < 1.57$)	0.7 (0.027)
$40 \leq t < 80$ ($1.57 \leq t < 3.15$)	0.9 (0.035)
$80 \leq t < 150$ ($3.15 \leq t < 5.91$)	1.1 (0.043)
$150 \leq t < 250$ ($5.91 \leq t < 9.84$)	1.2 (0.047)
$t \geq 250$ ($t \geq 9.84$)	1.3 (0.051)

15.3.2(c) (1 July 2019)

Thickness tolerances are not applicable to areas repaired by grinding in accordance with 2-1-1/3.7.1, unless more stringent requirements are specified by the purchaser and agreed by ABS Materials Department.

15.3.2(d) (1 July 2019)

Plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard such as ASTM A20, unless otherwise specified by the purchaser and agreed by ABS Materials Department.

15.3.3 Average Thickness

15.3.3(a) The average thickness of a product is defined as the arithmetic mean of the measurements made in accordance with the requirements of 2-3-1/15.3.4.

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

15.3.4 Thickness Measurements

15.3.4(a) Thickness is to be measured at locations as defined in 11.13 FIGURE 1. Automated or manual measurement methods may be used.

15.3.4(b) The procedure and records of measurements are to be made available to the Surveyor and copies provided on request.

PART 2

CHAPTER 3
Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 2
Steel Plates for Machinery, Boilers and Pressure Vessels

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Manufacturer Approval *(2024)*

All grades of steel plates for Group I boiler and pressure vessels are to be manufactured at steel works approved by ABS for the type and grade of steel contemplated. The suitability of the steel plates for welding and assumed forming is to be demonstrated during the initial approval test at the steel mill. Approval of the steel mill is to be in accordance with Part 2, Appendix 4.

Certification on the basis of ABS Quality Assurance Program for Rolled Products is to be in accordance with 2-1-1/1.5.

1.2.1 Examination at Mills *(2024)*

i) All tests are to be conducted in the presence of the Surveyor at the place of manufacture prior to shipping, unless the plant is approved under ABS's Quality Assurance Program for Rolled Products.

ii) The material surfaces will be examined by the Surveyor when specially requested by the purchaser.

iii) Plates are to be free from defects and have a workmanlike finish.

iv) Certification of boilers and pressure vessels is to be in accordance with 4-4-1/1.9 TABLE 3 of the *Marine Vessel Rules* for vessels.

3 Process of Manufacture *(2024)*

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric furnace, vacuum-arc remelt, electro-slag remelt, or such other process as may be specifically approved. The steel may be cast in ingots or may be strand (continuous) casting. The ratio of reduction of thickness from strand (continuous) cast slab to finished plate is to be a minimum of 3 to 1 unless specifically approved.

3.1 Plates Produced from Coils *(2024)*

For coiled plate, the coil manufacturer and the processor (uncoiling facility) are to be approved by ABS. Data is to be submitted for review and approval to indicate that the manufacturing, processing, and testing will provide material which is in compliance with the Rules.

3.3 Chemical Composition

3.3.1 Ladle Analysis *(2024)*

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported and is to conform to the requirements of the applicable nationally recognized standard or proprietary specification.

3.3.2 Product (Check) Analysis *(2024)*

The chemical composition determined by check analysis is to conform to the requirements of the applicable standard or proprietary specification. The chemical tolerances of ASTM A20 or of other nationally recognized standards may be applied.

3.5 Condition of Supply *(2024)*

Refer to 2-1-2/7.

3.7 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for controlling and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the specified temperature.

Heat treatment is to be in accordance with the requirements of the applicable nationally recognized standard or proprietary specification.

3.7.1 Heat-treatment Instructions on Orders

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

3.7.2 Responsibility for Heat Treatment *(2024)*

i) When a fabricator is equipped and elects to perform the required heat treatment or fabricates by hot forming, 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.

ii) If the heat-treatment temperatures are not indicated on the purchase order, the plate manufacturer is to heat-treat 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.

iii) When the plates are to be heat treated at the plate manufacturer's plant, the mechanical properties are to be determined on specimens simultaneously treated with the plates.

5 Mechanical Properties *(2024)*

5.1 Tensile Properties

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area and are to meet the requirements of the applicable nationally recognized standard or proprietary specification.

5.3 Impact Properties

Charpy V-notch impact tests are to be carried out for materials subjected to low temperature service, which is defined as below -18°C (0°F) for machinery, boiler and pressure vessels.

Minimum Specified Yield Strength, N/mm² (kgf/mm², ksi)	*CVN Value (Longitudinal), J (kgf-mm ft-lbf)*	*CVN Test Temperature*
235-315 (24-32, 34-44)	27 (2.8, 20)	5°C (10°F) below design service temperature
316-420 (32-43, 45.5-61)	34 (3.5, 25)	
421-690 (43-70, 61-100)	42 (4.3, 31)	

5.5 Other Properties

Other properties, such as hardness, elevated or low temperature properties, fatigue properties, corrosion or wear resistance are to be established if required by the design criteria.

7 Test Specimens *(2024)*

7.1 Selection of Specimens *(2024)*

i) Test specimens are to be removed after final heat treatment, when applicable.

ii) One tension test specimen is to be taken from each plate, transverse to the final direction of rolling of the plate.

iii) The tension test specimen is to be taken from a corner of the plate.

iv) 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. The tension test specimen may be taken from either end when the final direction of rolling the plate is transverse to the original longitudinal axis of the ingot axis, or if the relationship of final rolling direction and original ingot axis is unknown.

v) 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 is produced and a second test specimen obtained from the approximate center lap.

vi) When required, impact tests are to be obtained adjacent to both tension test produced to the qualifying grade or specification.

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

For plates 19 mm (0.75 in.) and under in thickness, tension test specimens are to be the full thickness of the material and are to be machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 1 or with both edges parallel.

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

i) For plates over 19 mm (0.75 in.) in thickness, tension test specimens may be machined to the form and dimensions shown in 2-3-1/11.13 FIGURE 2. The axis of each such specimen is to be located as nearly as practicable midway between the center and the surface of the plate.

ii) 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 2-3-1/11.13 FIGURE 1 when adequate testing-machine capacity is available.

7.7 Stress Relieving

When required, test specimens are to be stress-relieved by gradually and uniformly heating 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). If applicable, 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.

7.9 Retests

7.9.1 For All Thicknesses *(2024)*

When any of the physical tests failed to meet the specified requirements, two additional specimens, at the request of the manufacturer, are to be taken from the same plate and tested. Results of both of the additional test specimens are to meet the requirements (see 2-3-1/9.5).

7.9.2 For Heat-treated Material *(2008)*

If any heat-treated material fails to meet the mechanical requirements, the material may be reheat-treated, and all physical tests are to be repeated. Where plates are specially ordered requiring surface inspection, the Surveyor is to reexamine the plate surfaces following any additional heat treatment.

9 Steel Plates for Boilers and Pressure Vessels *(2024)*

Materials are to be manufactured to a recognized national or international standards or proprietary specification suitable for the intended temperature range as agreed with ABS to meet the pertinent design requirements.The table below includes reference to ASTM grades along with the ABS designations that can be considered for these applications.

TABLE 1
ABS Grades for Boliers and Pressure Vessels *(2024)*

ABS Designation	*ASTM Specification*	*Grade*	*Yield Strength, N/mm^2 (kgf/mm^2, ksi)*	*Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*	*Minimum % Elongation 200 mm (8 in.), 50 mm (2 in.)*
1. Intermediate-Temperature Service					
MA	ASTM A285	A	165 (17, 24)	310-450 (31.5-46, 45-65)	27, 30
MB	ASTM A285	B	185 (19, 27)	345-485 (35-49, 50-70)	25, 28
MC	ASTM A285	C	205 (21, 30)	380-515 (39-53, 55-75)	23, 27
2. Intermediate-Temperature or Higher-Temperature Service					
MD	ASTM A515	55	205 (21, 30)	380-515 (39-53, 55-75)	23, 27
ME	ASTM A515	60	220 (22.5, 32)	415-550 (42-56, 60-80)	21, 25
MF	ASTM A515	65	240 (24.5, 35)	450-585 (46-60, 65-85)	19, 23

ABS Designation	*ASTM Specification*	*Grade*	*Yield Strength, N/mm² (kgf/mm², ksi)*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)*	*Minimum % Elongation 200 mm (8 in.), 50 mm (2 in.)*
MG	ASTM A515	70	260 (27, 38)	485-620 (49-63, 70-90)	17, 19
H	ASTM A204	A	255 (26, 37)	450-585 (46-60, 65-85)	19, 23
I	ASTM A204	B	275 (28, 40)	485-620 (49-63, 70-90)	17, 19
J	ASTM A204	C	295 (30.5, 43)	515-655 (53-67, 75-95)	16, 20
3. Intermediate-Temperature or Lower-Temperature Service					
K	ASTM A516	55	205 (21, 30)	380-515 (39-53, 55-75)	23, 27
L	ASTM A516	60	220 (22.5, 32)	415-550 (42-56, 60-80)	21, 25
M	ASTM A516	65	240 (24.5, 35)	450-585 (46-60, 65-85)	19, 23
N	ASTM A516	70	260 (27, 38)	485-620 (49-63, 70-90)	17, 19
4. Low Temperature Service [Below -18°C (0°F)]					

Notes:

1 Refer to 2-1-4/11 TABLE 1

2 Materials for Liquefied Gas Carriers are to comply with the applicable requirements of Section 5C-8-6 of the *Marine Vessel Rules*.

3 Materials for vessels using Gases or other Low-Flashpoint Fuels are to comply with the applicable requirements of Section 5C-13-7 of the *Marine Vessel Rules.*

4 Other special low temperature materials can be considered when the meet 5.3.

5 Austenitic Stainless Steel (304, 304L, 316, 316L, 321 and 347) in accordance with the ABS *Guide for Materials and Welding for Stainless Steels*.

11 Marking

11.1 Plates and Test Specimens *(2024)*

Each finished plate is to be legibly stamped on one place, not less than 300 mm (12 in.) from the edges, with the following information:

i) Name or brand of the manufacturer

ii) Grade of steel

iii) Manufacturer's identification numbers

iv) The letters "**PV**" to indicate pressure-vessel quality

Plates with maximum dimensions of length and width of not more than 1800 mm (72 in.), are to have the marking stamped in one place approximately midway between the center and an edge.

Note:

Thin plates may be stamped in accordance with 11.7.

Each test specimen is to be legibly stamped with the manufacturer's test identification number. All test specimens are to be ring-stamped, match-marked or otherwise suitably identified to the satisfaction of the attending Surveyor before being detached.

11.3 Heat-treatment Marking *(2024)*

The steel plates are to be supplied by the mill in the final heat treatment condition. When the heat treatment is to be carried out by the fabricator, the letter **G** is to also be stamped on each plate by the steel producer to indicate that the material is in the unheat-treated, (green condition). After heat treatment at the fabricator's plant, the letter **T** is to be stamped following the letter **G**.

11.5 ABS Markings *(2024)*

ABS markings, **AB**, are to be stamped on all plates near the manufacturer's markings, as specified in 2-3-2/1.3.1, to indicate compliance with the Rule requirements as furnished by the Surveyor. The certificates for the material are to be furnished to the Surveyor in accordance with 2-3-1/7.

For coiled steel which is certified for chemical analysis only, the marking **AB** without grade designation is to be marked on the outer wrap of each coil shipped.

11.7 Thin Plates

Plates under 6.4 mm (0.25 in.) in thickness are to be legibly stenciled with the markings specified in 2-3-2/1.3.1 and 2-3-2/1.3.2 instead of stamped.

11.9 Special Impact Testing *(2024)*

When steel is impact tested in accordance with 9 the grade marking is to be followed by the test temperature in degrees Celsius. A prefix capital letter "O" to the test temperature is to be used to indicate a temperature colder than zero degrees Celsius.

13 Thickness Variation *(2024)*

No plate is to vary more than 0.25 mm (0.01 in.) or 6% under the thickness specified, whichever is the lesser (See 4-4-1-A1/1.7 of the *Marine Vessel Rules*). Alternative requirements may be agreed with the designer and accepted by ABS Materials Department.

15 Inspection and Rectification *(2024)*

15.1 General *(2024)*

The steels are to have a workmanlike finish and are to be free from cracks, injurious surface flaws, injurious laminations and similar defects harmful to the use of the material for the intended application.

15.3 Manufacturer Responsibility *(2024)*

i) The responsibility for meeting the surface quality and internal soundness requirements rests with the manufacturer of the material, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery.

ii) The inspection methods and acceptance criteria are to be in accordance with the applicable design codes or recognized national or international standard agreed between purchaser and manufacturer, accepted by ABS.

15.5 Rectification *(2024)*

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

17 Forming *(2024)*

Forming is to be in accordance with the requirements of the applicable design codes such as ASME or EN 13445 or another nationally recognized standard. Also refer to 2-4-1/3.13.

19 Weldability *(2024)*

All of the grades referenced in 9 TABLE 1 are intended for fusion welding, but welding technique is of fundamental importance and welding procedures are to be in accordance with approved methods. See Part 2, Chapter 4.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 3

Seamless Forged-steel Drums

1 General *(2024)*

1.1 Objective

The objective of this section is to identify the procedures to be taken to verify compliance with the Goals, Functional Requirements, and prescriptive requirements outlined in the cross referenced sections.

1.2 Scope

This section covers requirements for seamless forged-steel drums intended for boilers or pressure vessels.

Requirements for ABS grade seamless forged-steel drums are in 5. Alternatively, forgings which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

1.3 Manufacture and Testing

i) Selection of seamless forged-steel drums for boiler and pressure vessel application is to be specifically approved for each application.

ii) Manufacture and certification of seamless forged-steel drums is to be in accordance with Section 2-3-7.

iii) One tension test is to be taken from each end of the forging midway between the inner and outer surfaces of the wall in a tangential direction. Both the specimens are to be taken from opposite sides of the drum and the material properties are to meet the requirements of a designated standard or proprietary specification.

3 Heat Treatment *(2024)*

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

5 ABS Grade Seamless Forged-Steel Drums for Boilers and Pressure Vessels *(2024)*

ABS grade seamless forged-steel drums for boilers and pressure vessels may be manufactured in accordance with the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 1
ABS Grade Seamless Forged-Steel Drums for Boilers and Pressure Vessels

ABS Designation	*ASTM Specification*	*Grade*	*Yield Strength, N/mm^2 (kgf/mm^2, ksi)*	*Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*	*Minimum % Elongation 50 mm (2 in.), 62.5 mm (2.5 in.)*
Grade A	ASTM A266	1	205 (21, 30)	415-585 (42-60, 60-85)	23, 21
Grade B	ASTM A266	3	260 (26.5, 37.5)	515-690 (53-70, 75-100)	19, 17

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 4

Seamless-steel Pressure Vessels

1 General

1.1 Objective *(2024)*

The objective of this section is to identify the procedures to be taken to verify compliance with the Goals, Functional Requirements, and prescriptive requirements outlined in the cross referenced sections.

1.2 Manufacture *(2024)*

Manufacture of seamless-steel pressure vessels may be in accordance with Section 2-3-12.

3 Tension Test *(2024)*

i) Test specimens are to be cut from each cylinder before the necking-down process, stamped with the identification mark of the Surveyor and are to be heat treated in the same furnace with the cylinders.

ii) A standard test specimen cut either longitudinally or circumferentially from each cylinder is to show the material properties comply with the applicable steel grade and specifications as per approved design. The table below includes tensile properties that may be proposed for seamless pressure vessels.

TABLE 1
Tensile Properties for Seamless Pressure Vessels *(2024)*

Maximum Yield Strength, N/mm^2 (kgf/mm^2, ksi)	*Minimum Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*	*Minimum % Elongation 50 mm (2 in.)*
290 (30, 42)	415 (42, 60)	10

5 Flattening Test

A ring 200 mm (8 in.) long is to be cut from each cylinder and is to stand being flattened without signs of fracture until the outside distance over the parallel sides is not greater than six times the thickness of the material.

7 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 submerged 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 prescribed test pressure. This test is to be made without previously subjecting the cylinder to any pressure in excess of one-third of the working pressure.

9 Inspection *(2024)*

All cylinders are to be heat treated as required by material grade. Materials are to be free from seams, cracks or other defects 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 ascertain that the thickness of the material is in accordance with the approved plan.

11 Marking

Upon satisfactory compliance with the above requirements, the cylinders will be stamped **AB** with the identification mark of the Surveyor, the serial number, hydrostatic pressure and the date of acceptance.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 5

Boiler and Superheater Tubes

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of seamless and electric resistance welded tubes made of either ferritic or austenitic steels intended for boiler, boiler flues, superheater, and heat exchanger tubes for machinery, boiler, pressure vessel and piping system.

Requirements for ABS grade boiler and superheater tubes are in 41. Alternatively, tubes which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

i) The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric furnace, electroslag remelt, vacuum-are remelt or such other process as may be specifically approved.

ii) The steel is to be killed, and either be cast in ingots or may be strand (continuous) casting.

iii) Tubes produced by seamless process can be either hot finished or cold drawn. Cold-drawn tubes are to be furnished in the heat-treated condition to the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

iv) Tubes produced by electric-resistance welding are to be normalized at a temperature above the upper critical temperature.

7 Marking *(1998)*

7.1 *(2024)*

For tubes less than 31.8 mm (1.25 in.) in diameter and tubes under 1 m (3 ft) in length, the required information can be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

7.3 *(2024)*

For tube 31.8 mm (1.25 in.) in diameter and over and tubes length of 1 m (3 ft) and over, each tube is to be legibly stenciled.

7.5 *(2024)*

The stenciled marking or tagging is to contain the following information, when applicable.

i) The name or brand of the manufacturer

ii) The ABS grade or ASTM designated grade or another grade per the recognized standard or proprietary specification

iii) Dimensions of the tube (outside diameter and wall thickness)

iv) Delivered condition either hot finished or cold finished

v) The letter "**ERW**" is to be legibly stenciled on each tube or tag attached to the bundle or box for electric resistance welded tubes

vi) The letter "**RW**" is to be legibly marked for tube repair by welding

vii) For austenitic stainless steel with grain size requirement, the marking is to be include the heat number and heat treatment lot identification

viii) For austenitic stainless steel ordered with high sulfur contents as permitted by specific standard, the marking is to be include letter "**S**", following the grade designation.

7.6 *(2024)*

Bar coding is acceptable as supplementary identification method. The purchaser may specify in the order a specific bar-coding system is to be used.

7.7

ABS markings as furnished by ABS Surveyor and that indicate satisfactory compliance with the Rule requirements.

9 Chemical Composition *(2024)*

9.1 Ladle Analysis *(2024)*

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported and is to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

9.3 Product (Check) Analysis *(2024)*

The product (check) analysis is be performed in accordance with ASTM A751 or other recognized national standards as agreed with ABS. The chemical composition determined by check analysis is to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

11 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

13 Mechanical Tests Required

13.1 Test and Results *(2024)*

Mechanical tests and results are to be in accordance with requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification. For a description and requirements of each test see 17 through and including 33. For retests see 35.

13.3 Other Tests *(2024)*

Other tests, such as, air pressure test, grain size, corrosion test, may be performed when required by the purchaser.

15 Test Specimens

15.1 Selection of Specimens *(2024)*

Test specimens for flattening, flanging, flaring, tension, crushing and reverse flattening tests are to be taken from each end of drawn tubes after any heat treatment and straightening, but prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They are to be smooth on the ends and free from burrs and defects.

15.3 Tension Test Specimens *(2024)*

Tension tests may be made on full sections of the tubes up to the capacity of the testing machine. For larger-size tubes, the tension test specimen is to consist 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, irrespective of the thickness, is to be 25 mm (1 in.); the gauge length is to be 50 mm (2 in.).

i) One tension test is to be taken from one tube for lots of not more than 50 tubes.

ii) Two tension tests are to be taken from two tubes for lots more than 50 tubes.

15.5 Flattening Test Specimen *(2024)*

One test specimen is to be taken from each end of two tubes selected from each lot.

15.7 Reverse Flattening Test Specimen *(2024)*

One test specimen is to be taken from each 450 m of finished tubing.

15.9 Flaring Test Specimen *(2024)*

One test specimen is to be taken from each end of two tubes selected from each lot.

These tubes are to be selected apart from those used for the flattening test.

15.11 Flange Test Specimen *(2024)*

One test specimen is to be taken from each end of two tubes selected from each lot.

15.13 Hardness Test Specimen *(2024)*

Hardness test is to be performed on specimens from two tubes from each lot.

15.15 Hydrostatic Test Specimen *(2024)*

Each tube is to be subjected to either hydrostatic or the nondestructive electric test, as agreed with the purchaser.

15.17 Testing Temperature

All tests are to be carried out at room temperature.

15.19 Alternative Test Specimens *(2024)*

Alternatives to requirements in 15.1 to 15.15 may be agreed in accordance with a recognized national standard or proprietary specification.

17 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 41 or a recognized national standard or proprietary specification.

19 Flattening Test *(2024)*

When required, flattening test is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

21 Reverse Flattening Test *(2024)*

When required, flattening test is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

23 Flange Test *(2024)*

When required, flange test is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

25 Flaring Test *(2024)*

When required, flaring test is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

27 Crush Test *(2024)*

When required, crush test is to be performed in accordance with ASTM A178 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

29 Hardness Tests *(2024)*

When required, hardness test is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

31 Hydrostatic Test *(2024)*

When applicable, hydrostatic test is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

33 Nondestructive Examination *(2024)*

For all grades of tubes, if the results of the mechanical tests do not conform to the requirements, retests may be made 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 conform to the test requirements, the individual tubes, groups or lots of tubes represented, may be re-heat-treated and resubmitted for retest, as indicated. Only two reheat treatments will be permitted.

33.1 General *(2024)*

When applicable, nondestructive examination is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS. The results are to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

33.3 Affidavits

When each tube is subjected to an approved nondestructive electrical test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

35 Retests

35.1 *(2024)*

When any of the mechanical tests do not meet the specified requirements, retests may be made on additional tubes from the same lot, re-test quantity to be double the original number of tests specified, each of which is to conform to the specified requirements.

35.3 *(2024)*

If heat-treated tubes do not meet the specified test requirements, the individual tubes, groups or lots of tubes represented, may be re-heat-treated and resubmitted for retest at the option of the tube manufacturer. Not more than two reheat treatments are permitted.

37 Finish *(2024)*

Tubes are to be examined by the Surveyor prior to fabrication or installation in accordance with the applicable requirements as noted below,

i) Reasonably straight and have smooth ends free from burrs.

ii) They are to be free from defects and are to have a workmanlike finish.

iii) Surface imperfections may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by product specification.

iv) Ferritic alloy cold finishing steel tubes are to be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

v) Ferritic alloy hot-finished steel tubes are to be free of loose scale and suitable for inspection.

vi) Austenitic stainless-steel tubes are to be pickled free of scale. When bright annealing is used, pickling is not necessary

vii) Any special finish requirements are to be subject to agreement between the supplier and the purchaser.

viii) Welding repair to any tube is not to be carried out without the purchaser's approval and is to be to the Surveyor's satisfaction.

39 Permissible Variations in Dimensions *(2024)*

The following dimensions of finished tubes is to be performed in accordance with ASTM A450 or other recognized national standards as agreed with ABS,

i) Wall Thickness

ii) Outside Diameter

iii) Length

iv) Height of Flash on Electric-Resistance-Welded Tubes

41 ABS Grade Boiler and Superheater Tubes *(2024)*

ABS grade tubes may be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 1
ABS Grades for Boiler and Superheater Tubes

ABS Grade Notation	*Specification*	*Grade*	*Yield Strength, N/mm², (kgf/mm², ksi*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi*	*Minimum % Elongation 50 mm (2 in.)*
1. Electric-Resistance-Welded Carbon Steel and Carbon Manganese Steel Boiler and Superheater Tubes					
D[1, 2]	ASTM A178	A	180 (18.5, 26)	325 (33, 47)	35
F	ASTM A178	C	255 (26, 37)	415 (42, 60)	30
2. Seamless Carbon Steel Boiler Tubes for High Pressure Service					
H[2,3]	ASTM A192	-	180 (18.5, 26)	325 (33, 47)	35
3. Seamless Medium Carbon Steel Boiler and Superheater Tubes					
J	ASTM A210	A-1	255 (26, 37)	415 (42, 60)	22
4. Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes					
K	ASTM A209	T1	205 (21, 30)	380 (39, 55)	30
L	ASTM A209	T1a	220 (22.5, 32)	415 (42, 60)	30
M	ASTM A209	T1b	195 (19.5, 28)	365 (37.5, 53)	30
5. Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat-Exchanger Tubes					
N[1]	ASTM A213	T11	205 (21, 30)	415 (42, 60)	30
O	ASTM A213	T12	205 (21, 30)	415 (42, 60)	30
P[1]	ASTM A213	T22	205 (21, 30)	415 (42, 60)	30
R	ASTM A213	TP321	205 (21, 30)	515 (52, 75)	35
S	ASTM A213	TP347	205 (21, 30)	515 (52, 75)	35

Notes:

1 Tensile properties for this grade are not provided in the referenced ASTM standard. The values are provided by ABS for design purposes only. Alternative tensile properties may be agreed subject to ABS technical assessment and approval.

2 Tensile tests are not required for certification.

3 Tensile properties for this grade are provided for design purposes only.

43 Forming *(2024)*

43.1

Tubes when inserted in the boiler, tubes are to withstand expanding and bending without showing cracks or flaws or opening at the weld.

43.3

Tubes when properly manipulated are to withstand all forging, welding, and bending operations necessary for application without developing defects.

Commentary:

Certain ferritic steels will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly chromium-containing steels with chromium of 4% and higher. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

End of Commentary

45 Welding and Brazing *(2024)*

All grades proposed for boiler and superheater tubes are to be suitable for welding or brazing. Welding or brazing procedures are to be in accordance with Part 2, Chapter 4.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 6

Boiler Rivet and Staybolt Steel and Rivets *(2024)*

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Scope *(2024)*

This section covers requirements for manufacture, testing and certification of boiler rivets and staybolt steel and rivets.

Requirements for ABS grade boiler rivets and staybolt steel and rivets are in 15. Alternative grades which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

3 Process of Manufacture *(2024)*

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric-furnace. Rivets are to be manufactured from the applicable bar grade. All bars and rivets will be tested and examined at the mills by the ABS Surveyor when specially requested by the purchaser. They are to be free from defects and have a workmanlike finish.

3.1 Chemical Composition *(2024)*

3.1.1 Ladle Analysis

A ladle analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported and is to conform to the requirements of the applicable ABS grade in 15 or recognized national standard or proprietary specification.

3.1.2 Product (Check) Analysis

The product (check) analysis is to be performed in accordance with ASTM A751 or of other recognized national standards may be applied. The chemical composition determined by check analysis is to meet requirements of the applicable ABS grade in 15 or recognized national standard or proprietary specification.

5 Tensile Properties *(2024)*

Tension test on bars is to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 15 or a recognized national standard or proprietary specification.

7 Bending Properties *(2024)*

Bending test on bars and rivets are to be performed to determine the ductility and soundness of the materials and is to meet the requirements of the applicable ABS grade in 15 or a recognized national standard or propriety specification.

9 Test Specimens for Bars *(2024)*

i) Bend and tension test specimens are to be the full diameter of the bars as rolled.

ii) In the case of rivet bars which have been cold drawn, the test specimens are to be normalized before testing.

iii) Two tension tests are to be performed from each heat.

iv) Two bend tests are to be performed from each heat.

11 Retests *(2024)*

When the test result of any of the mechanical tests on the bars or the finished rivets do not meet specified requirements of the applicable ABS grade in 15 or a recognized national standard or proprietary specification, 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 are to conform to the requirements.

In the case of tension tests, retest is to be allowed when the percent of elongation obtained is less than required.

13 Tests of Finished Rivets

13.1 Bending Properties *(2024)*

Three bend tests are to be performed from each size in each lot of rivets in accordance with requirements of the applicable ABS grade in 15 or a recognized national standard or proprietary specification.

13.3 Flattening Tests *(2024)*

Three flattening tests are to be performed from each size in each lot of rivets in accordance with requirements of the applicable ABS grade in 15 or a recognized national standard or proprietary specification.

15 ABS Grade Boiler Rivet and Staybolt Steel and Rivets *(2024)*

ABS grade boiler rivet and staybolt steel and rivets may be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 1
ABS Grades for Boiler Rivet and Staybolt Steel and Rivets

ABS Designation	*ASTM Specification*	*Grade*	*Yield Strength, N/mm^2 (kgf/mm^2, ksi)*	*Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*	*Minimum % Elongation 50 mm (2 in.)*
RA	ASTM A31	A	160 (160, 23)	310-380 (31.5-39, 45-55)	27
RB	ASTM A31	B	200 (20, 29)	400-470 (41-48, 58-68)	22

17 Inspection *(2024)*

The steels are to have a workmanlike finish and are to be free from cracks, injurious surface flaws and similar defects harmful to the use of the material for the intended application.

19 Marking

19.1 *(2024)*

When the bars and/or rivets are loaded for shipment, they are to be properly separated in bundles or containers marked with the manufacturer name or brand, the grade, and the heat number.

19.3

ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be marked on the material or on each bundle or container near the marking specified in 2-3-6/19.1

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 7

Steel Machinery Forgings *(2024)*

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope *(2024)*

This section covers requirements for steel forgings intended to be used in machinery construction, as noted below,

i) Shaft and stock forgings intended to be used principally for propulsion units and stock type applications. Typical components include tail shafts, intermediate shafts, thrust shafts, other torsional shafts, bolts, sleeves, couplings, propeller nuts, rudder stocks and canard stocks used in shipboard units.

ii) Gear and pinion forgings intended to be used principally for propulsion units, auxiliary turbines and jacking gear systems. Typical components include forging rims and blanks for steel gears and pinions, used in shipboard gear assemblies.

iii) Forgings intended to be used for general shipboard applications.

Requirements for ABS grade steel forgings are provided in 2-3-7/3. Alternatively, forgings which comply with recognized national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

1.3 Process of Manufacture

1.3.1 Manufacture Approval *(2024)*

Forgings are to be made by a manufacturer approved by ABS. Approval covers manufacture of ABS Grades or alternative grades manufactured in accordance with recognized national standards or proprietary specifications.

ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of forging production, that may influence the final product properties,

i) Closed die preparation and die maintenance

ii) Source of raw material

iii) Forging temperatures

iv) Forging reduction or upset (2-3-7/1.3.2)

v) Heat treatment and heat treatment recording (2-3-7/1.5)

vi) Coupon preparation (2-3-7/1.9)

vii) Testing and inspection (2-3-7/1.7, 2-3-7/1.9, 2-3-7/1.11, 2-3-7/1.13)

viii) Rectification of defective forgings (2-3-7/1.15)

Any of the above can be included in a Survey patrol.

Raw materials for forging such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS. Steel is to be fully killed and is to be manufactured by a process approved by ABS.

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 by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval.

1.3.2 Degree of Reduction *(2024)*

The plastic deformation is to be such as to achieve the specified internal quality requirements and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast or semi-finished 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:

Products		*Total Forging Ratio (Cross-section)*	
		Where $L > D$	*Where $L \leq D$*
Forgings made from ingots, forged blooms, billets		Min. 3:1	Min. 1.5:1
Rolled products (rolled rings)		Min. 4:1	Min. 2:1
Rolled bars (in lieu of forgings)		Min. 6:1	
Forgings made by upsetting	Starting stock is to have minimum forging reduction of 1.5:1	Minimum upsetting is to be 1.5 (L/L_u)	
	As cast starting material	Minimum upsetting is to be 3 (L/L_u)	

Note:
L – Length (Height) before forging
D – Diameter before forging
L_u – Length (Height) after upsetting

Commentary:

Refer to ASTM A788 to calculate reduction ratio.

End of Commentary

1.3.3 Discard

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

1.3.4 Chemical Composition *(2024)*

All forgings are to be made from killed steel. The chemical composition is to be reported. The chemical composition of each heat is to be determined by the steel maker 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. Refer to 2-3-7/1.3.4(a) and 2-3-7/1.3.4(b) for ladle analysis and product (check) analysis.

Forgings that are intended to be welded or cladded, including rudder stocks and pintles are to be of weldable quality. To maintain weldability, carbon content is not to exceed 0.23% or carbon equivalent (Ceq) is not to exceed 0.41%, unless specially approved.

Weldability of steels with carbon content greater than 0.35% is reduced. Specially approved grades having more than the maximum specified carbon of 0.55% are to have **S** marked after the grade designation.

Commentary:

Weldability of a forging can be established through weld procedure qualification tests in accordance with Part 2 Chapter 4.

End of Commentary

1.3.4(a) Ladle Analysis *(2024)*

A ladle analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. 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 is to apply.

The chemical composition is to be reported and is to conform to the requirements of the applicable ABS grade in 2-3-7/3 or recognized national standard or proprietary specification.

1.3.4(b) Product (Check) Analysis *(2024)*

When required by the specification, the product (check) analysis is to be performed in accordance with ASTM A751 or alternatively other nationally recognized standards may be applied. The chemical composition determined by check analysis is to meet requirements of the applicable ABS grade in 2-3-7/3 or recognized national standard or proprietary specification.

1.3.5 Additional Requirements *(2024)*

i) For crankshafts, where grain flow is required in the most favorable direction with regard to the mode of stressing in service, the proposed method of manufacture may require special approval. In such cases, tests may be required to demonstrate that satisfactory microstructure and grain flow are obtained.

ii) For components used in the direct load path of a jacking system, refer to Section 6-1-9 of the *MOU Rules* for additional qualification requirements.

1.5 Heat Treatment

1.5.1 General *(2024)*

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approved by ABS.

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

An heat treatment facility (independent or sub-contracted) can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

The ABS 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 forgings are to be heat treated using one of the following procedures in a furnace of suitable proportions to bring the forgings to a uniform temperature:

i) Annealed

ii) Normalized

iii) Normalized and tempered

iv) Quenched and tempered

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

Heat treatment is to be carried out in furnaces, which are maintained with 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 subject to ABS technical assessment and approval. If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated following the hot working. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, the manufacturer is to determine if a subsequent stress relieving heat treatment is necessary. 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.

Commentary:

If a forging is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses. The stress relief temperature should be established in conjunction with the final heat treatment temperature and must not negatively affect the physical properties of the forging.

End of Commentary

1.5.2 Retreatment

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

1.5.3 Surface Hardening *(2017)*

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 to a condition suitable for subsequent machining and carburizing.

1.7 Mechanical Properties *(2024)*

1.7.1 Tensile Properties *(2024)*

Tensile properties of the forging are to meet the requirements of the applicable ABS grade in 2-3-7/3 or other recognized national standard or proprietary specification.

1.7.2 Impact Properties *(2024)*

Charpy V-notch impact tests are to be carried out as noted below,

Minimum Specified Yield Strength, N/mm^2 (kgf/mm^2, ksi)	*Minimum Average Absorbed Energy (Longitudinal), J (kgf-mm, ft-lbf)*	*CVN Test Temperature*[1,2]
205-690 (21-70, 30-100)	27 (2.8, 15)	At 20°C or at design service temperature, whichever is lower

Notes:

1 Refer to 6-1-9/9 of the *MOU Rules* for CVN test temperature of jacking systems.

2 Refer to Section 5C-8-6 or Section 5C-13-7 or Part 6 Chapter 1 or Part 6 Chapter 2 of the *Marine Vessel Rules*, when applicable.

1.7.3 Thermal Stability Test *(2024)*

If thermal stability test is required for alloy steel shaft and stock forgings in 2-3-7/3.3 TABLE 5 Item 2, refer to ASTM A472.

1.7.4 Hardness Test *(2024)*

Hardness tests are to be performed in accordance with 2-3-7/1.11 to meet requirements of the applicable ABS grade in 2-3-7/3 or other recognized national standard or proprietary specification.

1.9 Test Specimens

1.9.1 Location and Orientation of Specimens *(2024)*

i) Mechanical properties are to be determined from test specimens taken from prolongations which represent the ruling section area of the forging. Ruling section is defined as the diameter of the largest theoretical sphere which can be inscribed within the critical section of the forging. Also refer to ASTM A688 for more information about ruling section.

ii) Refer to 2-3-7/1.9.6 TABLE 1 for test specimen location, orientation and frequency for steel machinery forgings.

iii) Test results from other locations may be specially approved, provided appropriate supporting information is presented, which indicates that the specified location is in conformity with the specified tensile properties.

1.9.2 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.

1.9.3 Forgings Weighing Less Than 113 kg *(2024)*

In the cases of forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, a special representative 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 representative forgings should be subjected to the same or less amount of working and reduction as the forgings represented and should be heat-treated with those forgings.

1.9.4 Identification of Specimens *(2015)*

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 until 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 found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

1.9.5 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 2-3-1/9 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 2-3-7/1.5.3. After reheat-treating, the forgings are to be submitted for all mechanical testing.

1.9.6 Rejection *(2024)*

Any forging having injurious discontinuities that are observed prior to, or subsequent to, ABS acceptance at the manufacturer's plant may be rejected.

TABLE 1
Test Specimen Orientation, Location and Frequency for Steel Machinery Forgings *(2024)*

Application	*Orientation and Location*	*Number of Specimens*
Shaft and Stock forgings	1. Longitudinal specimens removed from mid-radius for solid forgings or mid-depth for hollow forgings	i. two tests for a large forging, see Note 1
	2. Transverse specimens removed from close to the surface for solid or hollow forgings as practicable	ii. one test per intermediate-sized forging, see Note 2
		iii. one test per lot for small forgings, see Note 3

Application	*Orientation and Location*	*Number of Specimens*
Forgings for propulsion units, auxiliary turbines, jacking gear systems	3. Longitudinal specimens removed 32 mm below the surface of the forging	iv. two tests for a large forging, see Note 1
	4. Tangential specimens removed from close to the surface of the forging as practicable	v. one test per intermediate-sized forging, see Note 2
		vi. one test per lot for small forgings, see Note 3
Reduction Gear Ring Forgings	5. Test specimens are to be in a tangential orientation at mid-wall of the ring as close as practical to the end of the surface of the forging. Refer to 2-3-7/1.9.6 FIGURE 1.	vii. two tests per forging, see Note 4
Reduction Gear Pinion and Gear Forgings	6. Longitudinal or tangential orientation from a location as close as practical to the mid-radius location of the main body (toothed portion) of solid forgings or the mid-wall of bored forgings. Refer to 2-3-7/1.9.6 FIGURE 2.	viii. one test per forging, see Note 5
Reduction Gear Shaft Forgings	7. Longitudinal specimens removed from mid-radius location of a full size prolongation refer to 2-3-7/1.9.6 FIGURE 3.	ix. one test per forging
Sleeves, Couplings and Nut Forgings	8. Longitudinal specimens removed from mid-radius location of a full size prolongation.	x. one test per forging for Alloy Steels, see Note 6
		xi. For Carbon steels, tests in accordance with Note 1, 2 or 3 as applicable.
Surface hardened forgings	See Note 7	See Note 7

Application	*Orientation and Location*	*Number of Specimens*
Continuous Heat Treatment	See Note 8	See Note 8

1) Large Forgings: In the case of large forgings with weight at time of heat treatment of 3180 kg (7000 lb) or over, one tension test specimen is to be taken from each end of the forging. In the case of ring and hollow cylindrical forgings, the two tensile test specimens may be taken 180 degrees apart from the same end of the forging.

2) Intermediate-Sized Forgings: In the case of forgings with weight at time of heat treatment is less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test specimen is to be taken from each forging.

3) Small Forgings: In the case of small normalized forgings with weight at the time of heat treatment less than 1000 kg (2200 lb), and quenched and tempered forgings with weight at the time of heat treatment 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 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.

4) Test specimens 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.

5) Extending the axial length of the main body (toothed portion) of the forging for a sufficient distance would be an acceptable location for tension specimen removal.

6) In the case of alloy steel ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the test specimen is to be taken from a full-size prolongation left on one end of each individual forging.

7) When forgings are to be surface hardened, sufficient test material is to be provided for two sets of tests, (1) preliminary core tests at the forge and; (2) final core tests after completion of surface hardening.

Two sets of test material are to be taken from one position, irrespective of the dimensions or mass of the forgings. The test positions are detailed in 2-3-7/1.9. In the case of forgings with integral journals, tests 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 core tests at the forge, one set of test material is to be subjected to a heat treatment simulating the surface hardening heat treatment cycle that will be subsequently applied to the forging. Surface hardening (carburizing, nitriding, etc) the test sample is not necessary. The intent of the preliminary tests is to establish that the chemistry is suitable for surface hardening and the mechanical properties will meet specified requirements for a given component.

For final core tests , the second set of test material is to be heat treated along with the forgings which they represent during surface hardening. The intent of this final core test is to verify the mechanical properties after exposure to the actual surface hardening heat treatment cycle, so the test material need not necessarily be surface hardened.

i) At the discretion of the forgemaster or gear manufacturer, test samples of a larger cross section may be used, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

ii) Surface hardness, depth and profile, and core hardness are to be determined from sectioned test samples.

iii) Additional tests may be needed in accordance with the applicable design code.

Alternative procedures for testing of forgings which are to be surface hardened may be specifically agreed upon by the ABS Materials Department.

Also refer to 2-3-7/1.5.3 for surface hardening procedure review.

8) Whereby a furnace incorporates a method of controlled moving of the component from the charging end, through the furnace at a predetermined temperature and time, to the discharging end. Test coupon sampling procedures are to be specially agreed upon by the ABS Materials Department.

Commentary:

All weights identified in this table are based on weight at the time of heat treatment.

End of Commentary

FIGURE 1
Gear Ring Forgings - Test Specimen Locations and Orientations *(2017)*

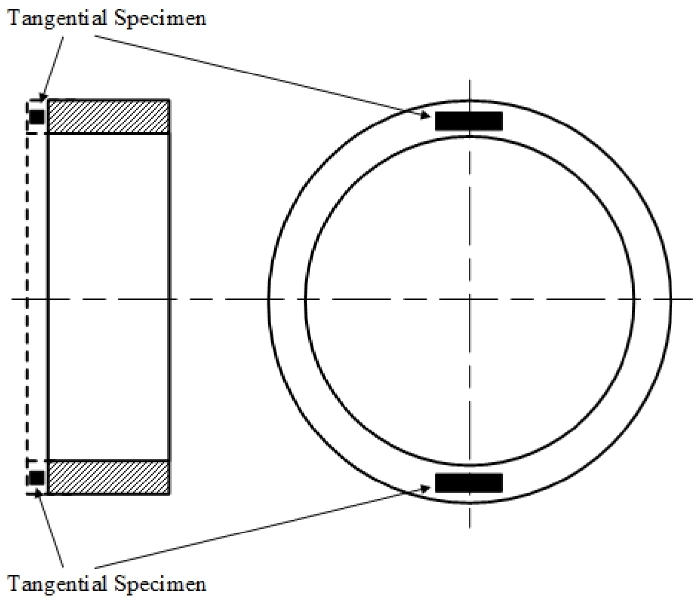


FIGURE 2
Reduction Gear Pinion or Gear Forging (as noted in 2-3-7/Table 1) - Test Specimen Locations and Orientations *(2024)*

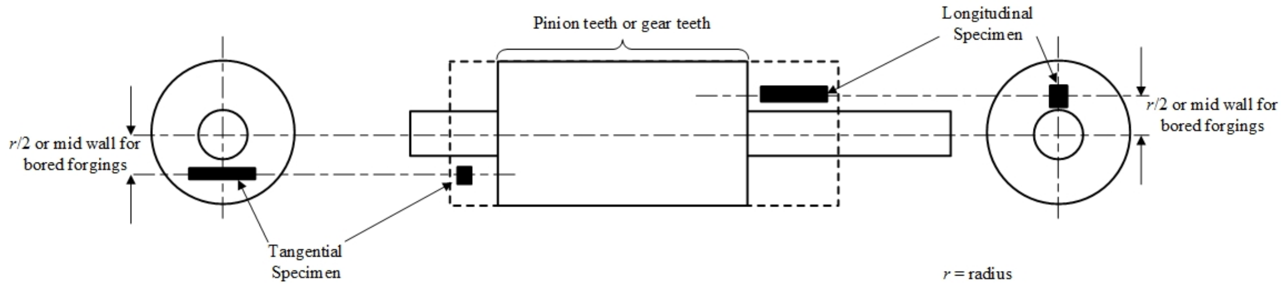
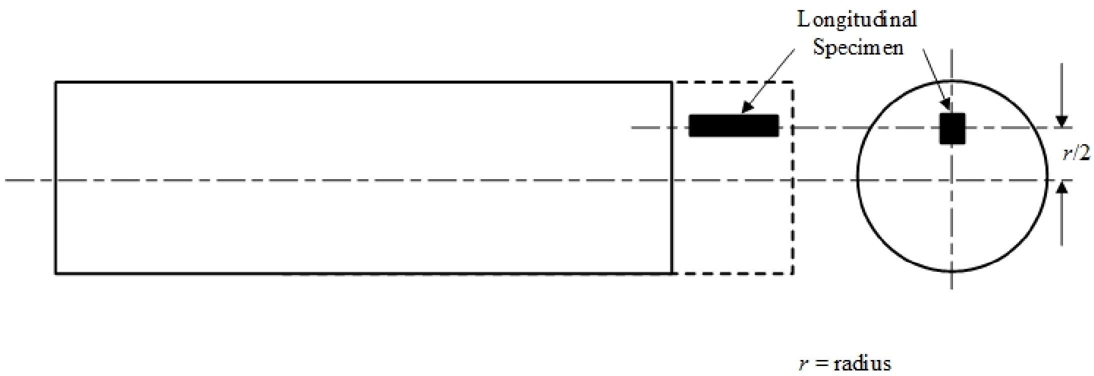


FIGURE 3
Gear Shaft Forging - Test Specimen Locations and Orientations *(2017)*



1.11 Hardness Tests – Locations and Frequency *(2024)*

1.11.1 Large, Intermediate and Small Sized Forgings *(2024)*

Each forging except those with weight at the time of heat treatment 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.

1.11.2 Reduction Gear Forgings

In the case of ring forgings for reduction gears, 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
203 to 305 (80 to 120)	3 on each end, 120 degrees apart
Over 305 (120)	4 on each end, 90 degrees apart

1.11.3 Reduction Gear Pinion and Gear Forgings *(2024)*

In the case of pinion and gear forgings with diameters 203 mm (8 in.) and over, four Brinell 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 180 degrees apart (0°/180°) and the tests on the other end are to be offset by 90 degrees (90°/270°).

On each forging under 203 mm (8 in.) in diameter, two Brinell hardness tests are to be made 180 degrees apart (0°/180°). Hardness tests are to be taken at the quarter length of the toothed portion diameter.

1.11.4 Disc, Ring and Hollow Forgings *(2024)*

Each forging except those with weight at the time of heat treatment of less than 113 kg (250 lbs) is to be hardness tested to meet the requirements of 2-3-7/1.11.1. Forgings are to be tested at the approximate mid-wall and 180 degrees apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

1.11.5 Small Forgings

In cases involving 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; see 2-3-7/1.9.3.

1.11.6 Reduction Gear Shaft Forgings *(2024)*

For shaft forgings for reduction gears, two hardness tests at each end, spaced at 180 degrees apart are to be taken.

1.11.7 Sleeves, Couplings and Nut Forgings *(2024)*

For 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*
up to 15 (6)	Batch testing
15 (6) to 102 (40)	1 on each end, 180 degrees apart
102 to 203 (40 to 80)	2 on each end, 180 degrees apart

1.13 Examination *(2008)*

All forgings are to be examined by the Surveyor after the final heat treatment and they are to be found free from defects. 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 ABS. Part 2, Appendix 7 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.

1.13.1 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. (See 4-3-2/3.7.3 of the ABS *Rules for Building and Classing Marine Vessels*, for surface inspection requirements in finished machined condition.)

1.13.2 Surface Inspection of Jacking Gear Forgings *(2020)*

Surface inspection such as magnetic particle, dye penetrant or other surface nondestructive method is to be applied on forgings in the final finished condition. Refer to 6-1-9/25.1 of the *MOU Rules* for inspection details/criteria. Any discontinuities are to be removed to the satisfaction of the Surveyor.

1.13.3 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. Conformity with Section 7-A1-12, "Ultrasonic Examination of Carbon Steel Forgings for Tail Shafts" of the ABS *Rules for Survey After Construction (Part 7)*, or equivalent, will be considered to meet this requirement.

1.13.4 Ultrasonic Examination of Jacking Gear Forgings *(2020)*

For direct load path components (refer to 6-1-9/5 of the *MOU Rules*), UT is to be carried out during the manufacturing of the gear in accordance with the approved design plan, This can be done either on the forged blank and/or at a later manufacturing stage.

Note: It may be more effective to UT the forged blanks (without the teeth or splines cut) than to UT a finished gear component containing complex profiles.

1.15 Rectification of Defective Forgings *(2018)*

Defects may be removed 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 ABS. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

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

Before undertaking 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.

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.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

1.17 Certification *(2005)*

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

i) Purchaser's name and order number

ii) Description of forgings and steel quality

iii) Identification number

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

v) Results of mechanical tests

vi) Results of nondestructive tests, where applicable

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

viii) Specification

3 ABS Grade Steel Forgings for Machinery Applications *(2024)*

3.1 ABS Grade Steel Shaft and Stock Forgings *(2024)*

ABS grade steel shafts and stock forgings may be manufactured in accordance with the following requirements, which are in substantial agreement with ASTM grade referenced in the table below to meet the design requirements. In addition to the chemical composition and tensile properties, impact requirements indicated in 2-3-7/1.7.2 are to be met.

TABLE 2
Grades for Steel Shaft and Stock Forgings *(2024)*

ABS Designation	*ASTM Specification and Grade*
2	A668, Class B
3	A668, Class D
4	A668, Class E
4C	A668, Class E

3.1.1 Chemical Composition

i) Carbon content of ABS Grades 2, 3 and 4 is not to exceed 0.23% or carbon equivalent (Ceq) of Grades 2, 3 and 4 is not to exceed 0.41%, unless specially approved, refer to the table below.

ii) The carbon content of Grade 4C is not to exceed 0.55%. Welding of Grade 4C is not permitted unless specifically approved.

iii) Grades having more than the maximum specified carbon are to have the **S** symbol marked after the grade designation.

TABLE 3
Chemical Composition Requirements for ABS Grade Steel Shaft and Stock Forgings [1], in percent *(2024)*

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 - 1.35
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

Notes:

i Single values are maxima, unless noted.

ii The carbon content may be increased above this level, provided that the carbon equivalent (Ceq) is not more than 0.41%, as calculated using the following formula:

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

iii Silicon minimum is applicable if the steel is silicon killed.

3.1.2 Tensile Properties *(2024)*

Tensile properties for ABS grade steel shaft and stock forgings are included in the table below.

TABLE 2
Tensile Property Requirements [1] for ABS Grade Steel Shaft and Stock Forgings *(2024)*

<table>
<tr><th rowspan="4">Grade</th><th rowspan="4">Size, in mm (in)</th><th rowspan="4">Tensile Strength [2] in N/mm^2 (kgf/mm^2, ksi)</th><th rowspan="4">Yield Strength [3] in N/mm^2 (kgf/mm^2, ksi)</th><th colspan="3">Longitudinal [4]</th><th colspan="3">Tangential [4]</th></tr>
<tr><th colspan="2">Elongation [5], in percent</th><th rowspan="3">RA, in percent</th><th colspan="2">Elongation [5], in percent</th><th rowspan="3">RA, in percent</th></tr>
<tr><th colspan="2">Gauge Length</th><th colspan="2">Gauge Length</th></tr>
<tr><th>4d</th><th>5d</th><th>4d</th><th>5d</th></tr>
<tr><td rowspan="2">2</td><td>≤ 300 (12)</td><td>415 (42, 60)</td><td>205 (21, 30)</td><td>25</td><td>23</td><td>38</td><td rowspan="2">20</td><td rowspan="2">18</td><td rowspan="2">29</td></tr>
<tr><td>> 300 (12)</td><td>415 (42, 60)</td><td>205 (21, 30)</td><td>24</td><td>22</td><td>36</td></tr>
<tr><td rowspan="4">3</td><td>≤ 200 (8)</td><td>515 (53, 75)</td><td>260 (26.5, 37.5)</td><td>24</td><td>22</td><td>40</td><td rowspan="4">18</td><td rowspan="4">16</td><td rowspan="4">28</td></tr>
<tr><td>> 200 (8) ≤ 300 (12)</td><td>515 (53, 75)</td><td>260 (26.5, 37.5)</td><td>22</td><td>20</td><td>35</td></tr>
<tr><td>> 300 (12) ≤ 500 (20)</td><td>515 (53, 75)</td><td>260 (26.5, 37.5)</td><td>20</td><td>18</td><td>32</td></tr>
<tr><td>> 500 (20)</td><td>515 (53, 75)</td><td>260 (26.5, 37.5)</td><td>19</td><td>17</td><td>30</td></tr>
</table>

Grade	*Size, in mm (in)*	*Tensile Strength (2) in N/mm² (kgf/mm², ksi)*	*Yield Strength (3) in N/mm² (kgf/mm², ksi)*	*Longitudinal (4)*			*Tangential (4)*		
				Elongation (5), in percent		*RA, in percent*	*Elongation (5), in percent*		*RA, in percent*
				Gauge Length			*Gauge Length*		
				4d	*5d*		*4d*	*5d*	
4, 4C(6)	≤ 200 (8)	585 (59.7, 85)	305 (31.1, 44)	25	23	40	17	16	27
	> 200 (8) ≤ 300 (12)	570 (58.5, 83)	295 (30.5, 43)	23	21	37			
	> 300 (12) ≤ 500 (20)	570 (58.5, 83)	295 (30.5, 43)	22	20	35			

Notes:

1 All tensile property requirements are minima, unless indicated.

2 In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm² (7 kgf/mm², 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); see 2-3-1/11.13 FIGURE 2.

6 *(2013)* Size over 500 mm (20 in.) will be specially considered.

RA = Reduction of Area

3.3 ABS Grade Steel Forgings for other Machinery Applications *(2024)*

ABS grade steel forgings for other machinery applications may be manufactured in accordance with the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 5
Steel Forgings for other Machinery Applications

ABS Designation(1)	*ASTM Specification*	*Grade/Class*	*Yield Strength, N/mm² (kgf/mm², ksi)(2)*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)(2)*	*Minimum % Elongation 50 mm (2 in.) (2)*
1. Alloy Steel Gear Forgings					
A1	ASTM A291	2/B	485 (49, 70)	655 (67, 95)	20
A2	ASTM A291	3/C	550 (56, 80)	725 (74, 105)	19
A3	ASTM A291	4/E	655 (67, 95)	825 (84, 105)	14
A4	ASTM A291	5/F	760 (77, 110)	930 (95, 135)	14
A5	ASTM A291	6/G	795 (81, 115)	965 (98, 140)	12
A6	ASTM A291	7/H	930 (95, 135)	1140 (116, 165)	10
2. Alloy Steel Shaft and Stock Forgings					
A7	ASTM A470	A/2	415 (42, 60)	550 (56, 80)	22
A8	ASTM A470	B/4	620 (63, 90)	725 (74, 105)	17

ABS Designation(1)	*ASTM Specification*	*Grade/Class*	*Yield Strength, N/mm^2 (kgf/mm^2, ksi)*(2)	*Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*(2)	*Minimum % Elongation 50 mm (2 in.)*(2)
A9	ASTM A470	C/6	620 (63, 90)	725 (74, 105) to 860 (88, 125)	18
A10	ASTM A470	C/7	690 (70, 100)	825 (84, 120) to 930 (95, 135)	18
3. General Shipboard Alloy Steel Forgings					
A11	ASTM A668	J	450 (46, 65)	620 (63, 90)	18
A12	ASTM A668	K	515 (53, 75)	690 (70, 100)	18
A13	ASTM A668	L	585 (60, 85)	760 (77, 110)	14
A14	ASTM A668	M	760 (77, 110)	930 (95, 135)	13
A15	ASTM A668	N	895 (91, 130)	1105 (112, 160)	11

Notes:

1 Requirements for chemical composition (2-3-7/1.3.4), impact properties (2-3-7/1.7.2) and test specimens (2-3-7/1.9) are also required to be met.

2 Refer to the applicable ASTM standard for the tensile properties for a given diameter. Tensile properties in this table are provided for reference.

5 Marking *(2024)*

The manufacturer is to adopt a system of identification that enables all finished forgings to be traced 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, ABS 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 discernible after machining and installation.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 7

Appendix 1 - Repair and Cladding of Shafts *(2024)*

1 General

1.1 Objective

The objective of this section is to perform work and verify compliance with the Goals, Functional Requirements, and prescriptive requirements outlined in the cross referenced sections.

3 Scope

3.1 General *(1 July 2024)*

This Appendix describes procedures for the repair welding and cladding of stern tube shafts, tailshafts, line shafts, rudder stocks/shaft, and pintles, including repair of clad areas when needed. Forgings or rolled bars are manufactured in accordance with Section 2-3-7 or 2-3-8, as applicable.

Procedures and techniques differing from those outlined herein will be specially considered by ABS provided that all the supporting documents are submitted for review.

Note that procedures described in the following sections are not applicable to engine crankshafts.

3.3 Materials

The Appendix is applicable to shafts made from

i) Carbon steel forgings such as ABS Grades 2, 3 and 4 or other weldable grades produced to recognized national standards or proprietary specifications as indicated on the ABS approved drawings.

ii) Alloy steel forgings such as those covered by specification MIL-S-23284, classes 3 and 4, or other weldable grades produced to recognized national standards or proprietary specifications as indicated on the ABS approved drawings.

iii) Rolled bars when permitted for shafting in lieu of forgings.

iv) Plates or castings when specially approved for flanges.

Repair of stainless steel shafts are subject to ABS technical assessment and approval.

3.5 Arrangements, Fees, and Renewal of Approvals for Welding and Cladding

Arrangements for witnessing of tests, examinations, payment of required fees, and other details are to be made with the local ABS Office.

Facility approvals for welding and cladding are subject to renewal after five years.

Re-approval is based on submission of satisfactory evidence of personnel qualifications, procedures, and experience with the approved procedures.

Facilities wishing to renew their approvals are required to advise the local ABS Office prior to the expiration of their approvals.

3.7 Repair without Welding *(1 July 2024)*

A defect may be removed by mechanical mean such as turning, grinding or filing if,

i) The excavation depth no deeper than 3.2 mm (⅛ in.) for shafts up to 255 mm (10 in.) diameter.

ii) The excavation depth no deeper than 6.4 mm (¼ in.) for shafts over 255 mm (10 in.) diameter.

For rudder stock/shaft under 200 mm (7.87 in.) not fitted with liners in way of bearings, refer to 3-2-14/15.1.6.i of the *Marine Vessel Rules* for further details. A defect may be removed by turning, grinding, or filing if the resulting excavation is no deeper than 3.2 mm (⅛ in.). The extent of excavation will depend upon the size of defect/pitting. The allowable size of repair will be subject to ABS technical assessment and approval.

All excavated areas are to have a smooth finish with a radius of no less than one fourth of the shaft/stock diameter.

Magnetic particle examination of the area is to be made to verify completely removal of defects.

5 Repair by Welding - Facility Approval

5.1 General

Weld repairs on shafts are to be performed at an ABS approved facility

5.3 Facility Approval

Application for facility approved is to be made to the ABS Materials Department. The following information is to be submitted:

- Submission of welder/operator qualifications
- Submission of qualification testing results (see 2-3-7-A1/5.9)
- Submission of ultrasonic examination procedure (see 2-3-7-A1/5.7)
- Submission of welding procedures (see 2-3-7-A1/5.5)
- Facility audit by ABS Surveyor

5.5 Welding Procedure

5.5.1 General

A weld procedure qualification test is required for each grade of steel for which approval is requested. Prior to conducting the qualification test, the preliminary welding procedure is to be approved by the Materials Department.

5.5.2 Welding Procedure Approval

After satisfactory completion of the weld procedure qualification test, a written welding procedure (WPS) is to be prepared along with qualification test report (PQR) and submitted to ABS Materials Department for review and approval.

Description of the welding procedure is to at least include the following (see also 2-3-7-A1/9):

- Base metal specification (and composition if known)
- Filler metals including brand, type and size
- Joint design
- Welding process
- Preheat temperature and method
- Interpass temperature
- Sequence and method of depositing weld beads
- Method of inspecting weld beads
- Postweld heat treatment and method
- Method of final inspection
- Ultrasonic examination procedure (see 2-3-7-A1/5.7)

5.5.3 Welding Procedure Qualification Test

The welding procedure qualification tests are to be conducted in the presence of an ABS Surveyor.

5.7 Ultrasonic Examination Procedure

The intent of ultrasonic examination in connection with welded shafts is to determine that:

i) The weld is free from defects

ii) The area beneath the aft liner (where fitted) is free from cracks

Facilities seeking approval for weld repairs are to submit an ultrasonic inspection procedure to the ABS Materials Department for review and approval. Refer to 2-3-7-A1/5.3.

After satisfactory review, the procedure is to be demonstrated to ABS Surveyor's satisfaction on a sample tail shaft or equivalent substitute, as noted below

i) The sample is to contain at least six simulated defects located forward of the large end of the taper, the farthest imperfection being 300 mm (12 in.) from the large end of the taper (2-3-7-A1/21 FIGURE 4).

ii) Detection of the defects is to be demonstrated by shear wave scanning on the tapered portion of the shaft.

The recommended frequency is 2.25 MHz.

5.9 Mechanical Tests

A test coupon of 292 mm ± 6.4 mm (11½ ± ¼ in.) long with the weld in the center is to be prepared. Upon the completion of the test coupon welding and the required stress relief treatment, mechanical test specimens in accordance with 2-3-7-A1/Figure 3 are to be machined and tested in the presence of a Surveyor.

Test results are to be submitted to the ABS Materials Department for final approval.

7 Preparation and Examination of Shafts Prior to Welding

i) The preparation and examination of defective shafts is to be performed in the presence of an ABS Surveyor.

ii) When deep cracks extend partially around the shaft circumference and repair welding is agreed upon by the ABS Materials Department, it is recommended that grooves be cut completely around the shaft to permit balanced welding. Alternatively, shallow defects may be removed by partial grooving and warpage due to welding may be controlled by peening or other means.

iii) To be considered for repair by welding, defect depths are not to exceed approximately 20% of the shaft diameter.

iv) Repairs to hollow shafts that involve the full wall thickness are subject to special consideration by ABS.

v) Prior to welding, defects are to be excavated to sound metal. Surface inspection is to be carried out to determine that all defects have been completely removed.

vi) All tail shafts with fitted aft liners to be repaired by welding are to be examined under the liner using the approved ultrasonic procedure in 2-3-7-A1/5.7. In general, the examination is to extend from the aft end of the liner to 300 mm (12 in.) forward. If the ultrasonic inspection shows indications of a defect under the liner, the liner is to be removed to the extent necessary to effect examination and repair. Precautions are to be taken to avoid marring the shaft surface during liner removal.

9 Production Welding

9.1 Submission of Details

The proposed repair procedure is to include a sketch showing the extent of each proposed repair, are to be summarized in brief form and submitted to the ABS Materials Department. The details are to include at least the following.

i) Name of vessel

ii) Original shaft markings

iii) Shaft type and Grade

iv) Shaft size/ dimension

v) Reference made to the proposed welding procedure

9.3 Welding Processes

i) Weld repairs may be made with an approved manual or automatic welding process.

ii) The storage and use of welding consumables is to be in accordance with manufacturer's recommendations.

iii) In all cases, the properties of the weld deposit, after heat treatment, are to be comparable to base metal. However, in the case of alloy steel shafts, weld deposits lower in strength than the base metal may be used for depositing the first bead of weld metal in the groove to minimize the effects of dilution and rapid quench on the strength and ductility of the weld metal.

iv) When possible, the welding is to be done in the flat or down hand position.

v) When welding shafting with circumferential grooves, the welding may be automated or semi-automated, utilizing a positioner or rotating device to position the shaft, and employing either a stationary welding heads for automatic welding or a handheld electrode holder for semi-automatic welding. Welding speed is to be regulated with the shaft rotation to prevent slag interference or incomplete fusion during welding.

9.3.1 Shielded Metal Arc and Gas Metal Arc Welding

Low hydrogen electrodes or processes are to be used. Gas metal arc welding is to be performed under conditions that result in a stable arc.

9.3.2 Submerged Arc Welding

When heat input rates in excess of 2165 Joules/mm (55,000 Joules/in.) are used, information submitted for procedure qualification is to show the use of a tempering bead technique, and the heat affected zone was not adversely affected by the heat input.

9.3.3 Other Welding Processes

The techniques used with welding processes other than those indicated in 2-3-7-A1/9.3.1 and 2-3-7-A1/9.3.2 above, will be specially considered by ABS.

9.5 Examination During Welding

The first weld layer is to be examined by magnetic particle method. Additionally, when using the submerged arc welding process, the last two layers are to be examined by magnetic particle method.

9.7 Preheat and Interpass Temperature

i) A minimum preheat and interpass temperature of 135°C (275°F) is to be used for ordinary strength carbon steels.

ii) For higher strength carbon steels and alloy steels the preheat and interpass temperatures are to be in the range of 135°C (275°F) to 260°C (500°F); the values specified being suitable for the particular material and welding process involved.

9.9 Distortion Control

Welding sequence is to be used to minimize or eliminate distortion. It may include appropriate application of peening or heating, or both. However, peening is not allowed on the final weld layer. Shafts are to be fitted with dial indicators to permit continuous checking of shaft alignment during welding operations. Residual distortion present prior to postweld heat treatment is to be corrected by adjusting supports or by other means to permit straightening the shaft during the postweld heat treatment.

9.11 Postweld Heat Treatment

i) Prior to heat treatment, the shafts are to be covered with a suitable heat resisting scale preventative.

ii) Carbon steel shafts are to be postweld heat treated at 635 ± 14°C (1175 ± 25°F).

iii) Alloy steel shafts are to be postweld heat treated at 663 ± 14°C (1225 ± 25°F). In case of stress relief temperatures other than 663 ± 14°C (1225 ± 25°F) may be subjected to special considered.

iv) iv. Postweld heat treated with a minimum holding time of 2 hours per 25.4 mm (1 in.) or fraction thereof of weld thickness , except that the maximum holding time not more than 8 hours for any repair, unless specially required otherwise.

v) The maximum heating and cooling rate is not to exceed 52°C (99°F) per hour.

vi) Shafts may be cooled in still air after reaching 232°C (450°F).

9.11.1 Intermediate Stress Relief

When the grooves to be welded are over 100 mm (4 in.) deep, an intermediate stress relief heat treatment is to be carried out after one half of the depth of groove, measured in depth, has been welded.

9.11.2 Stress Relief Methods

i) Furnace heating is required for shafts in which the repaired areas are not localized.

ii) For shafts with circumferential repairs where the repair by welding areas is relatively narrow, stress relieving by local heating with resistance or induction type portable units may be considered acceptable, provided the width of the heated area at each side of the weld is at least twice the weld thickness.

11 Examination after Welding

i) After post weld heat treatment, machining and cleaning of the shaft, the welds and adjacent areas are to be checked for cracks or other imperfections by magnetic particle inspection and an approved ultrasonic inspection.

ii) During the ultrasonic inspection, particular attention is to be directed toward inspecting for discontinuities under the aft liner, if fitted, in the deposited weld metal, and other areas not accessible to ultrasonic inspection because of interference from the defective area that had required repair.

iii) The shaft is to be checked for alignment after final heat treatment and be within the specified straightness tolerances.

13 Final Finishing

At the final finishing stage, itmay be necessary to take a light cut on the taper of the shaft. In such cases, the propeller clearance is to be verified using indicators such as Prussian Blue. When machining the forward end of the taper, small fillet radii are to be cut into the end of the liner to avoid a sharp step between the shaft and the end of the liner, as shown in 2-3-7-A1/21 FIGURE 5. Consideration is to be given at this time to provide relief grooves in both ends of the liner and at the bottom of the propeller hub counter bore, as shown in 2-3-7-A1/21 FIGURE 6.

15 Marking of Shafts Repaired by Welding

Shafts that are reconditioned by means of repair welding, in accordance with 2-3-7-A1/9, or an approved procedure, are to be stamped "**Welded-S.R**.", along with the attending Surveyor's identification marks, so that it will be clear to the installation Surveyor that such shafts have been welded and stress relieved. Where the original shaft identification marks have been obliterated, new marks are to be added in a low stress area.

17 Cladding of Shafts by Welding

17.1 General

Cladding of shafts by welding is to be performed by an ABS approved facility.

17.3 Facility Approval

Application for facility approved is to be submitted to ABS Materials Department. The following are to be submitted for review:

- Operator qualification data (see 2-3-7-A1/17.7)
- Clad weld procedure (see 2-3-7-A1/17.9)
- Clad weld procedure qualification test results (see 2-3-7-A1/17.9.2)

17.5 Materials

The procedures contained herein for cladding of shafts by deposition of austenitic stainless steel or monel with approved arc welding procedures. Cladding employing other overlay materials or other welding processes will be special considered.

Clad weld procedures are to be qualified in accordance with this section with following requirements.

i) The finished weld thickness does not exceed 3.2 mm (⅛ in.) for shafts up to 255 mm (10 in.) in diameter

ii) The finished weld thickness does not exceed 6.4 mm (¼ in.) for shafts over 255 mm (10 in.)

iii) The finished weld is to be post weld heat-treated in accordance with 2-3-7-A1/9.11. In such cases the minimum clad thickness of 2-3-7-A1/17.13 is not applicable. Unless specially approved otherwise, carbon steel cladding in excess of the thickness noted above is to be in accordance with 2-3-7-A1/5.

17.7 Welder or Operator Qualifications

ABS Surveyor is to be satisfied with the welders or operators are proficient in the type of work assigned to them, through due consideration of employment, training, apprenticeship, plant testing, inspection, etc. When qualification testing is considered necessary to verify proficiency, the tests indicated in 2-3-7-A1/21 FIGURE 8 are to be conducted.

17.9 Clad Weld Procedure Approval

Overlay procedures used are to be qualified in accordance with 2-3-7-A1/17.9.2 Procedure re-qualification is to be sought for any change in essential variables such as base metal grade, overlay material, etc. in accordance with the applicable welding code or Rules.

17.9.1 Procedure Qualification Record

Procedure qualification tests are to be conducted in the presence of and to the satisfaction of an ABS Surveyor on a test coupon of the same grade and diameter representative of production shaft.

The following details of the cladding procedure and the qualification test results are to be submitted to the ABS Materials Department for review and approval:

- Base metal specification included chemical composition and mechanical properties
- Welding process
- Preheat and interpass temperature
- Postweld heat treatment (if none - so state)
- Filler metal specification included manufacturer, trade name, and chemical composition
- Method of inspection

17.9.2 Required Test Results and Acceptance Criteria

The following qualification test results based on specimens in accordance with 2-3-7-A1/21 FIGURE 7 are to be submitted:

- Four side bend tests, refer 2-4-3/11.5.4 FIGURE 6. No cracking is permitted in the cladding or interface.
- Four macro-specimens across the weld located 90º apart. The macrographs are to be free from cracks at 10X magnification.
- Hardness surveys conducted across the welds by using microhardness or Rockwell hardness. The results are to be reported for information.

17.11 Cladding/Base Metal Dilution

i) Appropriate precautions are to be taken to minimize deleterious effects associated with the dilution of the clad layer by the base metal during welding.

ii) In the case of austenitic stainless-steel cladding on carbon or alloy steel shafting, the use of a stainless filler metal such as Type 309 or equivalent is required for the initial layer. An appropriate type of stainless steel is then to be used for subsequent layers.

17.12 Cladding on Taper

When cladding is carried out on any part of the taper shaft, these additional requirements are applicable:

i) Precautions are to be taken to avoid generating flaws and voids at the transitions between the straight part of the shaft and the taper region.

ii) The cladding is to extend over the entire surface of the taper including the transitions.

iii) An appropriate UT inspection technique that is capable of detecting weld flaws and voids is to be performed at the taper and transition region. The written procedure is to be validated by performing a demonstration to ABS Surveyor on the detectability of the inspection technique.

iv) Four macro-specimens located 90º apart across a taper transition (from the smaller diameter to the taper), can be taken from a test unit, as indicated in 2-3-7-A1/21 FIGURE 7. The macro-specimens are to be free from weld flaws and voids.

17.13 Finish Machining

i) The entire extent of the cladding, including that extending beyond the bearings, is to be machined to a maximum surface roughness of 3.2 micrometers (125 microinches) RMS (root mean-square), or equivalent.

ii) The ends of clad areas are to be tapered at an angle of approximately 15°.

iii) The clad/ shaft junctions are to be free from notches.

iv) The minimum thickness of cladding after machining is to be 4.8 mm (3/ in.), except at tapered ends.

17.15 Final Examination

The entire finish machined area of the cladding is to be examined by suitable surface and volumetric inspection techniques.

17.17 Marking of Shafts Clad by Welding

The cladded shaft is to be identified by stamping the cladding type in the flange recess, along with other applicable markings, e.g., 309-316 SS clad.

19 Repair of Clad Shafts

19.1 General

i) Repair of clad shafts by welding is to be performed by facilities and welders qualified under the provisions of 2-3-7-A1/17.

ii) Prior to repairing a clad shaft, the cladding material is to be identified either by reference to an existing stamping or the initial report describing the cladding, or spot tests as described in 2-3-7-A1/19.9.

iii) Any shaft lacking the stamp to identify clad material is to be appropriately marked in the flange recess after the clad material has been identified, (e.g., 309-316 SS clad).

19.3 Depth of Defect

i) Defects are to be smoothly ground out, and the removal is to be verified by a suitable surface inspection technique.

ii) An assessment is to be carried out to confirm the extend of repair is restricted to the cladding layer or into the base metal.

iii) The tests described in 2-3-7-A1/19.9 may be used to determine the extent of repair.

19.5 Repair of Defects That Do Not Penetrate into Base Metal

A defect in the cladded layer that does not penetrate into the base metal of the shaft may be repaired by either grinding the defect to a large radius so as to reduce the stress concentration or by chipping and grinding the defect to sound metal and then filling with the same type of filler metals used for the initial cladding.

When the grinding extends through the clad layer into the base metal, refer to 2-3-7-A1/19.7.

19.7 Repair of Defects That Penetrate into Base Metal

i) Clad shafts having defects that penetrate into the base metal of the shaft may be permanently repaired if the penetration into the base metal is less than 3.2 mm ($^1/_8$ in.) for shafts up to 255 mm (10 in.) in diameter or less than 6.4 mm ($^1/_4$ in.) for shafts exceeding 255 mm (10 in.) in diameter.

ii) When the penetration into the base metal is greater than those indicated in 2-3-7-A1/19.7i), repairs will be considered under the provisions of 2-3-7-A1/5 through 2-3-7-A1/15.

iii) For austenitic stainless steel-clad shafts, Type 309 or equivalent filler metal is to be used for the initial layer which is deposited on the carbon or alloy steel shaft to minimize dilution effects. Suitable type of stainless steel is to be used for subsequent layers.

iv) For monel clad shafts, Type Ni Cu-1 or 2 electrodes are to be used.

19.9 Cladding Identification Procedures

Chemical spot tests may be used to identify cladding material. See 2-3-7-A1/19.9.1 and 2-3-7-A1/19.9.2:

19.9.1 Nitric Acid Test

When a 50% nitric acid solution is placed on austenitic stainless steels, there is no chemical reaction. When the acid is placed in contact with carbon steel, the acid will turn brown. The acid will turn a greenish blue when placed on monel.

19.9.2 Copper Sulfate Test

When a 5% to 10% solution of copper sulfate is placed into an excavated areas that has been cleansed of grease and foreign matter, the carbon steel will become coated with a layer of metallic copper in a short time, while stainless steel or monel will not be affected.

21 Metal Spraying on Shafts and Liners

When shafts or shaft liners are to be metal sprayed, detailed information is to be submitted to the ABS Materials Department for review and approval prior to spraying. The information includes the details of the process, materials, procedure, service experience, and specifics of intended location to be sprayed.

FIGURE 1
Joint Design for Weld Repair in Solid Shafting for Procedure Approval

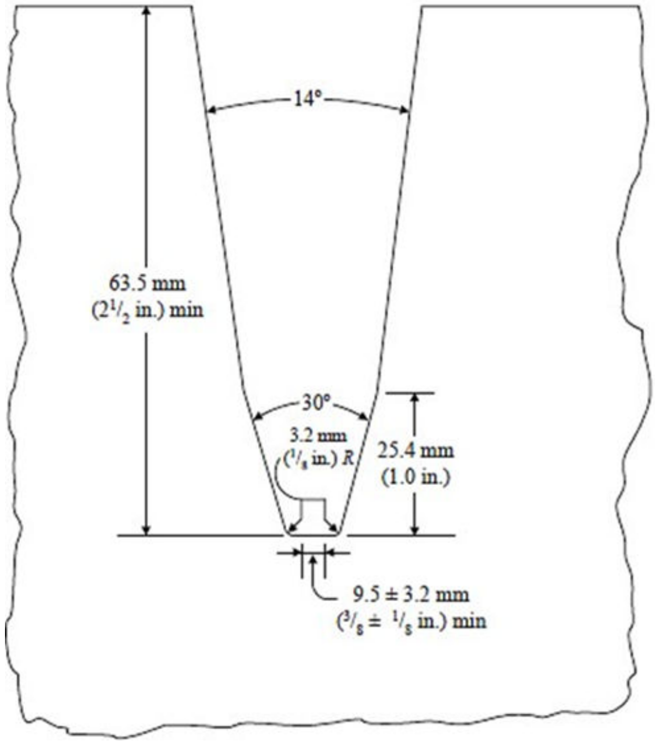


FIGURE 2
Joint Design for Weld Repair in Hollow Shafting for Procedure Approval

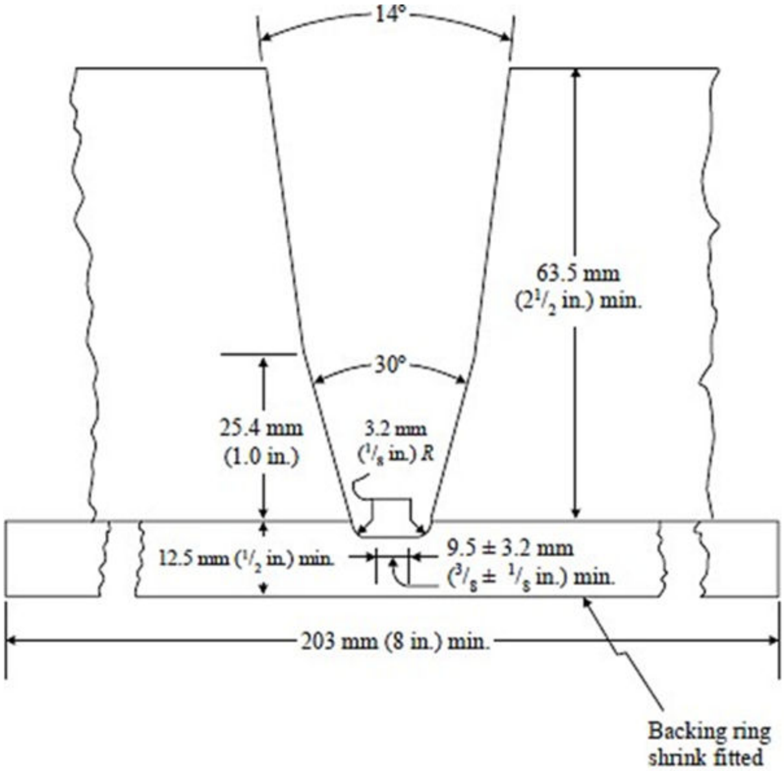
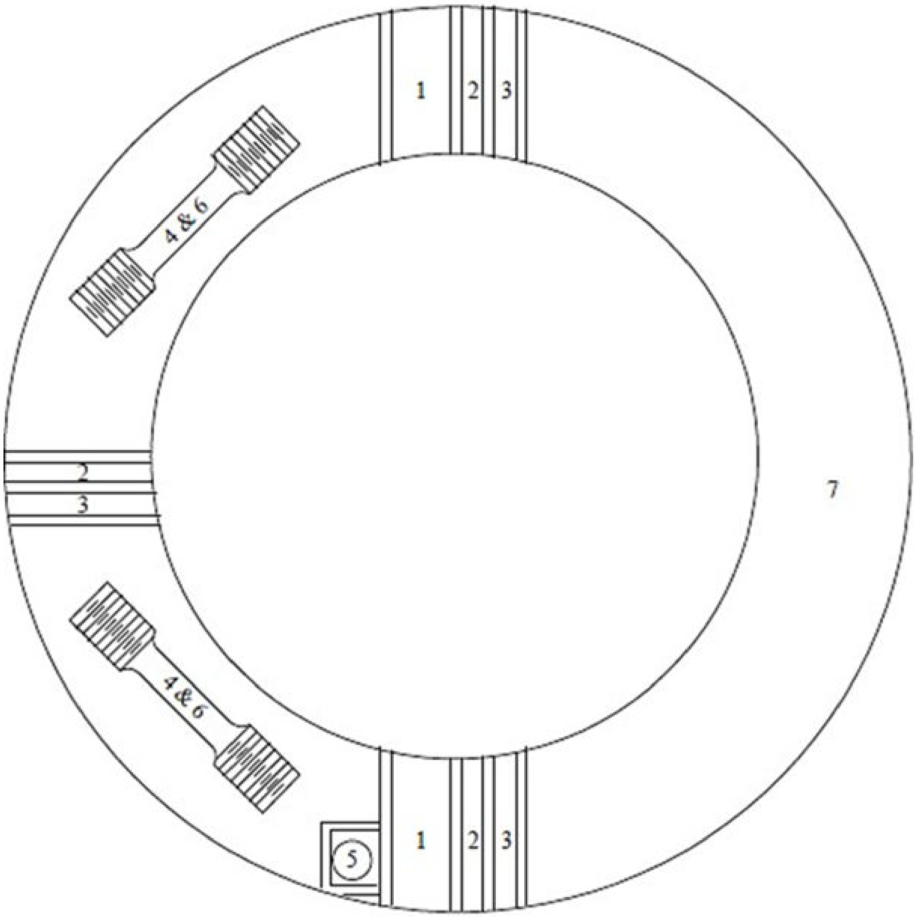


FIGURE 3A
Qualification Test Pieces for Weld Repair Procedure Approval



Qualification test specimen locations and frequencies from base metal and weldment.

No.	*Type of Test*	*Extent of Testing*
1	Transverse tension tests	2 Specimens, refer 2-4-3/11.5.4 FIGURE 3
2	Macro Examination and Hardness	3 Specimens
3	Side bend tests	3 Specimens, refer 2-4-3/11.5.4 FIGURE 6
4	All base metal tension tests, circumferential direction	2 Specimens with 12.5 ± 0.25 mm (0.500 ± 0.010 in.) diameter
5	All base metal, tension test longitudinal direction	1 Specimen with 12.5 ± 0.25 mm (0.500 ± 0.010 in.) diameter
6	All weld metal, tension test circumferential direction	2 Specimens with 12.5 ± 0.25 mm (0.500 ± 0.010 in.) diameter
7	Spare	NA

Acceptance Criteria:

1) Tensile and yield strength are to be compatible with the base metal.

2) Macro examination is to clearly reveal the weld metal, fusion line and heat affected zone. It is to be fully fused and free of cracks.

3) Hardness indentations are to be as 2-3-7-A1/Figure 3B. The values are to be reported for information.

4) Side bend test specimen is not to show any cracking or other open defect exceeding 3.2 mm on the convex side except at the corners.

FIGURE 3B
Location for Hardness Measurements Across the Weldment

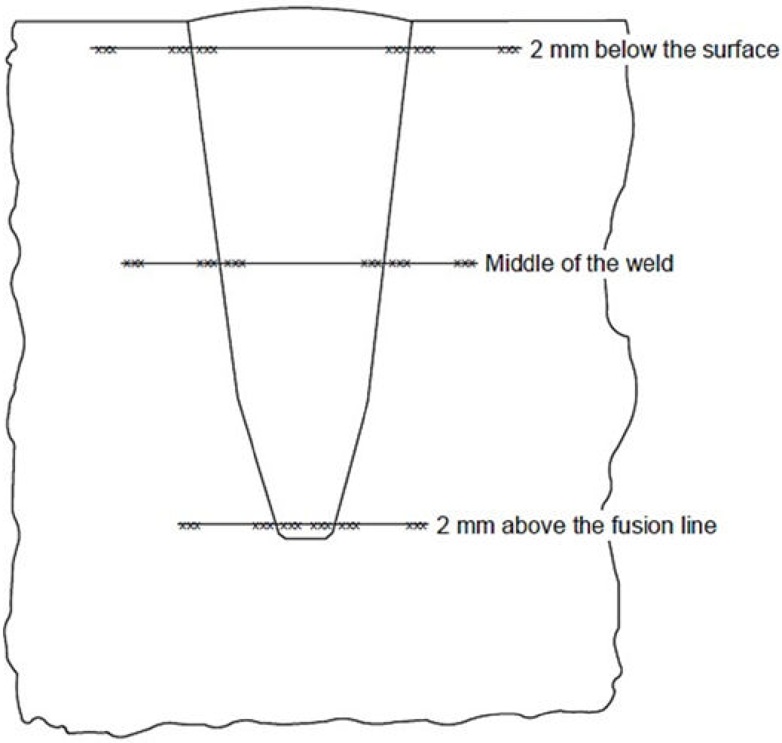
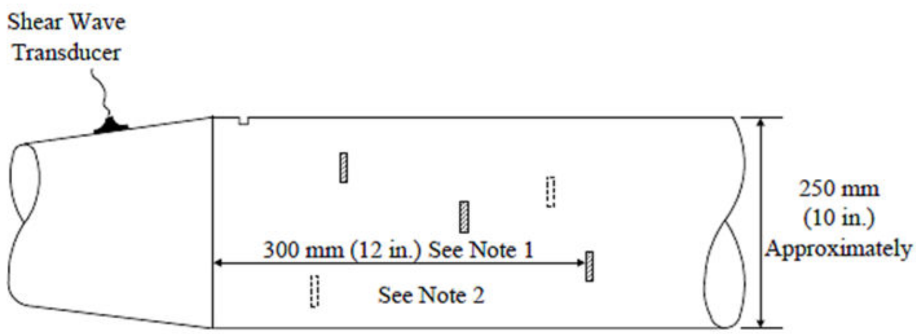


FIGURE 4
Ultrasonic Inspection on Shaft



Notes:

1 One notch 75 mm (3 in.) by 1.6 mm (0.0625 in.) by 1.6 mm (0.0625 in.).

2 Five or more additional notches ranging in depth from 0.65 mm (0.025 in.) to 3.2 mm (0.125 in.).

FIGURE 5
Recommended Contour for Shafting at Liner

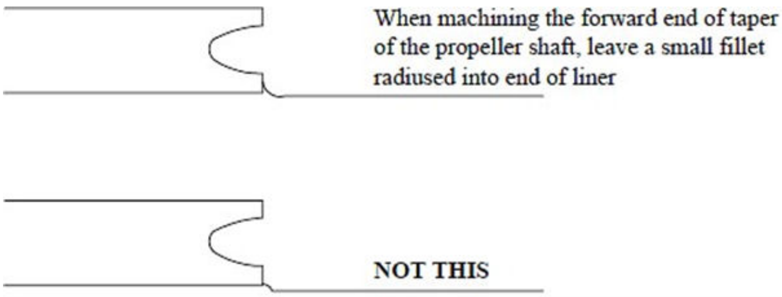


FIGURE 6
Suggested Hoop Stress Relief for Propeller Hub and Shaft Liner

It is important that the stress relief grooves be at least 12.5 mm ($^1/_2$ in.) deep and that the thickness of the lip at the edge be held at 1.6 mm ($^1/_{16}$ in.) The side of the stress relief groove adjacent to the shaft is to have an easy slope, as shown, to provide effective relief over a distance of at least 6.4 mm ($^1/_4$ in.) from the edge of the fit.

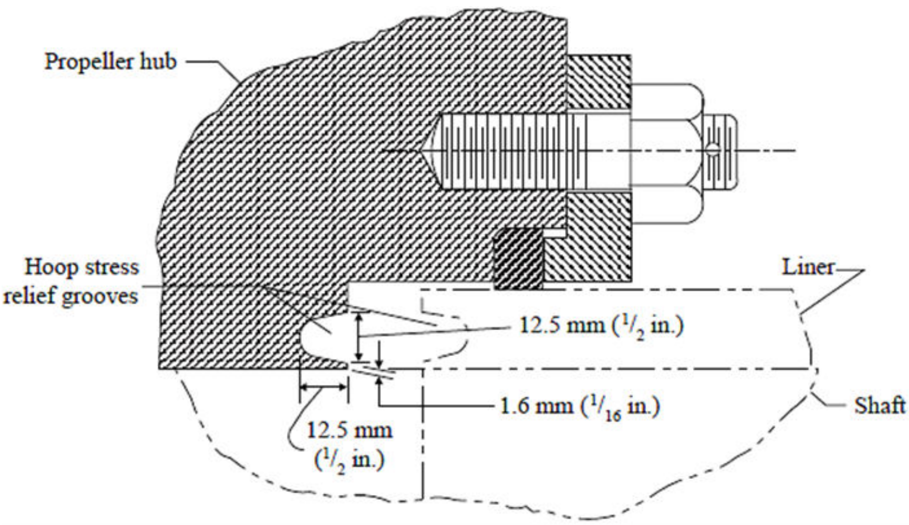


FIGURE 7
Qualification Test Pieces for Cladding Procedure Approval

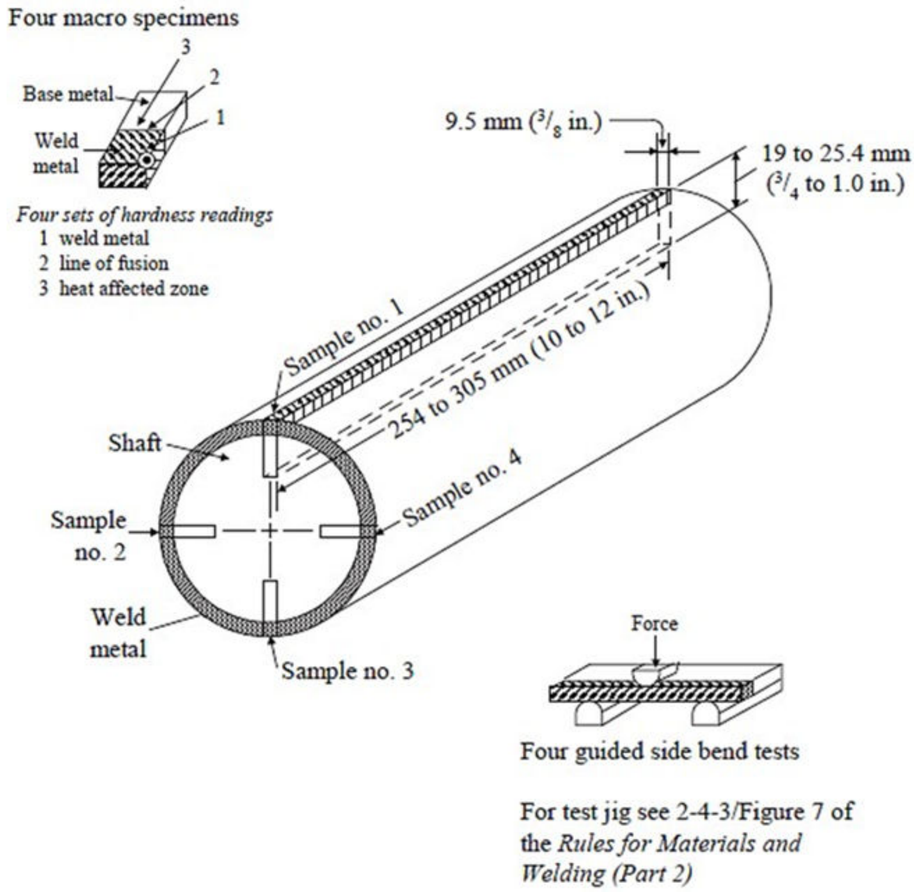
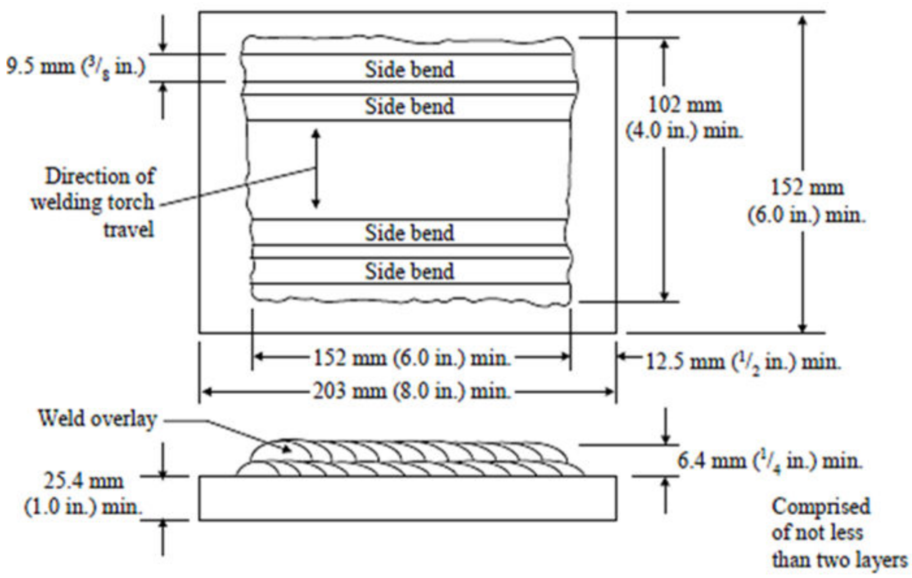


FIGURE 8
Welder Qualification Tests for Cladding



Annex Suggested Form for Ultrasonic Inspection of Shafts

Suggested Form for Ultrasonic Inspection of Shafts (Administrative Data)

1.	Report Number:
2.	Date
3.	Shipyard
4.	Propeller Shaft History Source (Manufacturer and/or Vessel) Condition (Describe or sketch any known defects, calibration notches or previous repairs) Service history (Indicate to extent known)
5.	Subject (Indicate if approval demonstration, shaft repair, periodic inspection, etc.)
6.	Attendees (Shipyard, ABS, Other)
7.	NDT personnel Conducting inspection (Name, Title, Basis of Qualifications (such as SNT-TC-1A, courses))
8.	Disposition of shaft (Indicate scrap, put in service, store, etc. on the basis of items 12 through 16)
9.	This report prepared by (Name and Title of Shipyard personnel) Date
10.	This report reviewed by (Name and Title of Shipyard personnel) Date
11.	This report reviewed by (ABS Surveyor) Date

Suggested Form for Ultrasonic Inspection of Shafts (Results of Tests)

12. (Indicate on location sketches, areas covered by inspections, positions of transducers, locate and number the areas showing significant visual, magnetic particle, dye penetrant and/or ultrasonic test indications, distance of keyway end to taper end)

13. Results of Ultrasonic Inspection (Conducted with liner in place or removed. Report all significant indications including those of known origin. If none so state)

Compression		Shear
End	Shoulder	On Taper

Transducer Background Level
(% Screen height)

Indication No. (As shown on location sketches attached)
% Screen Height
Length
Dept (Estimated)
Interpretation (Crack, keyway, etc.)

14. Result of visual and other than UT inspection

Indication No. (As shown on location sketches attached)	
Length	
Depth	

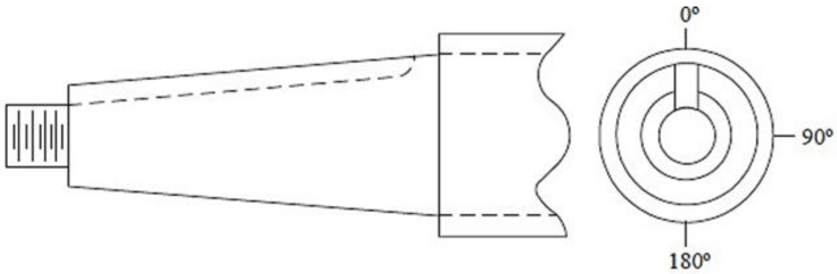
15. Discrepancies between inspections under 13 and 14 above
(Indicate presence of indication by + and absence by - in Table below)

Indication No.	Shoulder	End	Taper	Visual and other than UT	Remarks*

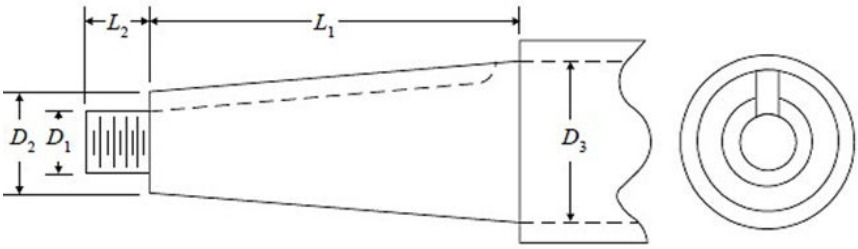
16. Results of re-inspection of shaft after any required repair
(Repair to be authorized by Materials Department)

* Report any unusual conditions which interfered with inspection, such as excessive attenuation, interfering notches, etc.

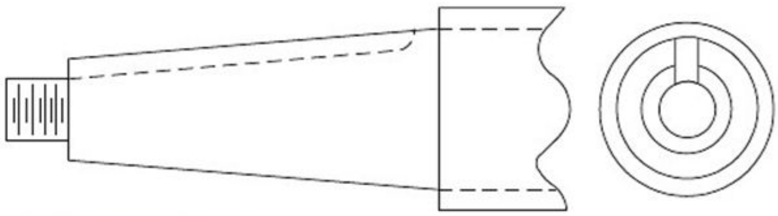
All significant indications are to be numbered 1, 2, 3, etc., prefaced by appropriate letter. When the same defect produces indication, show it as the same number in the respective sketch: S2, V2, etc.



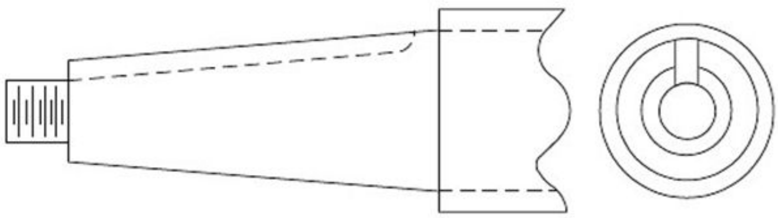
COMPRESSION (LONGITUDINAL) WAVE – END
(Preface indication Nos. with "E")



COMPRESSION (LONGITUDINAL) WAVE – SHOULDER
(Preface indication Nos. with "S")



SHEAR WAVE – TAPER
(Preface indication Nos. with "T")



VISUAL AND OTHER TESTS
(Preface indication Nos. with "V")

Details of Ultrasonic Technique

May be omitted if data was previously submitted

1. Basic instrument

   Brand and type

   Date calibrated

   Calibration method (Indicate specification (ASTM-E317-XX, etc.)

   Calibration criteria (Describe or indicate specification Mil-STD-0900-3010, etc.)

2. Transducers

Brand & model No.	Frequency (MHz)	Type (Shear or compression)	Angle size	Applicability* (Flat or contoured)

3. Couplant

4. Calibration block(s) (Include sketch(es) and indicate position(s) of transducer(s) and sound path(s))

5. Calibration settings

	Transducer	
	Compression	Shear
Distance calibration for full screen with display		
Sensitivity calibration (Indicate % full screen height or decibel level which corresponds to reference notch of calibration)		
Scanning level adjustment (Indicate % full screen height or decibel level used in scanning)		

* Indicate surface contours in range of diameters or "F" if flat.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 8

Hot-rolled Steel Bars for Machinery

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope

This section covers requirements for hot-rolled steel bars intended to be used in machinery construction, shaft and stock forgings intended to be used principally for propulsion units and stock type applications. Typical components include tail shafts, intermediate shafts, thrust shafts, other torsional shafts, bolts, rudder stocks and canard stocks, used in shipboard units.

2 Process of Manufacture *(2024)*

2.1 General *(2024)*

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.

Hot-rolled bars used in lieu of carbon-steel forgings (see Section 2-3-7) are to be fully killed, heat treated in accordance with 2-3-7/1.5.

2.3 Manufacturer Approval *(2024)*

Hot rolled bars are to be made by a manufacturer approved by ABS. ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of bar production.

Raw materials for rolled bar manufacturers such as cast steel or semi-finished products are to be manufactured at a facility approved by ABS.

2.5 Degree of Reduction *(2024)*

The cross-sectional area of the unmachined finished bar is not to exceed one-sixth of the cross-sectional area of the ingot. Also refer to 2-3-7/1.3.2.

2.7 Mechanical Properties *(2024)*

The mechanical properties are to meet the requirements of 2-3-7/1.7 for the proposed application.

2.9 Inspection *(2024)*

Hot-rolled bars used in lieu of forgings for tail shafts are to meet the nondestructive examination requirements of 2-3-7/1.13.

3 Number of Tests

i) Four 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 (2000 lb) or less, two tension tests may be taken.

ii) In any case, only one tension test will be required from any one bar.

iii) 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.

iv) 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

5 Certification *(2024)*

Certification is to be in accordance with 2-3-7/1.17.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 9

Steel Castings for Machinery, Boilers and Pressure Vessels

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

The following requirements cover steel castings intended to be used in machinery, boiler and pressure-vessel construction, such as crankshafts, turbine casings and bedplates.

Requirements for ABS grade steel castings are included in 2-3-9/13. Castings which comply with national or proprietary specifications may also be accepted, provided such specifications give reasonable equivalence to these requirements.

1.5 Manufacturer Approval and Process of Manufacture *(2024)*

Castings are to be made by a manufacturer approved by ABS. ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of casting production, that may influence the final product properties:

i) Mold preparation and chaplet positioning

ii) Pouring times and temperatures

iii) Mold breakout

iv) Heat treatment and heat treatment recording

v) Coupon preparation

vi) Testing and inspection

vii) Rectification of Defective Castings

Any of the above can be included in a Survey patrol.

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

When two or more castings are joined by welding 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.

3 Chemical Composition *(2024)*

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

Sulfur and phosphorous contents are to be less than 0.040% and silicon less than 0.60%.

To maintain weldability, carbon content is not to exceed 0.23%, or carbon equivalent (Ceq) is not to exceed 0.41%, unless specially approved.

Castings that are intended to be welded (or cladded) are to be of weldable quality.

Commentary:

i Weldability of a casting can be established through weld procedure qualification tests in accordance with ABS Rules Part 2 Chapter 4.

ii Weldability of steels with carbon content greater than 0.23% is reduced.

End of Commentary

3.1 Ladle Analysis *(2024)*

A ladle analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. 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 is to be carried out.

The chemical composition thus determined is to be reported and is to conform to the requirements of the applicable ABS grade in 2-3-9/13 or recognized national standard or proprietary specification.

3.3 Product (Check) Analysis *(2024)*

When required by the specification, the product (check) analysis is to be performed in accordance with ASTM A751 or of other recognized national standards may be applied. The chemical composition determined by check analysis is to meet requirements of the applicable ABS grade in 2-3-9/13 or recognized national standard or proprietary specification.

5 Heat Treatment *(2024)*

Heat treatment facilities used in producing ABS certified castings are to be approved by ABS.

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

A heat treatment facility (independent or sub-contracted) can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

The ABS 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 heat treated using one of the following procedures in a furnace of suitable proportions to bring the castings to a uniform temperature above the transformation range on the annealing or normalizing cycle, unless otherwise approved:

i) Fully annealed

ii) Normalized

iii) Normalized and tempered

iv) Quenched and tempered

For all types of steel, the tempering temperature is to be not less than 550°C (1022°F), unless specifically agreed with ABS Materials Department.

The furnaces are to be maintained and have adequate means for control and recording temperature. Castings are to be held soaking at the proper temperature for at least a length of time equivalent to one hour per 25.5 mm (1 in.) of thickness of the heaviest member.

No annealed casting is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C (850°F). Thermocouples are to be connected to the furnace charge to measure and record that its temperature is uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Local heating or cooling and bending and straightening of annealed castings are not permitted, except with the agreement of the Surveyor.

Commentary:

If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses. The stress relief temperature should be established in conjunction with the final heat treatment temperature and must not negatively affect the physical properties of the casting.

End of Commentary

The foundry 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.

7 Mechanical Properties *(2024)*

7.1 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet the requirements of the applicable ABS grade in 2-3-9/13 or a recognized national standard or proprietary specification. The alternative recognized national standard or proprietary specification is to at least meet the minimum tensile properties for ABS grade 1 steel casting unless a lower tensile property is approved to meet the design requirements.

7.3 Impact Properties *(2024)*

Charpy V-notch impact tests are to be carried out as noted below:

Minimum Specified Yield Strength, N/mm² (kgf/mm², ksi)	*Minimum Average Absorbed Energy, J (kgf-mm, ft-lbf)*	*CVN Test Temperature(1)*
205-690 (21-70, 30-100)	27 (2.8, 15)	At 20°C or at design service temperature, whichever is lower

Note:

1 When applicable, refer to Section 5C-8-6 or Section 5C-13-7 or Part 6 Chapter 2 of the *Marine Vessel Rules*.

9 Application

9.1 General and High-temperature Applications *(2024)*

Any of the ABS grades, identified in 2-3-9/13, may be used for miscellaneous applications. ABS 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 exceed 427°C (800°F). See 4-6-2/3.1.3 of the *Marine Vessel Rules*.

9.3 Alloy Steels or Special Carbon Steels

When alloy steels or carbon steels differing from the requirements of 2-3-9/13 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 A356 or A217 Grades WC1, WC6, or WC9, or other steels suitable for the intended service will be considered.

11 Test Specimens

11.1 Material Coupons *(2016)*

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).

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each casting. The physical properties are to be determined from test specimens prepared from coupons which, except as specified in 2-3-9/11.3, 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 detached until the heat treatment of the castings has been completed, nor until the coupons have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

Where the casting finished mass exceeds 10,000 kg (22,000 lb) or is of complex design, two test samples are to be provided. Where 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 is the diameter of the largest theoretical sphere which can be inscribed within the volume of the casting.

11.3 Separately Cast Coupons

In the case of 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.

11.5 Number of Tests

11.5.1 Machinery Castings *(2005)*

At least one tension test is to be made from each heat in each heat-treatment charge except where two or more samples are required as indicated in 2-3-9/11.1. If the manufacturer's quality-control procedure includes satisfactory automatic chart recording of temperature and time, then one tension test from each heat for castings subject to the same heat-treating procedure may be allowed at the discretion of the attending Surveyor.

11.5.2 Steel Propeller Castings

One tension test is to be made from each blade of a built-up propeller, 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.

11.7 Retests *(2005)*

If the results of the physical tests for any casting or any lot of castings do not conform to the requirements specified, the manufacturer may reheat-treat castings or lots of castings that have failed to meet test requirements. Two additional test samples representative of the casting or casting batch may be taken. If satisfactory results are obtained from both additional tests, the casting or batch of castings is acceptable. If one or both retests fail, the casting or batch of castings is to be rejected.

13 ABS Grade Steel Castings for Machinery, Boilers, and Pressure Vessels *(2024)*

ABS grade steel castings for other machinery applications may be manufactured in accordance with the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 1
Steel Castings for Machinery, Boilers, and Pressure Vessels *(2024)*

ABS Designation (1)	*ASTM Specification*	*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	ASTM A27	60-30	415 (42, 60000)	205 (21.0, 30000)	24	22	35
2	ASTM A27	70-36	485 (49, 70000)	250 (25.5, 36000)	22	20	30
3	ASTM A216	WCA	415 (42, 60000)	205 (21.0, 30000)	24	22	35
4	ASTM A216	WCB	485 (49, 70000)	250 (25.5, 36000)	22	20	35

Note:

1 Requirements for chemical composition (2-3-9/3), impact properties (2-3-9/7.3) and test specimens (2-3-9/11) are also required to be met.

15 Inspection and Repair

15.1 General *(1 July 2023)*

All castings are to be examined by the Surveyor after final heat treatment and thorough cleaning and they are to be found free from defects. Where applicable internal surfaces are to be inspected, surfaces are not to be hammered or peened or treated in any way which may obscure defects.

For welded composite cast 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 upon with ABS.

Part 2, Appendix 6 is regarded as an example of an acceptable standard specifying suitable minimum inspection requirements for castings.

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

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

When required by the relevant construction Rules, castings are to be pressure tested before final acceptance. The tests are to be carried out in the presence and to the satisfaction of the attending Surveyor.

15.3 Minor Defects *(2006)*

Defects are to be considered minor when the cavity prepared for welding has a depth not greater than 20% of the actual wall thickness, 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 resulting from the removal of defects may be accepted, provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Repairs of minor defects where welding is required are to be treated as weld repairs and repaired in accordance with an approved procedure. Minor defects in critical locations are to be treated as, and repaired in the same manner as, major defects.

15.5 Major Defects

Defects other than minor defects with dimensions greater than those given in 2-3-9/15.3 above, may, with the Surveyor's approval, be repaired by welding using an approved procedure.

15.7 Welded Repair *(2018)*

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

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

Before 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 work intended.

Removal of defects and weld repair are to be carried out in accordance with a recognized standard. See Part 2, Appendix 6. The defects are to be removed to sound metal, and before welding, the excavation is to be investigated by suitable approved, nondestructive examination methods to verify 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.

Temporary welds made for operations such as lifting, handling, staging, etc., are to be carried out to qualified welding procedures and qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

15.7.1 Weld Procedure Qualification for Repair of Castings *(1 July 2023)*

i) Castings are required to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs.

ii) Welding procedures are to be qualified and are to be appropriate for the delivery condition of the casting. Qualification of welding procedures is to follow Appendix 2-A9-1.

iii) Welding is to be performed in protected conditions free from adverse weather conditions, such a rain and drafts that could adversely affect weldment properties.

iv) Welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties are obtained after heat treatment as detailed in 2-3-9/7.

Commentary:

Recommendation for welding: For steels with $C \geq 0.23$ or $Ceq \geq 0.45$, the WPQT on which the WPS is based, should be qualified on a base material having a Ceq as follows: the Ceq of the base material should not fall below more than 0.02 of the material to be welded. (Example: WPQT for a material with actual $Ceq = 0.50$ may be qualified on a material with $Ceq \geq 0.48$.)

As far as possible, all welding is to be carried out in the downhand (flat) position.

End of Commentary

15.9 Postweld-repair Heat Treatment *(2024)*

All welded repairs of defects are to be given a suitable postweld heat treatment, as indicated in 2-3-9/5, or subject to the prior agreement of the ABS 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 2-1-5/13.

Commentary:

Subject to prior agreement by ABS, special consideration may be given to the omission of post weld heat treatment or to the acceptance of local stress-relieving heat treatment and depending upon the criticality of the location where the repaired area is small and machining of the casting has reached an advanced stage.

End of Commentary

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

The manufacturer is to maintain full records detailing 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 available to the Surveyor and copies provided on request.

15.11 Crankshaft Castings *(2024)*

The foregoing provisions may not apply in their entirety to the repair of crankshaft castings. In the case of repair of crankshaft castings, the applicable procedures and extent of repairs will be subject to ABS technical assessment and approval. All castings for crankshafts are to be suitably preheated prior to welding.

17 Nondestructive Testing *(2005)*

When required by the relevant construction Rules or by the approved procedure for welded 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 ABS. Part 2, Appendix 6 is regarded as an example of an acceptable standard. Additional NDE is to be considered at chaplet locations and areas of expected defects.

18 Identification and Marking

18.1 Identification *(2005)*

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

18.3 Marking *(2005)*

The manufacturer's name or identification mark and pattern number is to be cast on all castings, except those so small as to make this type of marking impracticable. The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor are to be stamped on all castings accepted in such a location as to be discernible after machining and installation. Grade 1, 2, 3 and 4 castings are to be stamped **AB/1**, **AB/2**, **AB/3**, and **AB/4**, respectively. In addition, 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.

19 Certification *(2005)*

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

i) Purchaser's name and order number

ii) Description of forgings and steel quality

iii) Identification number

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

v) Results of mechanical tests

vi) Results of nondestructive tests, where applicable

vii) Details of heat treatment, including temperature and holding times.

viii) Where applicable, test pressure.

ix) Specification

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 10

Ductile (Nodular) Iron Castings (2006)

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR8	The iron making is to be capable of producing iron within the specified chemical limits and quality requirements.
MAT-FR9	Chemical composition is to be appropriate to achieve the specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that could occur in materials which can be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the Goals and Functional Requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

i) Spheroidal or nodular graphite iron castings, as defined in the relevant construction Rules, are to be manufactured and tested in accordance with the requirements of this Section.

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

iii) Requirements for ABS grade ductile iron castings are provided in 13. Alternatively, castings which comply with recognized national standards or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

Commentary:

Ambient temperature is defined at above -10°C for vessels and 0°C for offshore structures.

End of Commentary

3 Process of Manufacture *(2024)*

3.1 Manufacturer Approval *(2024)*

Ductile iron castings (for example, castings that are required to be certified per 4-2-1/1.1 TABLE 1 of the *Marine Vessel Rules*) are to be made at ABS-approved foundries where the manufacturer has demonstrated to the satisfaction of ABS that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of casting production that may influence the final product properties:

i) Mold preparation and chaplet positioning

ii) Pouring times and temperatures

iii) Mold breakout

iv) Heat treatment and heat treatment recording

v) Coupon preparation

vi) Testing and inspection

vii) Casting rectification.

Any of the above can be included in a Survey patrol.

3.3 Fettling Procedures *(2024)*

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.

3.5 Temporary Attachments *(2024)*

Temporary attachments for handling are to be cast integrally or threaded. Welding of temporary attachments is to be avoided.

5 Chemical Composition

The chemical composition of the iron used is left to the discretion of the manufacturer, who is to verify that it is suitable to obtain the mechanical properties specified for the castings. The chemical composition of the ladle samples is to be reported to ABS.

7 Heat Treatment *(2024)*

Heat treatment facilities used in producing ABS certified castings are to be approved by ABS.

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

A heat treatment facility (independent or sub-contracted) can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

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

Castings may be supplied in either the as cast or heat-treated condition. For applications such as high temperature service or where dimensional stability is important, it may be required that castings be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining. The materials denoted in 13.3 TABLE 1 are to undergo a ferritizing heat treatment.

Where it is proposed to locally harden the surfaces of a casting, full details of the proposed procedure and specification are to be submitted to ABS for approval.

9 Mechanical Properties *(2024)*

9.1 Tensile Properties

Tension tests are to be performed to determine ultimate tensile strength and elongation, unless otherwise agreed upon. The results are to meet the requirements of the applicable ABS Grade in 13 or a recognized national standard or proprietary specification that meets design requirements.

9.3 Impact Properties

When applicable, Charpy V-notch impact tests are to be carried out if the design service temperature is below the ambient temperature.

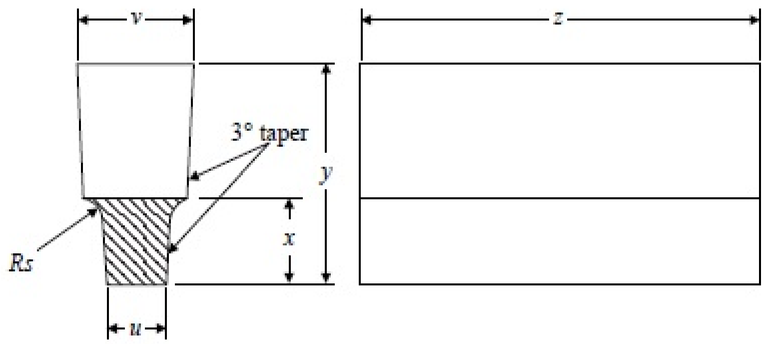
Minimum Specified Tensile Strength, N/mm^2 (ksi)	*CVN Value Average (Minimum)*	*CVN Test Temperature*
350 (51)	17J (14J)	+20°C
400 (58)	14J (11J)	

11 Mechanical Tests *(2024)*

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

ii) The test samples are generally to be one of the standard types detailed in 2-3-10/Figures 1, 2 and 3 with a thickness of 25 mm (1.0 in.). Test samples of other dimensions to 2-3-10/Figures 1, 2 and 3 may, however, be specially required for some components.

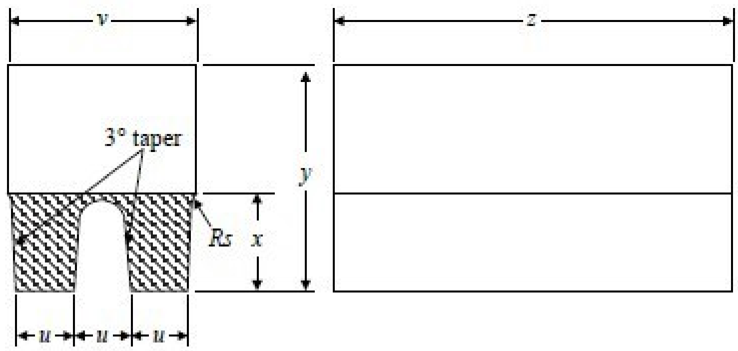
FIGURE 1
Type A Test Samples (U-type)



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)	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)

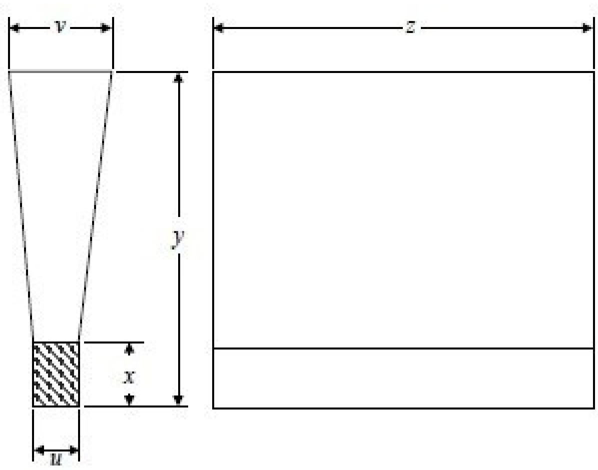
z	To suit testing machine
Rs	Approximately 5 mm (0.20 in.)

FIGURE 2
Type B Test Samples (Double U-type)



Dimensions – mm (in.)	*Standard Sample*
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 3
Type C Test Samples(Y-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 sample	40 (1.6)	40 (1.6)	80 (3.2)	80 (3.2)

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

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

v) As an alternative to 11.iii., a batch testing procedure may be adopted for castings with a fettled mass of 1,000 kg (2,200 lb) or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2,000 kg (4,400 lb) of fettled castings in the batch.

vi) Where separately cast test samples are used, they are to be cast in molds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the molds until the temperature is below 500°C (930°F).

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

viii) Where castings are supplied in the heat treated condition, the test samples are to be heat treated to gether with the castings which they represent.

ix) One tensile specimenis to be prepared from each test sample and is to be machined to the dimensions given in 2-3-1/11.13 FIGURE 2. Note that for nodular cast iron with an elongation less than 10%, the radius $R \geq 20$ mm (0.8 in.).

x) All tensile tests are to be carried out using test procedures in accordance with Section 2-3-1. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

xi) Impact tests may additionally be required. In such cases, a set of three specimens of an agreed type is to be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with 2-1-1/16 FIGURE 4.

xii) Where small castings are produced in large quantities, the manufacturer may employ alternative procedures for testing and inspection subject to approval by ABS.

xiii) Where castings of the same type are regularly produced in quantity, the manufacturer is to perform tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued effectiveness of the manufacturing technique. The Surveyor is to witness these tests.

13 Requirements for ABS Grade Ductile Iron Castings *(2024)*

13.1 General *(2024)*

ABS grade ductile iron castings may be manufactured in accordance with the requirements of the ASTM grade referenced in 13.3 TABLE 1 to meet the design requirements, the additional requirements identified in this section and any specific requirements of the relevant Rules.

13.3 Retests *(2024)*

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

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

TABLE 1
Mechanical Properties for ABS Grade Ductile (Nodular) Cast Iron *(2024)*

ABS Designation	*ASTM Specification*	*Grade*	*0.2% Proof Stress, N/mm^2 (ksi)*	*Specified Minimum Tensile Strength, N/mm^2 (ksi)*	*Elongation on 5.65 So (%) minimum*	*Typical Structure of Matrix See 17*
DI 1	ASTM A536	60-40-18	276 (40)	415 (60)	18	Ferrite
DI 2	ASTM A536	65-45-12	310 (45)	448 (65)	12	Ferrite/Pearlite
DI 3	ASTM A536	80-55-06	379 (55)	552 (80)	6	Ferrite/Pearlite
DI 4	ASTM A536	100-70-03	483 (70)	690 (100)	3	Pearlite

15 Inspection *(2024)*

i) All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any waywhich may obscure defects. Castings are to be free from surface or internal defects which would prove 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.

ii) All castings are to be visually examined by the Surveyor including, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer

iii) Supplementary examination of castings by suitable nondestructive test 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.

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

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

vi) Cast crankshafts are to be subjected to a magnetic particle inspection. Crack-like indications are not allowed.

17 Metallographic Examination

i) For crankshafts, a metallographic examination is to be carried out.

ii) When required, a representative sample from each ladle of treated metal is to be preparedfor metal lographic examination. These samples may be taken from the tensile test specimens but alternative arrangements for the provisions of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

iii) Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in 13.3 TABLE 1 and are intended for information purposes only.

19 Rectification of Defective Castings

19.1 Grinding *(2024)*

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

19.3 Cosmetic Repairs *(2024)*

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

19.5 Weld Repair *(2024)*

Repairs by welding are generally not permitted.

21 Identification and Marking of Castings *(2024)*

21.1 Identification *(2024)*

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

21.3 Marking *(2024)*

Before acceptance, all castings, which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

i) Grade of cast iron

ii) Identification number or other marking enabling the full history of the casting to be traced.

iii) Manufacturer's name or trademark.

iv) Date of final inspection.

v) Personal stamp of Surveyor responsible for inspection

vi) Test pressure, if applicable

21.5 Special Cases *(2024)*

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

23 Certification

The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casing or batch of castings which has been accepted:

i) Purchaser's name and order number

ii) Description of castings and quality of cast iron

iii) Identification number

iv) Results of mechanical tests

v) Where applicable, general details of heat treatment *vi)* Where specifically required, the chemical analysis of the ladle samples

vii) Where applicable, test pressure

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 11

Gray-iron Castings *(2006)*

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR8	The iron making is to be capable of producing iron within the specified chemical limits and quality requirements.
MAT-FR9	Chemical composition is to be appropriate to achieve the specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that could occur in materials which can be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

Gray-iron castings, as defined in the relevant construction Rules, are to be manufactured and tested in accordance with the requirements of this Section.

Requirements for ABS grade gray-iron castings are provided in 13. Alternatively, castings which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet specific requirements.

3 Process of Manufacture

3.1 Manufacturer Approval *(2024)*

Gray iron castings (for example, castings that are required to be certified per 4-2-1/15 TABLE 6 of the *Marine Vessel Rules*) are to be made at ABS-approved foundries where the manufacturer has demonstrated to the satisfaction of ABS that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of casting production, that may influence the final product properties.

i) Mold preparation and chaplet positioning

ii) Pouring times and temperatures

iii) Mold breakout

iv) Heat treatment and heat treatment recording

v) Coupon preparation

vi) Testing and inspection

vii) Casting rectification

Any of the above can be included in a Survey patrol.

3.3 Fettling Procedures *(2024)*

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.

3.5 Temporary Attachments *(2024)*

Temporary attachments for handling are to be cast integrally or threaded. Welding of temporary attachments is to be avoided.

5 Chemical Composition

The chemical composition of the iron used is left to the discretion of the manufacturer, who is to verify that it is suitable to obtain mechanical properties specified for the castings. The composition of ladle sample is to be reported to ABS.

7 Heat Treatment *(2024)*

Heat treatment facilities used in producing ABS certified castings are to be approved by ABS.

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

A heat treatment facility (independent or sub-contracted) can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the NDE requirements of the Rules or applicable standard, and that there is a feedback system to confirm same during production.

The ABS Surveyor is to attend the heat treatment facilityduring qualification, to verify that the heat treatment process is carried out according to specification.

Castings may be supplied in either the as cast or heat-treated condition. For applications such as high temperature service or where dimensional stability is important, it may be required that castings be given a suitable tempering or stress relieving heat treatment.

9 Mechanical Properties *(2024)*

9.1 Tensile Properties

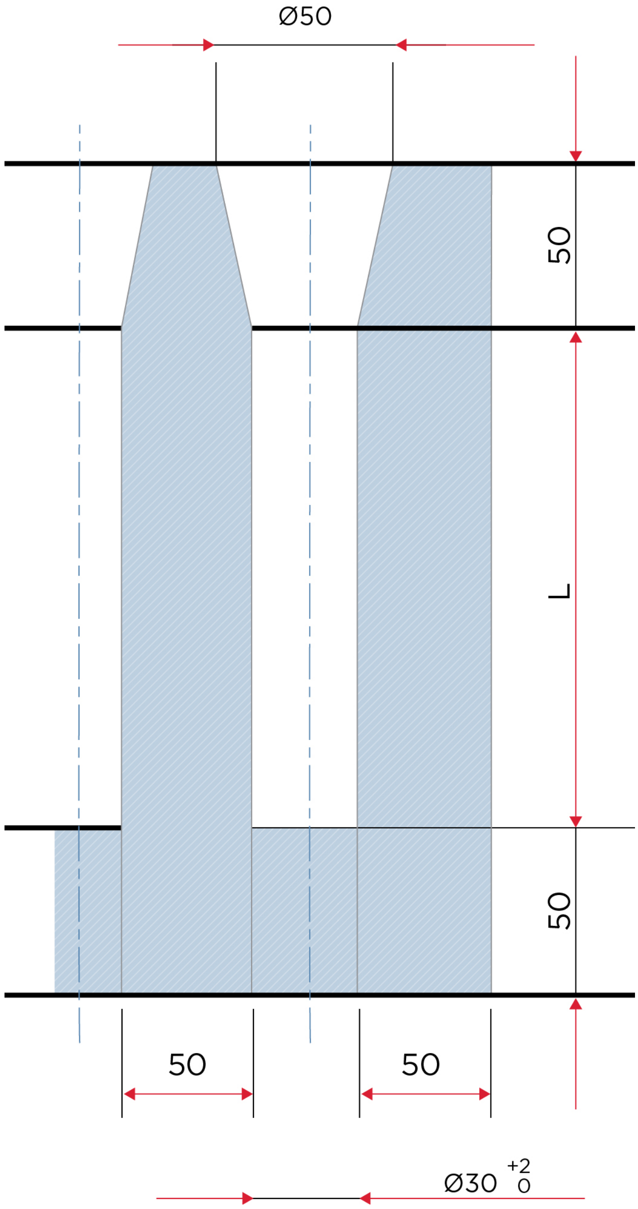
Tension tests are to be performed to determine ultimate tensile strength, unless otherwise agreed. The results are to meet the requirements of the applicable ABS grade in 13 or a recognized national standard or proprietary specification that meets design requirements.

11 Mechanical Tests *(2024)*

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

ii) 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 as given in the figure below.

FIGURE 1
Test Sample for Gray-iron Casting (Dimensions in millimeters) *(2024)*



iii) 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.

iv) With the exceptionof 11.vii, at least one test sample is to be cast with each batch.

v) With the exception of 11.vi., 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.

vi) For large mass casting 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 is not to be accelerated beyond the capacity of the caster.

vii) If one grade of cast iron is melted in large quantities and production is monitored by systematic ch ecking of the melting process, such as a chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals, as agreed by the Surveyor.

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

ix) 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 is not be removed from the casting until after the heat treatment.

x) 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 2-3-1/11.13 FIGURE 3. Where test samples of other dimensions are specially required, the tensile test specimens are to be machined to agreed dimensions.

xi) All tensile tests are to be carried out using test procedures in accordance with Section 2-3-1. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

xii) Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of ABS.

xiii) Where castings of the same type are regularly produced in quantity, the manufacturer is to perform tests as necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued effictiveness of the manufacturing technique. The Surveyor is to witness these tests.

13 Requirements for ABS Grade Gray-Iron Castings *(2024)*

13.1 General *(2024)*

ABS grade gray-iron castings may be manufactured in accordance with the requirements of the ASTM grade referenced in 13.5 TABLE 1 to meet the design requirements, the additional requirements identified in this section and any specific requirements of the relevant construction Rules.

13.3 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.

13.5 Retests *(2024)*

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

TABLE 1
Tensile Properties for ABS Grade Gray-iron Castings *(2024)*

ABS Designation	*ASTM Specification*	*Grade/Class*	*Specified minimum Tensile strength, N/mm^2 (ksi)*
GI 1	ASTM A48	No. 30	207 (30)
GI 2	ASTM A48	No. 40	276 (40)

15 Inspection *(2024)*

i) All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects. Castings are to be free from surface or internal defects which would prove 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.

ii) All castings are to be visually examined by the Surveyor including the examination of internal surfaces where applicable. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

iii) Supplementary examination of castings by suitable nondestructive testing procedures is not required unless otherwise stated on the approved plan or in circumstances where there is reason to suspect the soundness of the casting.

iv) When requiredby the relevant construction Rules, castings are to be pressure tested before final ac ceptance.

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

17 Rectification of Defective Casting

17.1 Grinding *(2024)*

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

17.3 Cosmetic Repairs *(2024)*

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

17.5 Weld Repair *(2024)*

Repairs by welding are generally not permitted. In cases where welding is proposed, full details of the proposed repair are to be submitted for review prior to commencing the repair.

19 Identification and Marking of Castings *(2024)*

19.1 Identification *(2024)*

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

19.3 Marking *(2024)*

Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

i) Grade of cast iron

ii) Identification number or other marking enabling the full history of the casting to be traced.

iii) Manufacturer's name or trademark.

iv) Date of final inspection

v) Personal stamp of Surveyor responsible for inspection

vi) Test pressure, if applicable

19.5 Special Class *(2024)*

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

21 Certification

The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:

- Purchaser's name and order number
- Description of castings and quality of cast iron
- Identification number
- Results of mechanical test
- Where applicable, general details of the heat treatment
- Where specifically required, the chemical analysis of ladle samples
- Where applicable, test pressures

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 12

Steel Piping

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of steel pipes.

Requirements for ABS grade pipes are provided in 41. Alternatively, pipes which comply with recognized national standards or proprietary specifications may be accepted by ABS, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric furnace, electroslag remelt, vacuum-arc remelt, or such other process as may be specifically approved by ABS. The steel is to be killed, and either be cast in ingots or strand (continuous) casting. A sufficient discard is to be made from each ingot to secure freedom from injurious piping and undue segregation.

7 Marking *(2024)*

Identification markings are to be legibly stenciled, stamped, or rolled on each length of pipe, except that 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:

i) Name or brand of the manufacturer

ii) Name and type of material grade (ABS or other)

iii) Heat number or manufacturer's number by which the heat can be identified *iv)* Test pressure or the letters "NDE"

v) Method of forming (i.e., butt-welded, lap-welded, electric-resistance-welded or seamless hot-finished or cold-drawn)

vi) “XS” for extra strong or “XXS” for double-extra strong (when applicable)

vii) ABS markings by the Surveyor

9 Chemical Composition *(2024)*

The chemical composition is to meet requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

11 Ladle Analysis *(2024)*

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition is to conform to the requirements specified in 2-3-12/9.

13 Product (Check) Analysis *(2024)*

When required by the specification, product (check) analysis is be performed in accordance with ASTM A751 or other recognized national standards as agreed upon by ABS. The chemical composition is to conform to the requirements specified in 9.

14 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for controlling and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

15 Mechanical Tests Required *(2024)*

Mechanical tests and results are to be in accordance with requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification. For a description and the requirements of each test see 2-3-12/17 through and including 2-3-12/29. For retests see 2-3-12/33.

17 Tension Test Specimens *(2024)*

Tension test specimens are to be in accordance with requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

19 Bend and Flattening Test Specimens

Test specimens for the bend and flattening tests are to consist of sections cut from a pipe and the specimens for flattening tests are to be smooth on the ends and free from burrs, except when made on crop ends.

21 Testing Temperature *(2024)*

All tests are to be carried out at room temperature.

23 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 41 or a recognized national standard or proprietary specification as agreed with design.

25 Bend Test *(2024)*

When required, bend tests are performed and meet the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

27 Flattening Test *(2024)*

When required, flattening test is to be performed and meet the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

29 Hydrostatic Test

29.1 General *(2024)*

When applicable, hydrostatic testing is to be performed and meet the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

29.3 Exceptions *(2024)*

The maximum test pressure for special service pipes, such as diesel engine high pressure fuel injection piping, is subject to ABS technical assessment and approval. The manufacturer is to submit the proposed maximum test pressure along with technical justification and manufacturing control process for the piping. The justification is to include pipe fiber stress analysis and substantiating prototype test results.

31 Nondestructive Examination *(2024)*

31.1 General *(2024)*

When applicable, nondestructive examination is to be performed to meet the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

31.3 Affidavits

When each tube is subjected to an approved nondestructive electric test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

33 Retests *(2024)*

For all grades of pipe, if the results of the mechanical tests of any lot do not conform to the requirements, retests may be made on additional pipe of double the original number from the same lot, each of which is to conform to the requirements specified. In addition, retests are to be performed and meet the requirements of the applicable ABS grade in 41 or recognized national standard or proprietary specification.

35 Pipe Testing and Inspection

35.1 Class I and Class II Piping *(2024)*

Pipes intended for use in Class I and Class II piping systems (see 4-6-1/5, *Rules for Building and Classing Marine Vessels*) are to be tested, preferably at the mill, to the satisfaction of the Surveyor. See also 4-6-7/3.5.1 of the *Rules for Building and Classing Marine Vessels*.

35.3 Finish *(2024)*

i) The pipes are to be reasonably straight, free from defects, and have a workmanlike finish. At a minimum, the finished pipe is to be visually inspected to the same frequency as that required for the tension tests specified in 17 for the applicable grade.

ii) Welding repair to the pipe is not to be carried out without the purchasers approval and is to be the Surveyors satisfaction.

iii) The material surfaces may be examined by the Surveyor when specifically requested by the purchaser.

37 Permissible Variation in Wall Thickness

The permissible variations in wall thickness for all pipe are based on the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application regardless 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 17 for the applicable grade.

39 Permissible Variations in Outside Diameter and Other Dimensions *(2024)*

The permissible variations in outside diameter and other dimensions, as applicable, for all pipe are based on the purchase order and are to conform to that given in the applicable ASTM designation for acceptance. At a minimum, the finished pipe is to be measured at the same frequency as that required for the tension test specified in 17 for the applicable grade.

41 ABS Grade Steel Piping *(2024)*

ABS grade pipes may be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 1
ABS Grade Steel Piping *(2024)*

ABS Designation	*ASTM Specification* (3, 4)	*Grade*	*Yield Strength, N/mm^2 (kgf/mm^2, ksi)*	*Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*
1	ASTM A53	A(1)	205 (21, 30)	330 (33.7, 48)
2	ASTM A53	A(2)	205 (21, 30)	330 (33.7, 48)
3	ASTM A53	B(2)	240 (24.5, 35)	415 (42, 60)
4	ASTM A106	A	205 (21, 30)	330 (33.7, 48)
5	ASTM A106	B	240 (24.5, 35)	415 (42, 60)
6	ASTM A335	P1	205 (21, 30)	380 (39, 55)
7	ASTM A335	P2	205 (21, 30)	380 (39, 55)
8	ASTM A135	A	205 (21, 30)	330 (33.7, 48)
9	ASTM A135	B	240 (24.5, 35)	415 (42, 60)
10	ASTM A335	P11	205 (21, 30)	415 (42, 60)
11	ASTM A335	P12	220 (22, 32)	415 (42, 60)
12	ASTM A335	P22	205 (21, 30)	415 (42, 60)
13	ASTM A335	P5	205 (21, 30)	415 (42, 60)

Notes:

1. Type F - Furnace Welded.
2. Type S – Seamless Welded or Type E – Electric Resistance Welded.
3. Refer to ASTM A530 or ASTM A999 for general requirements of steel piping depending on the ASTM grade.
4. Refer to the applicable ASTM standard for the properties for the grade. Tensile properties in this table are provided for reference.

43 Welding *(2024)*

All grades proposed for steel piping are to be suitable for welding. Welding procedures are to be in accordance with Section 2-4-2.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 13

Piping, Valves and Fittings for Low-temperature Service [Below -18°C (0°F)]

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of pipes, castings and forgings intended for piping, valves and fittings for design temperatures lower than -18°C (0°F).

Requirements for ABS grades for piping, valves and fittings for low temperature applications are provided in Section 2-3-13/33. Alternatively, components which comply with recognized national standards or proprietary specifications may be accepted by ABS, provided such specifications give reasonable equivalence to these requirements and meet specific requirements.

Materials for Liquefied Gas Carrier are to comply with Section 5C-8-6 of the *Marine Vessel Rules.*

Materials for vessels using Gases or other Low-Flashpoint Fuels are to comply with the applicable requirements of Section 5C-13-7 of the *Marine Vessel Rules*.

Materials for vessels intended to carry refrigerated cargoes are to comply with the applicable requirements of Part 6, Chapter 2 of the *Marine Vessel Rules*

5 Manufacture *(2024)*

i) The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen or electric furnace, electroslag remelt, vacuum-arc remelt, or such other process as may be specifically approved by ABS.

ii) The steel is to be killed, and either be cast in ingots or may be strand (continuous) casting.

iii) Piping, casting and forgings intended for low temperature applications are also required to meet the relevant section in Part 2, Chapter 3.

7 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for controlling and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-13/33 or recognized national standard or proprietary specification.

9 Marking *(2024)*

Marking is to include all the information as per applicable ABS grade in 2-3-13/33 or recognized national standard or proprietary specifications.

The name or brand of the manufacturer is to be legibly marked on each pipe, flange and fitting. The ABS grade and initials **AB** are to be placed on the material near the marking of the manufacturer.

11 Chemical Composition

11.1 Ladle Analysis *(2024)*

An analysis of each heat of steel is to be made by the manufacturer to determine the percentage of the elements specified. This analysis is to be made from a test sample taken during pouring of the heat. The chemical composition thus determined is to be reported and is to meet requirements of the applicable ABS grade in 2-3-13/33 or other recognized national standard or proprietary specification.

11.3 Product (Check) Analysis *(2024)*

When required by the specification, product (check) analysis is be performed in accordance with the applicable recognized standard for the material grade in 2-3-13/33 or as agreed with ABS. The chemical composition determined by check analysis is to meet requirements of the applicable ABS grade in 2-3-13/33 or other recognized national standard or proprietary specification.

13 Mechanical Tests

13.1 Tests and Results *(2024)*

Mechanical tests and results are to be in accordance with the requirements of the applicable ABS grade in 2-3-13/33, or a recognized national standard or proprietary specification to meet design requirements.

13.3 Supplementary Tests *(2024)*

Other supplementary tests, such as, special impact tests, non-destructive examination, grain size, corrosion test, may be performed when required by the purchaser.

15 Impact Properties *(2024)*

i) Materials selected from 2-3-13/33 are not to be used at temperatures lower than those indicated in 2-3-13/17.

ii) CVN impact tests are to be performed to meet the below requirements. Testing is to consist 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 made from each heat in each heat treatment charge.

iii) Subsize impact specimens may be in accordance with 2-1-2/11.5. Where material thicknesses are such that the quarter size impact specimen cannot be obtained, the requirements for toughness testing will be subjected to ABS technical assessment and approval.

iv) Where the test temperature is determined to be below -196°C (-320°F), testing may be conducted at -196°C (-320°F).

ABS Grade	*CVN Test Temperature* (1)	*Minimum Average Longitudinal CVN Value, J (kgf-mm ft-lbf)*	*Minimum Single Longitudinal CVN Value,J (kgf-mm ft-lbf)*
1L, 2L	5.5°C (10°F) below the minimum design service temperature	27 (2.8, 20)	18.5 (1.9, 13.5)
3L, 4L, 5L	5.5°C (10°F) below the minimum design service temperature	34 (3.5, 25)	22.5 (2.3, 16.5)

Note:

1 When applicable, refer to Section 5C-8-6 or Section 5C-13-7 or Part 6, Chapter 2 of the *Marine Vessel Rules*, as noted in 2-3-13/3.

17 Steels for Service Temperatures Between -18°C (0°F) and -196°C (-320°F)

The following grades may be used for the minimum design service temperature indicated.

Grade	*Minimum Design Service Temperature °C (°F)*
1L	-34 (-30)
2L	-46 (-50)
3L	-73 (-100)
4L	-101 (-150)
5L & 6L	-196 (-320)

19 Steels for Service Temperatures Below -196°C (-320°F)

Steels intended for service temperatures below -196°C (-320°F) are to be austenitic stainless steels. The chemical composition, heat treatment and tensile properties of these materials are to be submitted for each application.

21 Materials for Nuts and Bolts *(2024)*

The following grades may be used for nuts and bolts at the minimum design service temperature indicated.

Product	*ASTM Specification*	*Grade*	*Minimum Design Service Temperature °C (°F)*
Ferritic-alloy Nuts	ASTM A194	Grade 4	-101 (-150)
Ferritic-alloy Bolts	ASTM A320	L43	-101 (-150)
Austenitic-alloy Nuts	ASTM A194	8T, 8F	-196 (-320)
Austenitic-alloy Bolts	ASTM A320	B8T, B8F and B8M	-196 (-320)

23 <No Text>

25 <No Text>

27 Witnessed Tests *(1 July 2024)*

Pipes intended for temperature at or below -18°C (0°F) and valves, castings and forgings of pipe fittings intended for application at a working temperature at or below -55°C (-67°F) are to be tested in the presence of the Surveyor. Materials intended for the fabrication of pipes, valves and pipe fittings under low temperature conditions other than those aforementioned are to be tested by the manufacturers and, upon request, the test results are to be submitted to ABS.

For vessels intended to carry Liquefied Gases in Bulk, see 5C-8-6/2.2 of the *Marine Vessel Rules*.

29 Retests *(2024)*

When any of the mechanical tests fail to meet the specified requirements, retests may be made on additional material from the same lot in accordance with the requirements of the applicable ABS grade in 2-3-13/33 or recognized national standard or proprietary specifications. Each additional test is to conform to the specified requirements.

When the material fails to meet the specified average energy absorption requirements for the impact test, but the value is not below the minimum impact energy permitted for one specimen, retests are permitted in accordance with specific ABS grades or Rules or recognized national standard.

31 Welding *(2024)*

All grades proposed for piping, valves and fittings are to be suitable for welding. Welding procedures are to be in accordance with Part 2, Chapter 4.

33 ABS Grade Piping, Valves, Fittings for Low-temperature Service *(2024)*

ABS grade piping, valves and fittings may be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in the table below to meet the design requirements.

TABLE 1
ABS Grade Piping, Valves, Fittings for Low-temperature Service

ABS Designation(1,2)	*ASTM Specification*	*Grade*	*Yield Strength, N/mm² (kgf/mm², ksi)*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)*	*Elongation*(3)
1L (Carbon Steel)	ASTM A333	Grade1	205 (21, 30)	380 (39, 55)	35
		Grade 6	240 (24, 35)	415 (42, 60)	30
	ASTM A334	Grade1	205 (21, 30)	380 (39, 55)	35
		Grade 6	240 (24, 35)	415 (42, 60)	30
	ASTM A350	Grade LF1	205 (30)	415–585 (60-85)	25
		Grade LF2	250 (36)	485–655 (70, 95)	22
	ASTM A352	Grade LCB	240 (35)	450–620 (65, 90)	25
	ASTM A420	Grade WPL6	240 (35)	415-655 (60- 95)	22

ABS Designation[1,2]	*ASTM Specification*	*Grade*	*Yield Strength, N/mm² (kgf/mm², ksi)*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)*	*Elongation*[3]
2L (0.5 Mo)	A352	Grade LC1	240 (35)	450–620 (65.0–90.0)	24
3L (2.5 Ni)	A333	Grade 7	240 (35)	450 (65)	30
	A334	Grade 7	240 (35)	450 (65)	
	A352	Grade LC2	275 (40)	485–655 (70–95)	24
4L (3.5 Ni)	ASTM A333	Grade 3	240 (35)	450 (65)	30
	A334	Grade 3	240 (35)	450 (65)	
	A350	Grade LF3	260 (37.5)	485–655 (70, 95)	22
	ASTM A352	Grade LC3	275 (40)	485–655 (70–95)	24
	ASTM A420	Grade WPL3	240 (35)	450-620 (65- 90)	22
5L (9 Ni)	A333	Grade 8	515 (75)	690 (100)	22
	A334	Grade 8	520 (75)	690 (100)	
	A522	Type I	515 (75)	690 (100)	22
	A420	Grade WPL8	75 [515]	690-865 (100 -125)	16
6L (10 Ni 20 Cr or 20 Ni 25 Cr)	ASTM A351	CF8C	205 (30)	485 (70)	30
		CK20	195 (28)	450 (65)	

Notes:

1 Impact tests are also required to be carried out as noted in 2-3-13/15.

2 When applicable, refer to Section 5C-8-6 or Section 5C-13-7 or Part 6, Chapter 2 of the *Marine Vessel Rules*, as noted in 2-3-13/3.

3 The elongation values are based on either 4D small coupons or 50 mm (in) coupons and in accordance with the applicable grade and standard and provided for design purposes. The elongation values and coupon geometry is to be specified and agreed upon between the purchaser and manufacturer at the time of ordering.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 14

Bronze Castings

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

The following requirements cover bronze castings intended to be used as propellers and propeller blades.

Requirements for ABS grade bronze castings are included in this section. Alternatively, castings which comply with recognized national standards or proprietary specification may be accepted by ABS, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

3 ABS Grade Propellers and Propeller Blades *(2024)*

3.1 Foundry Approval

3.1.1 Process of Manufacture *(2024)*

All bronze propellers and propeller components are to be cast by ABS-approved foundries. The foundries are to demonstrate that they have available the necessary facilities and skilled personnel to manufacture propellers which are to satisfy these Rules and meet the manufacturing specifications.

ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of casting process that may influence the final cast physical and mechanical properties:

i) Mold preparation and chaplet positioning

ii) Pouring practice, times and temperatures

iii) Mold breakout

iv) Heat treatment and heat treatment recording

v) Coupon preparation

vi) Testing and inspection

vii) Casting rectification

Any of the above aspects can be included in a Survey patrol.

3.1.2 Scope of the Approval Test *(2024)*

The following aspects of manufacture are to be taken into account during initial and extension approval:

- Casting types and sizes
- Material specifications
- Ladle capacities
- Molding and casting equipment and practices
- Heat treatment equipment and practices
- Testing and inspection procedures (including NDE)
- Repair and finishing procedures

Cast test coupons of the propeller materials involved are to be tested in order to verify that the chemical composition and the mechanical properties comply with these Rules and the manufacturing specification.

3.1.3 Quality Control *(2024)*

In addition to 2-3-14/3.1.2, information as to the company's facilities and organization, especially as they relate to quality control, is also required to be presented, including certification in accordance with recognized national or international standards, such as ISO standards or equivalent are to be submitted.

3.2 Quality of Castings *(2024)*

i) The castings are to be free from defects and have a workmanlike finish.

ii) Inspection is to be conducted in accordance with 2-3-14/7.

iii) Minor casting defects such as small sand and slag inclusions, small cold shuts and scabs are to be suitably removed by mechanical means such as chipping or grinding. Refer to 2-3-14/9.3.

iv) When removal of defects requires welding repair, refer to 2-3-14/9.5 and 2-3-14/11.

3.3 Chemical Composition and Metallurgical Characteristics *(2024)*

3.3.1 Ladle Analysis *(2024)*

The chemical composition in % is to conform to an approved specification, four of which are listed in the 2-3-14/Table 1 below as representative of bronze alloys currently used for propellers and propeller blades. See also 2-3-14/3.19. The samples for chemical analysis may be taken from test coupons or representative castings.

TABLE 1
Chemical Composition (1) *(2024)*

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	1.50 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

Notes:

1 The manufacturer is responsible for chemical composition of Type 1 grade which is required to meet the mechanical properties identified in 2-3-14/3.9 TABLE 2.

2 The manufacturer is to maintain records of the chemical analyses of the production casts and these are to be made available to the surveyor.

3.3.2 Metallurgical Characteristics *(2024)*

The main constituents of microstructure in the Type 2 and Type 3 are alpha and beta phase. The concept of zinc equivalent may be used to control since it summarizes the effect of the tendency of various chemical elements to produce beta phase in the structure.

Commentary:

i Important properties such as ductility and resistance to corrosion fatigue are strongly influenced by the proportion of beta phase constituents (too high percentage of beta phase has a negative effect on those properties).

ii The proportion of beta phase constituents is to be kept low. For this purpose, the Zinc Equivalent defined in 2-3-14/3.5 can be used.

End of Commentary

3.5 Zinc Equivalent *(2024)*

The chemical composition of Type 2 and Type 3 alloys are to be so controlled that the zinc equivalent, based on the following equation, does not exceed 45.0%.

$$\% \quad \text{zinc equivalent} = 100 - \left(\frac{100 \times \%\,copper}{100 + A}\right)$$

where

$$A = (\%\,Tin) + (5 \times \%\,Aluminum) - (0.5 \times \%\,Manganese) - (0.1 \times \%\,Iron) - (2.3 \times \%\,Nickel)$$

Commentary:

The negative sign in front of the elements Mn, Fe and Ni signifies that these elements tend to reduce the proportion of beta phase constituents.

End of Commentary

3.7 Alternative Zinc Equivalent *(2024)*

For Type 2 and Type 3 alloys, when the alpha content of a specimen taken from the end of the acceptance test bar is determined by microscopic measurement to be 25% or more, the foregoing "zinc equivalent" requirement can be waived. The proportion of alpha content is to be determined by the average value of 5 counts.

3.9 Tensile Properties *(2024)*

The tension properties of ABS grade bronze propeller and propeller blades are to comply with 2-3-15/ Table 2, below. These values are applicable to test specimens taken from separately cast samples.

TABLE 2
Tensile Properties of Separately Cast Test Coupons [1, 2] *(2024)*

Type	*Tensile Strength*		*Yield Strength* [3]		*Elongation Min. percent (5d Gauge Length)*
	N/mm^2	*(kgf/mm^2, psi)*	*N/mm^2*	*(kgf/mm^2, psi)*	
1	205	(21, 30000)	NA	NA	15
2	450	(46, 65,000)	175	(18, 25,000)	18
3	515	(53, 75,000)	220	(22.5, 32,000)	16
4	590	(60, 86,000)	245	(25, 36,000)	15
5	630	(64, 91,000)	275	(28, 40,000)	18

Notes:

1. These properties are not representative of the tensile properties of the propeller casting itself, which could be substantially lower than that of a separately cast test coupon.
2. The tensile requirements of integral-cast test coupons are to be specifically agreed with ABS.
3. Yield strength is to be determined in accordance with 2-3-1/13.3.
4. The tension properties of other alloys not meeting the minimum values of 2-3-14/Table 2 are to comply with specification approved by ABS.

3.11 Test Specimens *(2024)*

The tension test specimen is to be the dimensions shown in 2-3-1/11.13 FIGURE 1 (Round Specimen Alternative C). The tension test coupons may be separately cast or integral with the casting.

3.13 Separately Cast Coupons *(2024)*

Separately cast test coupons as shown in 2-3-14/3.13 FIGURE 1also required to meet the following,

i) Poured from the same ladles of metal used to pour the propeller casting.

ii) In cases where more than one ladle of metal is required for the propeller, a test coupon is to be provided for each ladle.

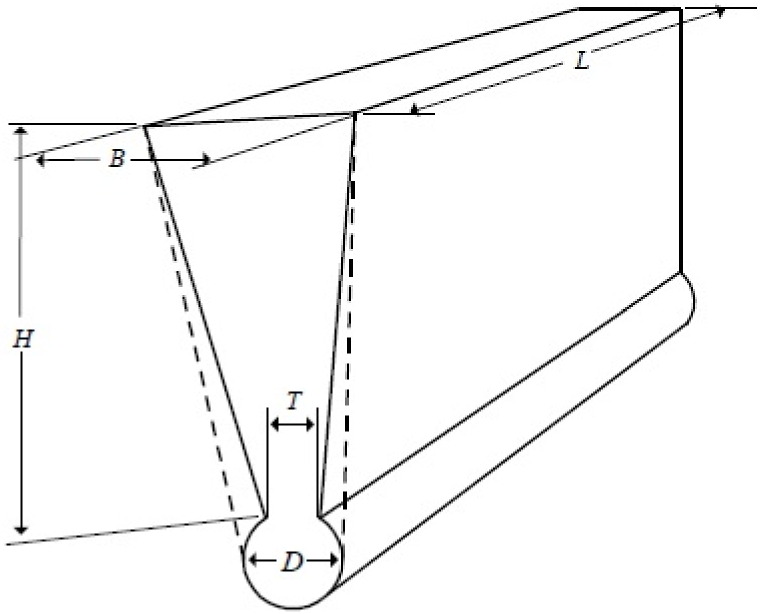
iii) Cast in mold made of same material as the mold for the propeller casting.

iv) They are to be cooled down under the same conditions as the propeller casting.

v) When heat treatment is applicable, the test samples are to be heat treated together with the propeller.

vi) Satisfactory evidence is to be furnished the Surveyor to identify the test coupons as representing the material to be tested.

FIGURE 1
Test Coupons *(2024)*



H = 100 mm (4 in.)
B = 50 mm (2 in.)
L > 150 mm (6 in.)
T = 15 mm (0.59 in.)
D = 25 mm (1 in.)

Note:

1 Test coupon according to the broken line can be accepted.

3.15 Integrally Cast Coupons *(2024)*

For integrally cast test coupons, the following are to be met.

i) Furnished as coupons attached to the hub or on the blade.

ii) Where possible, test bars attached on blades are to be located in an area between 0.5 to 0.6*R*, where *R* is the radius of the propeller.

iii) Test bars are not to be detached from the casting until final heat treatment has been carried out.

iv) The test samples are to be removed by non-thermal process.

3.17 Number of Tests

i) For separately cast test coupons, at least one tension test to be taken from each ladle.

ii) For integrally cast test coupons, at least one tension test to be taken for each casting.

iii) The test results are to comply with the requirements prescribed in 2-3-14/3.9.

3.19 Special Compositions *(2024)*

It is recognized that other bronze alloys have been developed and proven by tests and service experience to be satisfactory. When other grades of propeller materials with different chemical compositions to 2-3-14/3.3.1 TABLE 1 are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

3.21 Stress Corrosion Cracking *(2024)*

Mn bronze (Type 2) and NiMn bronze (Type 3) propellers are susceptible to stress corrosion cracking. Propellers made of these alloys are to be stress relieved after they are repaired to reduce any residual stresses to safe levels before the propellers are placed in service.

Commentary:

It is not necessary to stress relieve new castings made of these alloys which have been allowed to cool slowly in the mold unless it is found necessary to subsequently perform welding, straightening or repitching.

End Commentary

Since NiAl bronze is practically immune to stress corrosion cracking in propeller applications, stress relieving treatments are not usually necessary.

3.23 Embrittlement or Hot Shortness *(2024)*

Certain bronze alloys may exhibit embrittlement or hot shortness when exposed to or hot worked within certain temperature ranges.

Hot working of NiAl bronze at temperatures within the range 300-500°C (570-930°F) is to be avoided.

Hot working of MnNiAl bronze at temperatures within the range 260-480°C (500-900°F) or exposure of MnNiAl bronze for prolonged periods to temperatures within the range 350-565°C (660-1050°F) is to be avoided, unless the manufacturer indicates that this precaution is not applicable.

5 Definition of Skew and Severity Zones *(2024)*

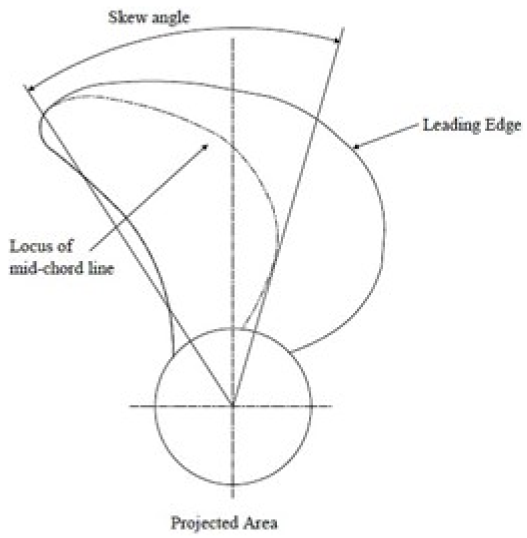
5.1 Definition of Skew

The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centerline and a second line through the shaft centerline, that acts as a tangent to the locus of the midpoints of the helical blade section. See the figure below.

i) High skew propellers have a skew angle greater than 25°

ii) Low skew propellers have a skew angle of up to 25°

FIGURE 2
Definition of Skew Angle *(2024)*



5.3 Severity Zone

In order to relate the degree of inspection to the criticality of defects in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into the three severity zones designated A, B and C.

5.3.1 Zone A

Zone A is the region carrying the highest operating stresses and which, therefore, requires the highest degree of inspection. Blade thicknesses are greatest in this area, giving the greatest degree of restraint in repair welds. This in turn leads to the highest residual stresses in and around any repair welds. High residual stresses frequently lead to fatigue cracking during subsequent service so that relief of these stresses by heat treatment is essential for any welds made in this zone.

Welding is not permitted in Zone A unless specially agreed upon by ABS Materials Department. Every effort is to be made to rectify a propeller that is either defective or damaged in this area without recourse to welding even to the extent of reducing scantlings, if this is acceptable. If a repair using welding is agreed, post-weld stress relief heat treatment is mandatory except for NiAl bronze (Type 4); see 2-3-14/11.13 TABLE 6.

5.3.2 Zone B

Zone B is a region where the operation stresses may be high. Welding in Zone B is to be avoided. Special consideration may be given provided that the complete details of the defect/damage and the intended repair procedures are submitted for ABS Materials for special approval.

5.3.3 Zone C

Zone C is a region in which the operation stresses are low and where the blade thicknesses are relatively small so that repair welding is safer and, if made in accordance with an approved procedure, is freely permitted.

5.5 Low and High Skew Propellers

5.5.1 Low-skew Propellers

i) Zone A is in the area on the pressure side of the blade, from and including the fillet to 0.4R and bounded on either side by lines at a distance 0.15 times the cord length CR from the leading edge and 0.2 times CR from the trailing edge, respectively (see 2-3-14/5.5.2

FIGURE 3). Where the hub radius (R_B) exceeds 0.27R, the other boundary of zone A is to be increased to 1.5R_B.

Zone A also includes the parts of the separate cast propeller hub that lie in the area of the windows as described in 2-3-14/5.5.2 FIGURE 5 and the flange and fillet area of controllable pitch and built-up propeller blades as described in 2-3-14/5.5.2 FIGURE 6.

ii) Zone B is on the pressure side of the remaining area up to 0.7R and on the suction side, the area from the fillet to 0.7R (see 2-3-14/5.5.2 FIGURE 3).

iii) Zone C is the area outside 0.7R on both sides of the blade. It also includes all surfaces of the hub of a monoblock propeller and all the surfaces of the hub of a controllable pitch propeller other than those designated Zone A above.

5.5.2 High-skew Propellers

i) Zone A is the area on the pressure face contained within the blade root-fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0.9R and passing through the mid-point of the blade chord at 0.7R and a point situated at 0.3 of the chord length from the leading edge at 0.4R. It also includes an area along the training edge on the suction side of the blade from the root to 0.9R and with its inner boundary at 0.15 of the chord lengths from the trailing edge.

ii) Zone B constitutes the whole of the remaining blade surfaces. Zones A and B are illustrated in 2-3-14/5.5.2 FIGURE 4.

FIGURE 3
Severity Zones for Integrally Cast Low Skew Propellers

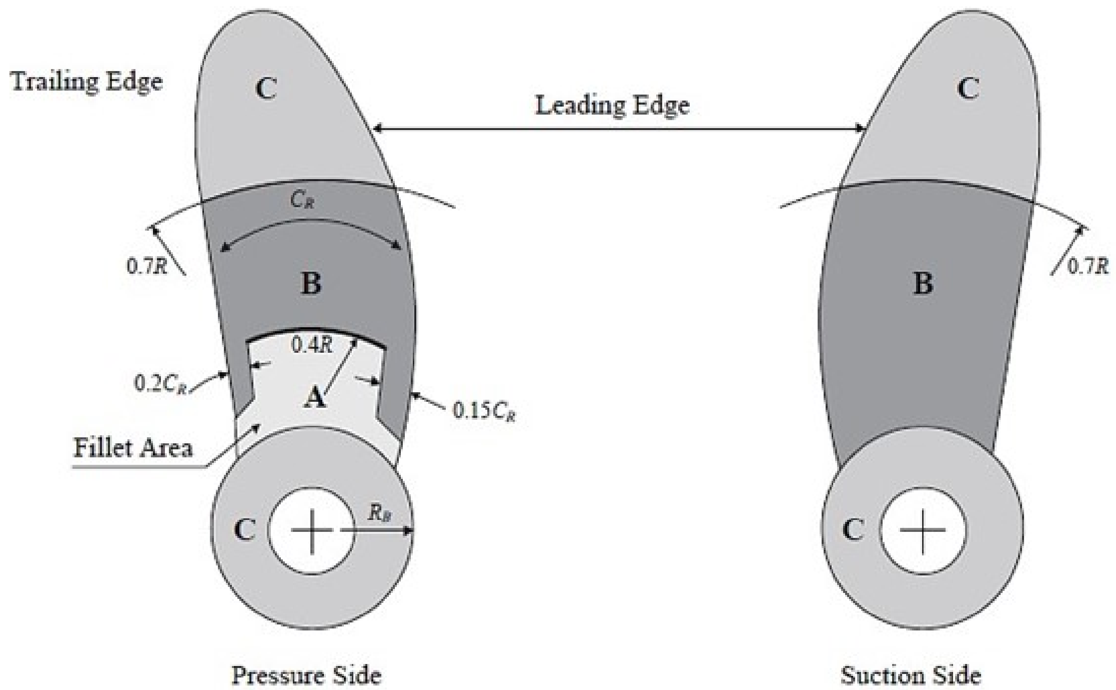


FIGURE 4
Severity Zones in Blades with Skew Angles Greater than 25°

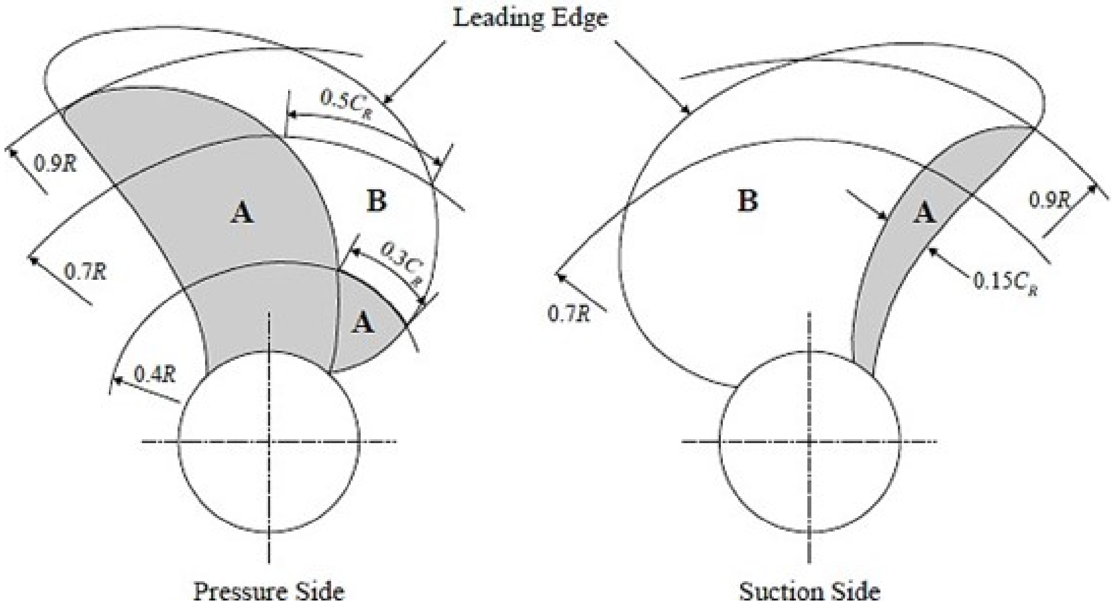


FIGURE 5
Severity Zones for Controllable Pitch Propeller Boss

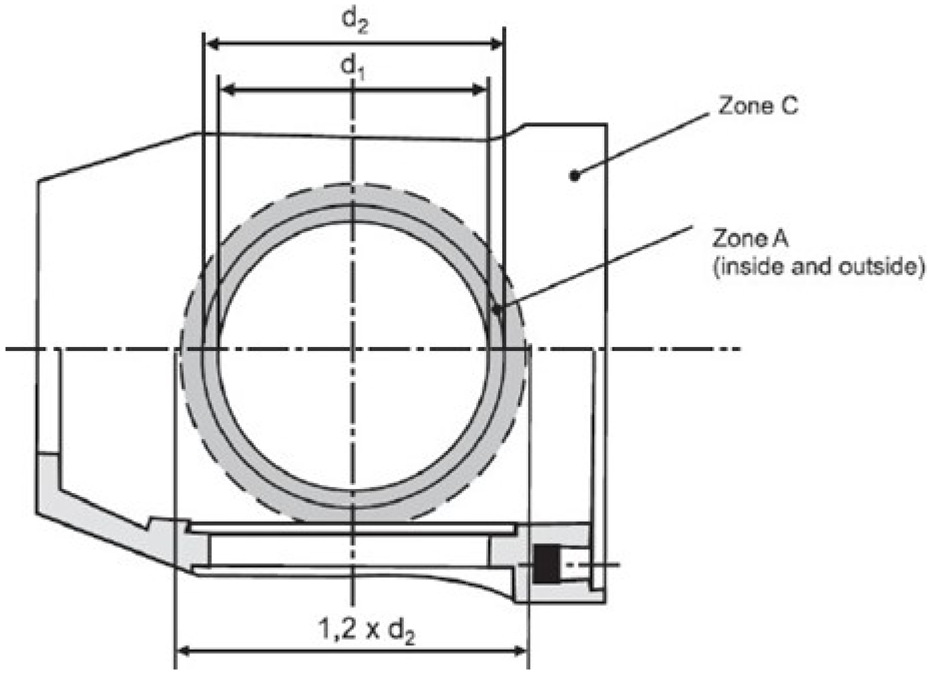
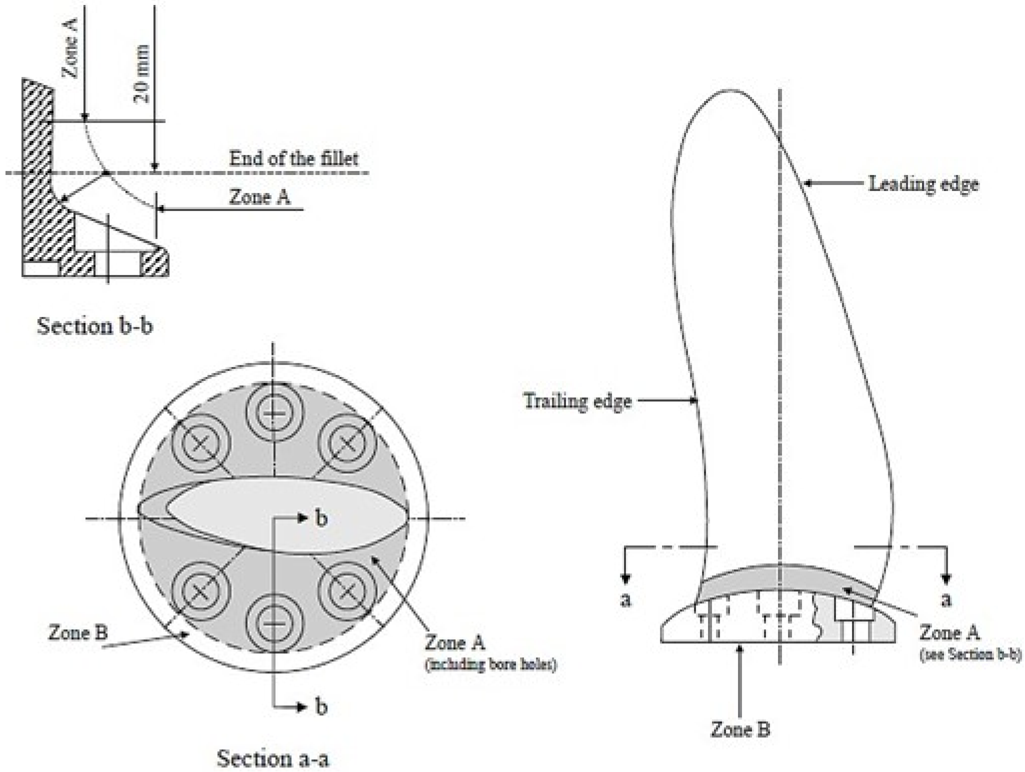
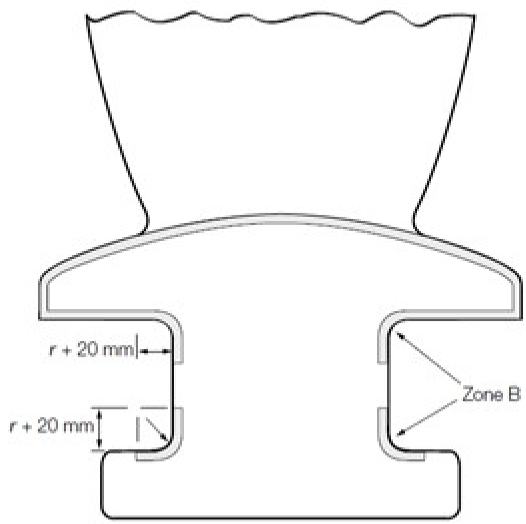


FIGURE 6
Severity Zones for Controllable Pitch and Built-up Propeller Blades



Note: The remaining surface of the propeller blade is to be divided into the severity zones as given for solid cast propellers (see 2-3-14/5.5.2 FIGURE 3 and 2-3-14/5.5.2 FIGURE 4).

FIGURE 7
Severity Zones for Integrally cast CPP blade Journals



Note: The surface of the journal which are not shaded are to be considered as severity Zone C.

7 Inspection *(2024)*

7.1 Visual Examination

All finished castings are to be 100% visually inspected by the manufacturer. Castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings. A general visual examination is to be carried out by the Surveyor.

7.3 Dimensions, Dimensional and Geometrical Tolerances

i) The dimensions, dimensional and geometrical tolerances are governed by the data contained in the approval drawings or order documents. These are to be provided to the Surveyor at the time of the test. The accuracy and verification of the dimensions and weight are the responsibility of the manufacturer and must be confirmed by an attending surveyor.

ii) The report on the relevant examinations is to be submitted to the Surveyor. Checks may be required to be made in Surveyor's presence.

iii) Static balancing is to be carried out on all propellers in accordance with the approved drawing and reference is to be made to the provisions of ISO 484. Dynamic balancing is necessary for propellers running above 500 rpm.

iv) In addition to the above requirements, Controllable Pitch Propeller (CPP) blades are to undergo the following:

a) Each blade is to be weighed and recorded for all accuracy classes, CPP blades (ISO 484/1 & 2). The deviation of each blade is to be less than the maximum permissible balancing mass as defined by ISO 484/1 & 2 or as specified on the approved drawing.

b) 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. Alternatively, a 1.5 times hydrostatic working pressure test for 30 minutes minimum as specified in the assembly drawing may be carried out.

c) A liquid penetrant examination of the flange and bolt hole area of the CPP blade is to be made regardless of blade size. The liquid penetrant examination is to be witnessed by ABS Surveyor and is to be free from any significant surface defects. Refer to 2-3-14/7.5.

7.5 Surface Inspection

i) Surface inspection (liquid penetrant inspection or other) is to be performed in accordance with a procedure approved by ABS.

ii) Liquid penetrant inspection may be performed in accordance with ISO 3452-1:2013 or a recognized standard.

iii) Liquid penetrant testing in severity zone A is to be witnessed by the Surveyor.

iv) In severity zones B and C, the liquid penetrant testing is to be performed by the manufacturer and may be witnessed by the Surveyor upon his request.

v) The acceptance criteria for surface inspection of bronze propellers are shown in the table below.

TABLE 3
Acceptance Criteria for Surface Inspection of Bronze and Stainless-Steel Propellers [7]

<table>
<tr><th rowspan="2">Location of Discontinuity</th><th rowspan="2">Type of Discontinuity [1]</th><th rowspan="2">Max. Acceptable Discontinuity in mm (in.)</th><th colspan="2">Discontinuity Acceptance Standards</th><th rowspan="2">Allowable Areas of Concentration</th></tr>
<tr><th>Max. Number [2] 150 mm × 150 mm (6 in. × 6 in.) Area of Concentration [3,4]</th><th>Min. Spacing Between Aligned Discontinuities [5,6]</th></tr>
<tr><td>Zone A</td><td>Non - linear
Linear</td><td>3.2 (⅛)
3.2 (⅛)</td><td>10
3</td><td>D
4D</td><td rowspan="3">5% of propeller surface area with distribution by a max. of 5% for each blade surface</td></tr>
<tr><td>Remaining surfaces of the blade</td><td>Non - linear
Linear</td><td>3.2 (⅛)
6.4 (¼)</td><td>20
8</td><td>D
4D</td></tr>
<tr><td>Propeller hub</td><td>Non - linear
Linear</td><td>6.4 (¼)
9.5 (⅜)</td><td>15
6</td><td>D
4D or 25.4 mm (1 in.) whichever is less</td></tr>
<tr><td>Weldments</td><td>Non - linear
Linear</td><td>1.6 (1/16)
0 (0)</td><td>12
0</td><td>4D
-</td><td>5% of total weld area</td></tr>
</table>

Notes:

1 A linear discontinuity is one in which the length is greater than three (3) times the width. For dimensional purposes, the size of the actual discontinuity, not the size of the indication, is to be used.

2 The total number of non-linear discontinuities may be increased to the combined total, or part thereof, represented by the absence of linear discontinuities.

3 Randomly dispersed casting discontinuities whose major dimensions are 1.6 mm ($^{1}/_{16}$ in.) or less are not to be counted in determining total number of discontinuities within an area of concentration.

4 More than six (6) discontinuities whose major dimensions are greater than 2.4 mm ($^{3}/_{32}$ in.) in any 150 mm × 150 mm (6 in. × 6 in.) area of the propeller surface constitute an area of concentration. Each area of concentration is to be separated from an adjacent area of concentration by a minimum of 455 mm (18 in.).

5 Minimum spacing is the distance separating two adjacent discontinuities in terms of the major dimension of the larger discontinuity (D). Aligned non-linear discontinuities are to consist of four or more discontinuities in a line; aligned linear discontinuities are to consist of two or more discontinuities whose major dimensions are oriented in a line. However, when the total length of the aligned discontinuities does not exceed the maximum length permitted for a single discontinuity, these aligned discontinuities are to be considered as one discontinuity and are not to be cause for rejection.

6 When the major dimension of clustered discontinuities does not exceed the maximum size permitted for a single discontinuity, these clustered discontinuities are to be considered as one discontinuity and are not to be cause for rejection. Scattered discontinuities, separated from the cluster by 3.2 mm ($^{1}/_{8}$ in.) or more, are not to be considered as part of the cluster.

7 Definitions

i) Relevant Indication: Only indications which have any dimension greater than 1.5 mm is to be considered relevant for the categorization of indications.

ii) Non-linear indication: An indication with a largest dimension less than three times its smallest dimension (i.e., $\ell < 3\ w$).

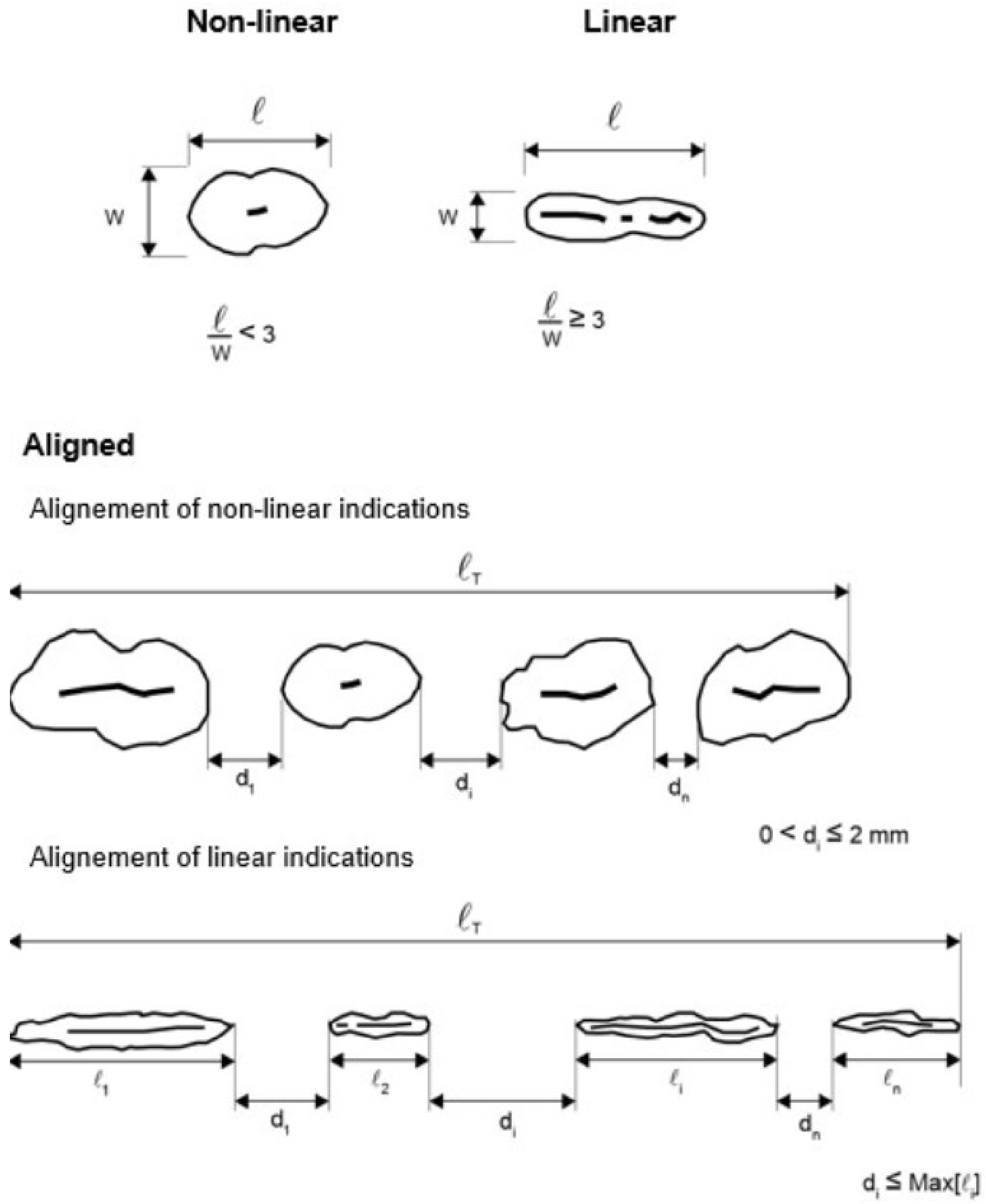
iii) Linear indication: An indication with a largest dimension three times or more than its smallest dimension (i.e., $\ell \geq 3\ w$).

iv) Aligned indication:

a) Non-linear indications form an alignment when the distance between indications is less than 2mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.

b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

FIGURE 8
Illustration of Indications



7.7 Volumetric Inspection

Additional volumetric inspection (radiographic or ultrasonic examination) is to be carried out when deemed necessary by ABS or manufacturer. The acceptance criteria are to be in accordance with agreed recognized standard as agreed with ABS.

Commentary:

i Due to the attenuating effect of ultrasound within cast copper alloys, ultrasonic testing may not be practical in some cases, depending on the shape/ type/ thickness and grain growth direction of the casting. In such cases, effective ultrasound penetration into the casting is to be practically demonstrated on the item. This is normally determined by way of back-wall reflection, and/or target features within the casting.

ii Volumetric inspection may be required if there are extensive surface indications which require rectification.

End of Commentary

9 Rectification *(2024)*

9.1 General

Indications including cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blow holes and other discontinuities which may impair the safe service of the propeller must be rectified.

9.3 Repair without Welding

i) Repairs may be carried out by mechanical means (e.g., by grinding, chipping or milling). After milling or chipping, grinding is to be carried out for such defects that are not to be welded.

ii) Grinding is to be done in such a manner that the contour of the ground depression is as smooth as possible to avoid stress concentrations or to minimize cavitation corrosion.

iii) Grinding may be carried out to an extent which maintains the blade thickness of the approved drawing.

iv) Complete elimination of the defective materials is to be verified by liquid penetrant examination.

9.5 Repair by Welding

Welding repair may be applied subject upon agreement by ABS and as permitted in this section. Weld repair procedures are to be qualified in accordance with 2-3-14/11.

Welding repair for the sake of appearance only is to be avoided. Defects up to 3.2 mm (⅛ in.) deep are to be dimpled. Welding of areas less than 5 cm^2 is to be avoided.

i) Minor Repair: Welding repairs include the repair of edges on the outer ⅓ of the propeller diameter and in general are to be limited to the repair of sections under 32 mm (1¼ in.) thick.

ii) Major Repair: All other repairs except 2-3-14/9.5 item i are considered to be major repairs.

9.5.1 Repair of Defects in Severity Zone A

Repairs in Zone A are to be made by mechanical means, as noted in 2-3-14/9.3.

Weld repairs in Zone A are required to be approved by ABS Materials Department, prior to the repair.

Commentary:

The propeller designer may propose a modified zone A based on detailed hydrodynamic load and stress analysis to ABS for technical assessment and approval.

End of Commentary

9.5.2 Repair of Defects in Severity Zone B

Defects not deeper than (t/40) mm (t = min. local thickness in mm according to the Rules) or 2 mm (whichever is greatest) below minimum local thickness according to the Rules are to be removed by grinding. Refer to 2-3-14/9.3. All other defects are to be repaired by welding in accordance with weld procedures approved by ABS Materials Department.

9.5.3 Welding Repair to Severity Zone C

Repair welds are permitted and may be carried out after agreement with the Surveyor.

9.7 Repair Documentation

The foundry is to maintain records of repair documentation include inspections, welding, and any subsequent heat treatment, traceable to each casting.

11 Weld Repair Procedure Qualification *(2024)*

11.1 General

Before commencing repair welding, full details of the extent and location of the repair, the proposed welding procedure, weld preparation, heat treatment and subsequent inspection procedures are to be submitted to ABS Materials Department for approval.

11.3 Preheat and Interpass Temperatures

i) The preheat and interpass temperatures are to be extended entirely through the section being repaired to a distance of about 300 mm (12 in.) on all sides of the repair area so that a maximum temperature gradient of about 55°C per 300 mm (100°F per ft) can be maintained in the surrounding area.

ii) Heating is to be accomplished by means of soft gas (natural gas, LPG) torches or strip heaters or by means of moving oxyacetylene torches used with proper precaution to avoid local overheating.

iii) The temperature is to be checked at frequent intervals by means of temperature indicating crayons or contact pyrometers.

iv) The preheat and interpass temperatures are to be maintained throughout the entire welding operation.

v) Adequate support to be provided to minimize distortion during the preheat and welding operations.

vi) Preheat and Interpass Temperature Ranges. The ranges listed in 2-3-14/11.13 TABLE 4 through 2-3-14/11.13 TABLE 7 are required for the various welding processes and alloys.

11.5 Stress Relief

11.5.1 General

i) Repairs such as welding, straightening and repitching made on Mn bronze, NiMn bronze and MnNiAl bronze propellers are to be stress relieved within the appropriate temperature range shown in 2-3-14/11.13 TABLE 4, 2-3-14/11.13 TABLE 5 and 2-3-14/11.13 TABLE 7.

ii) Stress relieving treatment is usually carried out immediately after welding. However, the welded area can be allowed to cool to room temperature and following by a stress relieving treatment as soon as practicable to reduce the possibility of post weld crack.

iii) NiAl bronze propeller repairs do not require stress relieving treatment, as denoted in 2-3-14/11.13 TABLE 6 and 2-3-14/15.7 TABLE 11. Stress relief treatment of NiAl bronze propeller castings may be required after major repairs in Zone B (and specially approved welding in Zone A) or if a welding consumable susceptible to stress corrosion cracking is used. In such cases, the propeller is to be either stress relief heat treated in the temperature range of 450-500°C or annealed in the temperature range of 650-800°C depending on the extent of repair. See 2-3-14/11.13 TABLE 6.

11.5.2 Furnace Stress Relief

i) Where possible, furnace stress relief is to be carried out after repairs especially for heavy sections such as the hub or the fillet areas. This may be done either by heating the entire propeller or by heating a complete section containing the areas to be stress relieved in a furnace.

ii) Furnace stress relief of an entire propeller is to be slowly heated to a target temperature range, and the soaking time at temperature is to be a minimum of 6 hours.

iii) Where only a section of the propeller is furnace stress relieved, the holding time is to be at least 20 minutes per 25.4 mm (1 in.) of section measured at the thickest portion of the repair area.

iv) The heating and cooling rate of the propeller or propeller section in the furnace are to be slow enough so that a maximum temperature differential of 55°C (100°F) is not exceeded anywhere on the propeller.

11.5.3 Local Stress Relief

i) Local stress relief is to be slowly heated to the target stress relieving temperature so that the temperature gradient of 55°C per 300 mm (100°F per ft) is not exceeded.

ii) Heating is to be accomplished by soft gas torches or strip heaters or by moving of oxyacetylene torches with proper precaution to avoid local overheating.

iii) The soaking time at target temperature range is to be at least 20 minutes per 25.4 mm (1 in.) of thickness at the repair area. In the case of a weld repair, the weld thickness is to be used to determine the soaking time, but in no case the soaking time to be less than one hour.

iv) Cooling is to be slowly cooled so that a temperature gradient of 55°C per 300 mm (100°F per ft) is not exceeded. Slow cool from the stress relieving temperature may be accomplished by covering with insulating blankets.

v) For a local stress relief, the band is to measure approximately 300 mm (12 in.) on all sides of the repair and is to extend through the entire thickness of the blade.

vi) For a local stress relief of a major repair, the band is to extend across the entire width of the blade.

11.5.4 Distortion Control

Adequate support to minimize distortion is to be provided during any of the above stress relieving treatments.

11.7 Burn-in (Hot Flow Process) Repair Method

i) The burn-in (hot flow) process is considered satisfactory method for major repairs on Mn bronze or NiMn bronze propellers.

ii) Burn-ins are to extend completely through the section being repaired. It is not to be used on a partly chipped out section, because it is necessary to examine the underside of the burn-in sections to be sure of proper fusion. For this reason and because of excessive distortion, burn-ins are not frequently used for repairs to propeller hubs.

iii) A preheat and stress-relief are to be in accordance with 2-3-14/11.13 TABLE 4 and 2-3-14/11.13 TABLE 6.

11.9 Preparation for Welding Repair

Defects are to be removed to sound metal prior to welding (refer to 2-3-14/9.3) and the area to be weld repaired is to be appropriately prepared (see 2-3-14/11.9 FIGURE 9 and 2-3-14/11.9 FIGURE 10). For blade tip replacement, appropriate grooves such as shown in 2-3-14/11.9 FIGURE 11 are to be used.

FIGURE 9
Typical Shallow Groove Preparation for Welding Repair

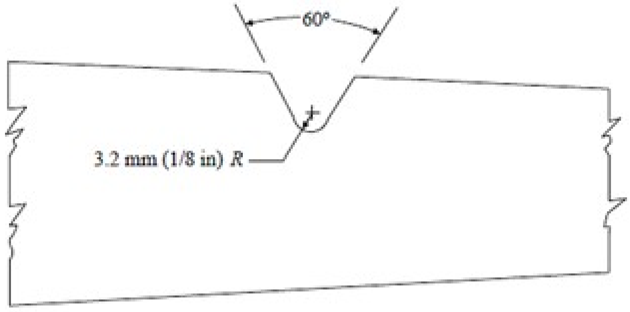


FIGURE 10
Typical Deep Groove Preparation for Welding Repair

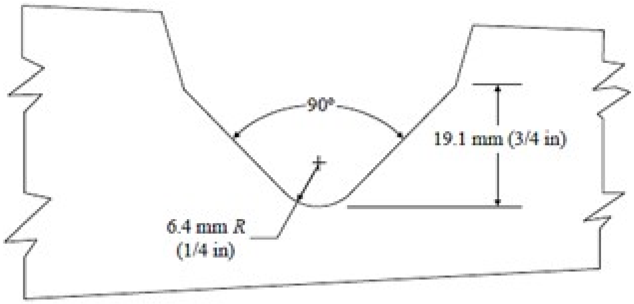
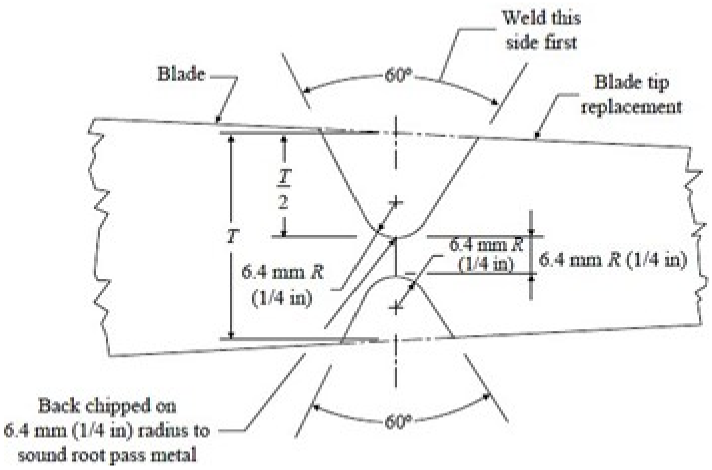


FIGURE 11
Typical Blade Tip Replacement Preparation for Welding Repair



11.11 Inspection Prior to and After Welding Repair

Prior to welding, dimensional inspection is to be conducted in accordance with 2-3-14/7.3. Nondestructive inspection of the propeller surfaces is to be conducted, to the extent indicated below, prior to welding (if applicable) and after repair.

11.11.1 Inspection prior to welding

The area prepared for welding is to be inspected using liquid penetrant to verify the complete removal of defects. In addition, other suspect areas of the propeller are to be inspected to the satisfaction of the Surveyor. As a minimum, random inspection of the other blades and the hub area is to be conducted.

11.11.2 Final Inspection After Repair

The completed repair and any suspect areas in the repair vicinity are to be inspected using liquid penetrant. The acceptance criteria for surface inspection are in accordance with 2-3-14/7.5 TABLE 3.

11.13 Welding Processes, Filler Metals and Temperature Range

i) The welding processes, filler metals and temperature range listed in 2-3-14/11.13 TABLE 4 through 2-3-14/11.13 TABLE 7 are required for the repair of bronze propellers of the alloy types indicated.

ii) Shielded metal arc welding, gas metal arc welding, and gas tungsten arc welding are satisfactory for all major and minor repairs on all types of propellers.

iii) All propellers are to be welded in the down hand (flat) position. Where this is not possible, gas shield metal arc welding is to be carried out.

iv) Oxyfuel gas welding is permitted on Mn bronze and NiMn bronze but is to be limited to the repair of edges on the outer one third of the propeller radius and sections under 32 mm (1¼ in.) thick.

a) *Peening*. Usually, the first weld layer is not to be peened. The last layer is not to be peened unless the weld is to be subsequently stress relieved. Peening of the intermediate weld layers is optional; heavy peening is to be avoided.

b) *Solder or Silver Brazing*. The repair of defects by means of solders or silver brazing alloys is not permitted.

c) *Position of Welding*. When practicable, welding is to be done in the flat (downhand) position.

d) *Draft-free shop*. All welding work is to be carried out preferably in the shop, free from drafts and influence of the weather.

TABLE 4
Parameters for Welding of Type 2, Mn Bronze

Filler Metal (1)	*Shielded Metal Arc Welding*	*Gas Metal and Gas Tungsten Arc Welding*	*Oxyfuel Gas Welding* (2)
AWS Specification **AWS Classification**	**A5.6** **E CuAl-A2** **E CuNiAl**	**A5.7** **ER CuAl-A2** **ER CuNiAl**	**A5.27** **R CuZnB** **R CuZnC**
Temperature Range in °C (°F)			
Preheat-interpass range	260-300 (500-572)	150-300 (300-572)	315-425 (600-800)
Stress relief	315-500 (600-932)	315-500 (600-932)	315-500 (600-932)

Notes:

1 Equivalent specifications may be used.

2 Permitted only for minor repairs, as defined in 2-3-14/9.5.

TABLE 5
Parameters for Welding of Type 3, NiMn Bronze

Filler Metal (1)	*Shielded Metal Arc Welding*	*Gas Metal and Gas Tungsten Arc Welding*	*Oxyfuel Gas Welding* (2)
AWS Specification **AWS Classification**	**A5.6** **E CuAl-A2** **E CuNiAl**	**A5.7** **ER CuAl-A2** **ER CuNiAl**	**A5.27** **R CuZnB** **R CuZnC**
Temperature range in °C (°F)			
Preheat-interpass range	260-300 (500-572)	150-300 (300-572)	315-425 (600-800)
Stress relief	370-550 (700-1022)	370-550 (700-1022)	370-550 (700-1022)

Notes:

1 Equivalent specifications may be used.

2 Permitted only for minor repairs, as defined in 2-3-14/9.5.

TABLE 6
Parameters for Welding of Type 4, NiAl Bronze

Filler Metal (1)	*Shielded Metal Arc Welding*	*Gas Metal and Gas Tungsten Arc Welding*
AWS Specification A **WS Classification**	**A5.6** **E CuAl-A2** **E CuNiAl** (2)	**A5.7** **ER CuAl-A2** **ER CuNiAl** (2)
Temperature range in °C (°F)		
Preheat-interpass range	40-205 (100-400)	40-205 (100-400)
Stress relief	See 2-3-14/11.5 Item iii	See 2-3-14/11.5 Item iii

Notes:

1 Equivalent specifications may be used.

2 EcuNiAl/ERCuNiAl are preferred.

TABLE 7
Parameters for Welding of Type 5, MnNiAl Bronze

Filler Metal (1)	*Shielded Metal Arc Welding*	*Gas Metal and Gas Tungsten Arc Welding*
AWS Specification **AWS Classification**	**A5.6** **E CuMnNiAl**	**A5.7** **ER CuMnNiAl**
Temperature range in °C (°F)		
Preheat-interpass range	40-205 (100-400)	40-205 (100-400)
Stress relief	565-649 (1050-1200)	565-649 (1050-1200)

Notes:

1 Equivalent specifications may be used.

2 When a minor repair, as defined in 2-3-14/9.5, involves a limited area, stress relief may be waived at the discretion of the Surveyor.

11.15 Extent of Testing – Weld Repair Procedure Qualification and Welder Qualification

11.15.1 General

i) Welding qualification tests are to be made at each foundry or repair facility where it is intended to perform welding repair on the propellers.

ii) The welding qualification test is to be made in accordance with 2-3-4/11.17 Figure 12 with the same process, equipment, electrodes, preheat temperature and stress relief as would normally be used in making the production repair welds.

iii) A test coupon of the same grade of propeller with minimum plates thickness of 30 mm (1¼ in.) is to be used.

iv) Qualification testing is to be conducted for each position in which welding is to be performed.

v) Welding procedures qualified at a manufacturer are valid for welding in the repair shops under the same technical and quality management.

vi) Welding of test assembly and qualification testing are to be witnessed by the ABS Surveyor.

11.15.2 Weld Repair Procedure Qualification

i) Test assembly is to be examined non-destructively and destructively in accordance with the table below.

TABLE 8
Extent of Testing for Weld Repair Procedure Qualification

Type of Test	*Extent of Testing*
Visual Inspection	100% in accordance with 2-3-14/7
Liquid Penetrant Examination	100% in accordance with 2-3-14/7
Transverse tensile Test (Reduced-Section)	2 Specimens in accordance with 2-3-14/11.15.4 FIGURE 13
Macro Examination	4 Specimens
Hardness Test	1 Specimen (taken from macro examination)

ii) The qualification tests results are to meet the following acceptance criteria:

a) *Non-destructive Inspection*. No cracks are permitted. Imperfections detected by liquid penetrant testing are to be assessed in accordance with 2-3-4/7.5.

b) *Macro Examination*. The etched specimen is to be clearly reveal the weld metal, fusion line and heat affected zone. It is to be free of cracks and lack of fusion, no welding discontinuity over 1.6mm (1/16 in.) is permitted.

c) *Hardness Test*. One of the macro-sections is to be used for hardness testing. Indentations are to be traverse 2 mm below the surface. At least three individual indentations are to be made in the weld metal, both side of HAZ, and both side of the base material. The values are to be reported for information.

d) *Tensile Test*. Minimum tensile strength to be achieved, N/mm^2 (kg/mm^2, ksi).

Bronze Cast	*Arc Process*	*Oxyfuel Gas Process*
Type 2- Mn Bronze	380 (39, 55)	275 (28, 40)
Type 3- NiMn Bronze	410 (42, 60)	315 (32, 45)
Type 4- NiAl Bronze	500 (51, 72)	NA
Type 5- MnNiAl Bronze	550 (56, 80)	NA

iii) The welding procedure qualification tests are to be witnessed by ABS Surveyor.

11.15.3 Welder Qualification

i) Four macro examination specimens are to be prepared in accordance with 2-3-14/11.15.4 FIGURE 12.

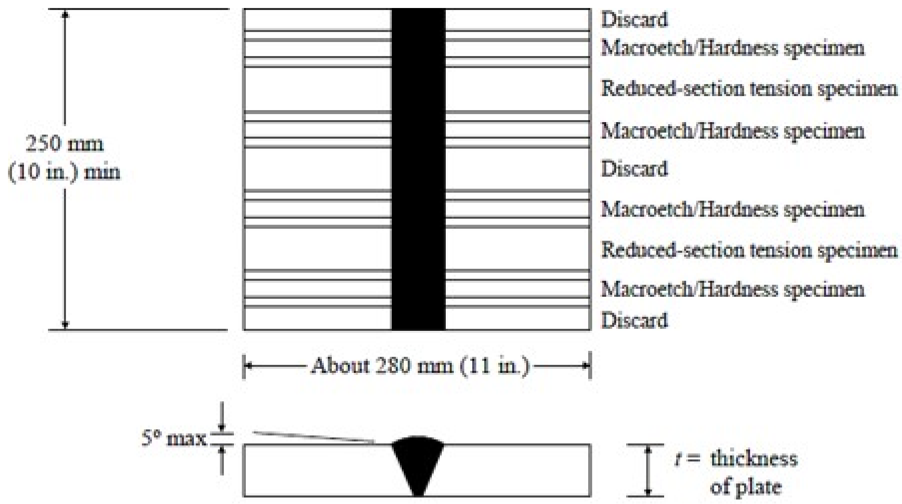
ii) The tested specimens are to meet the acceptance criteria as per 2-3-14/11.17.2ii).

iii) Welding of the test assemblies and associated testing for performance qualification are to be witnessed by the ABS Surveyor.

11.15.4 Re-testing

If the test piece fails to comply with the requirements as per 2-3-14/11.17.2ii), reference is made to re-test the procedure in accordance with 2-A9-1/7.7.

FIGURE 12
Welding Qualification Test Coupon- Location of Test Specimens

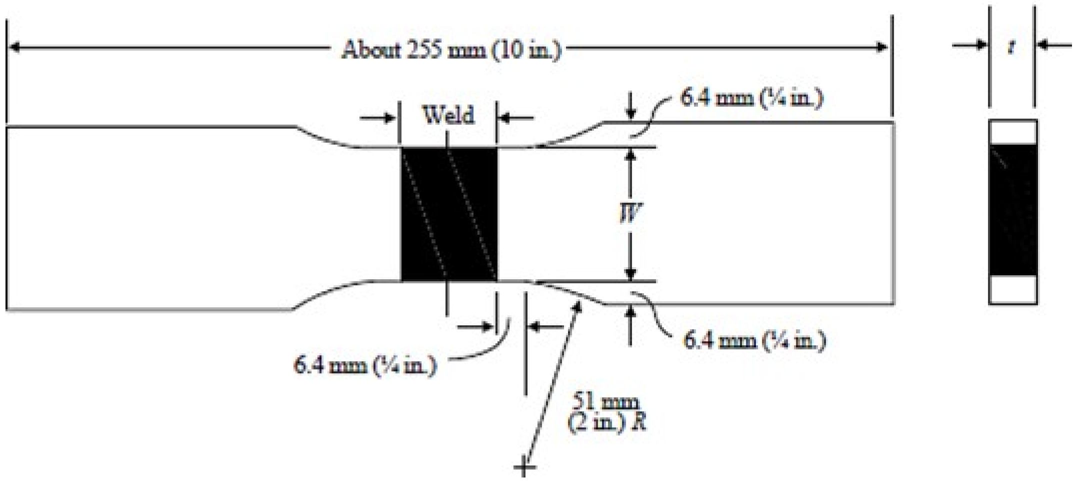


Notes:

1 The test assembly is to be of size sufficient for reasonable heat distribution and qualification test specimens.

2 Test coupon of minimum t = 30 mm (1¼ in.) is to be used.

FIGURE 13
Reduced-section Tension Specimen



Notes:

1 Both faces of weld are to be machined flush with plate.

2 *t* = 30 mm (1¼ in.); W = 25.4 mm (1 in.).

3 When the capacity of the available testing machine does not permit 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.

11.15.5 Range of Approval

All the conditions of validity stated below are to be met independently of each other. Changes outside of the ranges specified require a new welding procedure qualification.

i) *Welding Position*. Approval for a test made in any position is restricted to that position. If a range of qualification is required, welding is to be performed in the highest heat input and lowest heat input positions.

ii) *Welding Process*. The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run process to a single run process and vice verse.

iii) *Filler Metal*. The approval is only valid for the filler metal designation used in the welding procedure qualification test.

iv) *Heat Input*. The upper limit of heat input approval is 25% greater than that used in qualification test. The lower limit of heat input approved is 25% lower than that used in qualification test.

v) *Preheating and Interpass Temperature*. The minimum preheating temperature is not to be less than that used in the qualification test. The maximum interpass temperature is not to be higher than that used in the qualification test.

vi) *Post Weld heat Treatment*. The heat treatment used in the qualification test is to be specified in WPS; soaking time may adjusted as a function of thickness.

vii) *Base Metal and Thickness*. The range of qualification related to base metal and thickness is shown in 2-3-14/11.17.5 Tables 9 and 10.

TABLE 9
Range of Qualification for Base Metal

Grade used for Qualification	*Range of Approval*
Type 2	Type 2
Type 3	Type 2; Type 3
Type 4	Type 4
Type 5	Type 5

TABLE 10
Range of Qualification for Thickness

Thickness of the Test Piece, t (mm)	*Range of Approval*
$30 \leq t$	≥ 3 *mm*

13 Straightening *(2024)*

13.1 Major and Minor Straightening Repairs

Minor straightening repairs include the repair of edges on the outer $^1/_3$ of the propeller diameter and are to be limited to the repair of sections under 32 mm (1¼ in.) thick. All other repairs, including repairs to the critical area of high skew propellers, are considered to be major repairs.

13.3 Stress Relieve

For Mn bronze, NiMn bronze and MnNiAl bronze, a stress relieving treatment in accordance with 2-3-14/15.7 TABLE 11 is necessary.

NiAl bronze propellers do not require stress relieving treatments after straightening.

13.5 Cold Straightening

Straightening at a temperature below 205°C (400°F) by dynamic loads is to be used for minor straightening repairs at the tips or at the thin edges of Mn bronze.

For Mn Bronze, NiMn bronze and MnNiAl bronze propellers, cold straightening is to be followed by a stress relief treatment as shown in 2-3-14/15.7 TABLE 11.

13.7 Hot Straightening

i) Hot straightening by dynamic loads and pressure loads may be used for all straightening repairs.

ii) The portion of the propeller which is being straightened is to be kept within the required temperature range during the straightening by means of soft gas torches or strip heaters.

iii) A 500 mm (20 in.) wide zone surrounding the section to be straightened is to be heated through its entire thickness to the required temperature. After the straightening operation has been completed, the propeller is to be slowly cooled to room temperature by covering with insulating blankets, or by other suitable means.

iv) Mn bronze, NiMn bronze and MnNiAl bronze propellers are to be stress relieved as soon as practical after the straightening operation, as per 2-3-14/15.7 TABLE 11.

v) Weld repaired areas may be subject to hot straightening, provided it can be demonstrated that weld properties are not impaired by the hot straightening operations.

13.9 Inspection After Straightening

After straightening and stress relief (if applicable), the propeller is to be inspected in accordance with 2-3-14/7 as applicable.

13.11 Marking

After straightening repair and final inspection, the propeller is to be marked in accordance with 2-3-14/17.3.

15 Repitching *(2024)*

15.1 General

Repitching of a propeller is subject to special approval unless the change in pitch, measured at 0.7 radius, is less than 5% and the repitching is accomplished with uniform deformation and outside the blade 0.4 radius.

No repitching of a propeller that has previously undergone repitching is to be undertaken without special approval by ABS unless the cumulative absolute change in pitch is less than 5% and the above provisions are complied with.

15.3 Repitching by Pressure Loading

i) Repitching by slowly applied uniform loads may be carried out at the temperature ranges indicated in 2-3-14/15.7 TABLE 11. Repitching by dynamic loading is not allowed.

ii) The portion of the propeller which is being repitched is to be kept within the required temperature range during the repitching by soft gas torches or strip heaters.

iii) A 500mm wide zone surrounding the section to be repitched is to be heated through its entire thickness to the required temperature.

iv) After the repitching has been completed, the propeller is to be slowly cooled to room temperature by covering with insulating blankets or by other suitable means.

v) Mn bronze, NiMn bronze and MnNiAl bronze propellers are to be given a suitable stress relief treatment as soon as practical after the repitching operation as indicated in 2-3-14/15.7 TABLE 11.

15.5 Inspection After Repitching

After repitching and stress relief (if applicable), the propeller is to be inspected in accordance with 2-3-14/7 as applicable.

15.7 Marking

After repitching operations and final inspection, the propeller is to be marked in accordance with 2-3-14/17.3.

TABLE 11
Temperatures for Straightening and Repitching Bronze Propellers

	Type 2 *Mn Bronze*	*Type 3* *NiMn Bronze*	*Type 4* *NiAl Bronze*	*Type 5* *MnNiAl Bronze*
Temperature for Minor Straightening in °C (°F)				
Cold Dynamic Loading	Ambient to 205 (Ambient to 400)	Ambient to 205 (Ambient to 400)	Ambient to 205 (Ambient to 400)	Not Recommended
Hot Dynamic Loading	595-760 (1100-1400)	595-760 (1100-1400)	760-955 (1400-1750)	790-870 (1450-1600)

	Type 2 Mn Bronze	*Type 3 NiMn Bronze*	*Type 4 NiAl Bronze*	*Type 5 MnNiAl Bronze*
Cold Pressure Loading	Any temperature	Any temperature	Ambient to 205 (Ambient to 400)	Not Recommended
Hot Pressure Loading	Any temperature	Any temperature	760-955 (1400-1750)	705-815 (1300-1500)
Temperature for Major Straightening in °C (°F)				
Dynamic Loading	595-760 (1100-1400)	595-760 (1100-1400)	760-955 (1400-1750)	790-870 (1450-1600)
Pressure Loading	Any temperature	Any temperature	760-955 (1400-1750)	705-815 (1300-1500)
Temperature for Repitching in °C (°F)				
Pressure Loading	Any temperature	Any temperature	760-955 (1400-1750)	705-815 (1300-1500)
Temperature for Stress Relief After Straightening or Repitching in °C (°F)				
Stress Relief	315-425 (600-800)	370-425 (700-800)	None	565-649 (1050-1200)

17 Marking of Propellers *(2024)*

17.1 New Propellers *(2024)*

i) The manufacturer's name and other appropriate identification markings are to be stamped in such location as to be discernible after finishing and assembly. Propellers are to be stamped on the hub between the blades and preferably in line with the filling plugs, if present.

ii) For separately cast blades, a marking location inside the flange area is preferred.

iii) Type 1, 2, 3, 4 and 5 castings are to be stamped **AB/1**, **AB/2**, **AB/3**, **AB/4**, or **AB/5** respectively, to indicate satisfactory compliance with Rule requirements.

iv) Bronze propellers produced to specifications other than the alloys covered herein are to be stamped **AB/S** and with the applicable manufacture specification number.

17.3 Repaired Propellers *(2024)*

Repaired propellers are to be marked at appropriate locations, preferably adjacent to the existing markings as per 2-3-14/17.1, to indicate that a repair has been conducted.

These provisions relative to marking are not applicable to repairs normally accomplished by the propeller manufacture of a new propeller.

The marking and information to be stamped are as follows:

i) RECON followed by stamping which indicates the type of repair:

  a) "W" for welding repair

  b) "S" for straightening repair

  c) "RP" for repitching

ii) Report Number

iii) Date

iv) Diameter

v) Pitch

19 Manufacturer's Certificate *(2024)*

For each propeller, the manufacturer is to supply to the Surveyor a certificate containing the following details:

i) Purchaser and order number

ii) Shipbuilding project number, if known

iii) Description of the casting with drawing number

iv) Diameter, number of blades, pitch, direction of turning

v) Grade of alloy and chemical composition of each heat

vi) Heat or casting number

vii) Final weight

viii) Results of nondestructive tests and details of test procedure where applicable

ix) Portion of alpha-structure for Types 2 and 3 alloys

x) Results of mechanical tests

xi) Casting identification number

xii) Skew angle for high skew propellers

xiii) Details of weld repairs including location, or by reference to the sketches required (see 2-3-14/9.7).

PART 2

CHAPTER 3
Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 15
Stainless Steel Propeller Castings *(2024)*

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	Steel making is to be capable of producing steel within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope

The following requirements cover stainless steel castings intended to be used for propeller and propeller blades.

This section provides requirements for ABS grade stainless steel castings. Alternatively, castings complying with recognized national standards or proprietary specifications may be considered by ABS, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

3 ABS Grade Propeller and Propeller Blades *(2024)*

3.1 Process of Manufacture *(2024)*

The stainless steel is to be melted by open hearth or electric furnace process with or without separate refining such as argon oxygen decarburization (AOD), unless otherwise specified in the individual specification, or other process as may be approved.

Chemical composition and tensile property requirements for ABS grade stainless steel castings can be found in 5 and 2-3-5/7 respectively.

Austenitic stainless steel castings (CF-3 and CF-8) are to be in solution heat treated.

Martensitic stainless steel castings (CA-6NM, CB-6 and CA-15) are to be austenitized and tempered.

3.3 Foundry Approval

3.3.1 Approval *(2024)*

All stainless steel propellers and propeller components are to be cast by ABS-approved foundries. The foundries are to demonstrate that they have available the necessary facilities and skilled personnel to manufacture propellers which are to satisfy these Rules and meet the manufacturing specifications.

ABS approval is valid for 5 years subject to annual endorsement by the attending Surveyor. The following are important aspects of casting process that may influence the final cast physical and mechanical properties:

i) Mold preparation and chaplet positioning

ii) Pouring practice, times and temperatures

iii) Mold breakout

iv) Heat treatment process and recording chart

v) Coupon preparation

vi) Testing and inspection

vii) Casting rectification

Any of the above aspects can be included in a Survey patrol.

3.3.2 Scope of the Approval Test *(2024)*

The following aspects of manufacture are to be taken into account during initial and extension approval:

- Casting types and sizes
- Material specifications
- Ladle capacities
- Molding and casting equipment and practices
- Heat treatment equipment and practices
- Testing and inspection procedure
- Repair and finishing procedure

Cast test coupons of the propeller materials involved are to be tested in order to verify that the chemical composition and the mechanical properties comply with these Rules and the manufacturing specification.

3.3.3 Quality Control *(2024)*

In addition, information as to the company's facilities and organization, quality control documentations, certification in accordance with recognized national or international organizations standards, such as ISO standards or equivalent are to be submitted to ABS.

3.5 Quality of Castings *(2024)*

i) The castings are to be free from defects and have a workmanlike finish.

ii) Surface inspection is to be conducted in accordance with 13.

iii) Minor casting defects such as small sand and slag inclusions, small cold shuts and scabs are to be suitably removed by mechanical means such as chipping or grinding. Refer to 15.

iv) When removal and welding repair is necessary, refer to 15.

5 Chemical Composition

5.1 Ladle Analysis *(2024)*

An analysis of each heat is to be made by the manufacturer from a test sample that is representative of the heat and that is taken during the pouring of the heat. The chemical composition in % thus determined is to conform to the requirements specified in 2-3-15/Table 1 below for different ABS grade stainless steel propellers and propeller blades.

TABLE 1
Chemical Composition, in Percent (1, 2, 3) *(2024)*

Elements/Grade	*Grade CF-3*	*Grade CF-8*	*Grade CA-6NM*	*Grade CB-6*	*Grade CA-15*
Carbon	0.03	0.08	0.06	0.06	0.15
Manganese	1.50	1.50	1.00	1.00	1.00
Silicon	2.00	2.00	1.00	1.00	1.50
Sulfur	0.04	0.04	0.03	0.03	0.04
Phosphorus	0.04	0.04	0.04	0.04	0.04
Chromium	17.0 to 21.0	18.0 to 21.0	11.5 to 14.0	15.5 to 17.5	11.5 to 14.0
Nickel	8.0 to 12.0	8.0 to 11.0	3.5 to 4.5	3.5 to 5.5	1.00
Molybdenum	-	-	0.40 to 1.0	0.50	0.50

Notes:

1. All values are maximum except when a range is provided.
2. Chemical analysis and limits for elements not specified for the grade ordered is to be as agreed upon between the manufacturer and purchaser.
3. The manufacturer is to maintain records of the chemical analyses of the production casts and are to be made available to the surveyor.

7 Tensile Properties *(2024)*

The tensile properties of ABS grade stainless steel propellers and propeller blades are shown in 2-3-15/Table 2 below. These values are applicable to test specimens taken from separately cast or integrally cast test coupons. Testing is to be in accordance with 9.

TABLE 2
Tension Properties (1) *(2024)*

Property/Grade	*CF-3*	*CF-8*	*CA-6NM*	*CB-6*	*CA-15*
Tensile Strength, in N/mm^2 (kg/mm^2, psi)	485 (49, 70,000)	485 (49, 70,000)	755 (77, 110,000)	790 (81, 115,000)	620 (63, 90,000)
Yield Strength in N/mm^2 (kg/mm^2, psi) (0.2% offset)	205 (21, 30,000)	205 (21, 30,000)	550 (56, 80,000)	580 (59, 85,000)	450 (46, 65,000)
Elongation, in 50 mm (2 in.), in percent	35	35	15	16	18

Note:

1 The tension properties of other alloys not meeting the minimum values of 2-3-15/Table 2 are to comply with specification approved by ABS.

9 Test Specimens *(2024)*

9.1 General *(2024)*

The tension test specimen is to be machined to the dimensions shown in 2-3-1/11.13 FIGURE 2. The tension test coupons may be separately or integrally cast.

9.3 Separately Cast Coupons *(2024)*

When the test specimens are separately cast, they are to meet the following:

i) Poured from the same ladles of metal used to pour the propeller casting.

ii) In cases where more than one ladle of metal is required for the propeller, a test coupon is to be provided for each ladle.

iii) Cast in mold made of same material as the mold for the propeller casting.

iv) Specimens are to be cooled down under the same conditions as the propeller casting.

v) When heat treatment is applicable, the test samples are to be heat treated together with the propeller.

vi) Satisfactory evidence is to be furnished the Surveyor to identify the test coupons as representing the material to be tested.

9.5 Integral Coupons *(2024)*

For integrally cast test coupons, the following requirements are to be met:

i) Furnished as coupons attached to the hub or on the blade.

ii) 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.

iii) Test bars are not to be detached from the casting until final heat treatment has been carried out.

iv) The test samples are to be removed by non-thermal process.

9.7 Number of Tests

i) Separately cast test coupons, at least one tension test is to be taken from each ladle.

ii) Integrally cast test coupons, at least one tension test is to be taken for each casting.

iii) The test results are to comply with the requirements prescribed in 7.

9.9 Special Compositions *(2024)*

It is recognized that other alloys have been developed and proven by tests and service experience to be satisfactory. When other grades of propeller materials with different chemical compositions to 5.1 TABLE 1 are proposed, specifications are to be submitted for approval in connection with the approval of the design for which the material is intended.

9.11 Intergranular Corrosion *(2024)*

Intergranular corrosion affects austenitic stainless steels (e.g., grades CF-3, CF-8) which can be detected by liquid penetrant examination and manifests as a pattern of surface cracks. Refer to 13.

When required by the purchase order, tests are to be carried out in accordance with ASTM A262 to detect susceptibility of austenitic stainless steels to intergranular attack.

Commentary:

Exposure of austenitic stainless steels to a temperature range of 950ºF - 1450ºF could potentially lead to sensitization, where chromium carbide ($Cr_{23}C_6$) precipitates at grain boundaries resulting in intergranular corrosion. Common practices such as welding, stress relieving or hot forming can expose the austenitic stainless steel to the sensitizing temperature range. Formation of chromium carbides can be reversed by solution anneal heat treatment.

End of Commentary

9.13 Ferrite Count *(2024)*

When low-ferrite or nonmagnetic properties are required for CF-8, the mechanical property requirements and volume fraction of ferrite can be determined in accordance with ASTM A890 as agreed in the purchase order.

9.15 Preparation for Storage *(2024)*

Unless they are intended for use immediately after manufacture or repair, the surfaces of propellers are to be suitably protected from the possible adverse corrosive effects of certain atmospheric environments common to shipyards and foundries.

11 Definition of Skew and Severity Zones *(2024)*

Refer to 2-3-14/5.

13 Inspection *(2024)*

Refer to 2-3-14/7.

Commentary:

i A dye penetrant examination of the entire propeller is to be made for the martensitic stainless steel propellers, a magnetic particle examination may be used in lieu of dye penetrant examination, provided that proper precaution to prevent arc strike is taken.

ii For austenitic stainless steel propellers, particular attention is to be given to detect cracking typical of intergranular corrosion.

End of Commentary

15 Rectification *(2024)*

Refer to 2-3-14/9.

17 Weld Repair Procedure Qualification *(2024)*

17.1 General

Before repair welding is started, full details of the extent and location of the repair, the proposed welding procedure, weld preparation, heat treatment and subsequent inspection procedures are to be submitted to ABS Materials Department for approval.

17.3 Preheat and Interpass Temperatures

i) The preheat and interpass temperatures are to be extended entirely through the section being repaired to a distance of about 300 mm (12 in.) on all sides of the repair area so that a maximum temperature gradient of about 55°C per 300 mm (100°F per ft) can be maintained in the surrounding area.

ii) Heating is to be accomplished by means of soft gas (natural gas, LPG) torches or strip heaters or by means of moving oxyacetylene torches used with proper precaution to avoid local overheating.

iii) The temperature is to be checked at frequent intervals by temperature indicating crayons or contact pyrometers.

iv) The preheat and interpass temperatures are to be maintained throughout the entire welding operation.

v) Adequate support is to be provided during the preheat and welding operations to minimize distortion.

vi) The preheat and interpass temperature ranges listed in 17.13 TABLE 3 through 17.13 TABLE 6 are to be used for the various welding processes and alloys.

17.5 Cooling After Welding

The welded areas of martensitic stainless-steel propellers are to be slowly cooled by wrapping with insulating blankets to reduce the possibility of cracking. To achieve a favorable microstructural response to subsequent stress relieving, the welded areas of martensitic stainless steel propellers are to be slowly cooled to the temperature noted below:

i) Grade CA-6NM and CB-6: 95°C (200°F)

ii) Grade CA-15: 205°C (400°F)

The welded areas of austenitic stainless-steel propellers may be air cooled after welding.

17.7 Stress Relief

17.7.1 General

i) After repairs (welding, straightening and repitching), martensitic grades CA-6NM, CA-15, and CB-6 propellers are to be stress relieved within the appropriate temperature range as shown in 17.13 TABLE 3 through 17.13 TABLE 6.

ii) Grades CF-3 and CF-8 austenitic stainless steel propeller repairs do not require stress relieving treatments as shown in 17.13 TABLE 3, except when special approval for straightening is required, as per 19.3.1.

17.7.2 Furnace Stress Relief

i) Where possible, furnace stress relief is to be carried out after repairs, especially for heavy sections such as the hub or the fillet areas. This may be done either by heating the entire propeller or a complete section containing the areas to be stress relieved in a furnace.

ii) Furnace stress relief of an entire propeller is to slowly and uniformly heat to a temperature in the appropriate temperature range, and the soaking time at temperature is to be a minimum of 6 hours.

iii) When only a section of the propeller is furnace stress relieved, the holding time is to be at least 20 minutes per 25.4 mm (1 in.) of section measured at the thickest portion of the repair area.

iv) Cooling of the entire propeller or section propeller is to be slow and uniform to 315°C (600°F) followed by air cooling.

17.7.3 Local Stress Relief

i) Local stress relief is to be slowly heated to the target stress relieving temperature, so that a temperature gradient of 55°C per 300 mm (100°F per ft) is not exceeded.

ii) Heating is to be accomplished by means of soft gas torches or strip heaters or by use of oxyacetylene torches with proper precautions to avoid local overheating.

iii) The soaking time at target temperature is to be at least 20 minutes per 25.4 mm (1 in.) of thickness at the repair area. In the case of a weld repair, the weld thickness is to be used to determine the soaking time, but in no case is the soaking time to be less than one hour.

iv) Cooling is to be slow and uniform down to 315°C (600°F) and followed by air cooling.

v) For local stress relief, the band is to measure approximately 300 mm (12 in.) on all sides of the repair and is to extend through the entire thickness of the blade.

vi) In addition, for local stress relief of a major repair, the band is to extend across the entire width of the blade.

17.7.4 Distortion Control

Adequate support to minimize distortion is to be provided during stress relieving treatments.

17.9 Preparation for Welding Repair

Defects are to be removed to sound metal prior to welding (refer to 2-3-14/9.3) and the area to be weld repaired is to be appropriately prepared (see 2-3-14/11.9 FIGURE 9 and 2-3-14/11.9 FIGURE 10). For blade tip replacement, appropriate grooves such as shown in 2-3-14/11.9 FIGURE 11 are to be used.

If carbon arc gouging is used, grinding of the prepared groove surface is required to remove any carbon pick-up. All prepared surfaces are to be cleaned to bright metal before welding.

17.11 Inspection Prior to and After Welding Repair

Refer to 2-3-14/11.13.

17.13 Welding Processes, Procedures and Filler Metals

The processes, filler metals and procedures listed in 17.13 TABLE 3 through 17.13 TABLE 6 are to be used for the repair of stainless-steel propellers of the grades indicated.

a) *Peening*. The first weld layer is not to be peened. The last layer also is not to be peened unless the weld is to be subsequently stress relieved. Peening of the intermediate weld layers is optional for the repair shop based on their past experiences.

b) *Soldering or Brazing*. The repair of defects by means of soldering or brazing is not permitted.

c) *Position of Welding*. When practicable, welding is to be done in the flat (downhand) position.

d) Welding is to be done under controlled conditions free from drafts and adverse weather.

TABLE 3
Parameters for Welding of Grades CF-3 and CF-8 Stainless Steel

Filler Metal [1]	***Shielded Metal Arc Welding***	***Gas Metal and Gas Tungsten Arc Welding***
AWS Specification	A5.4	A5.9
AWS Classification [2]	E 308L E 347	ER 308L ER 347
Temperature range in °C (°F)		
Preheat & Interpass Temperature Range	15-260 (60-500)	15-260 (60-500)
Stress relief	None	None

Notes:

1 Equivalent specifications, such as for flux cored filler metals, may be used.

2 Type 308 filler metal may be used for repair of CF-8.

TABLE 4
Parameters for Welding of Grade CA-6NM Stainless Steel

Filler Metal [1]	*Shielded Metal Arc Welding*	*Gas Metal and Gas Tungsten Arc Welding*
AWS Specification	A5.4	A5.9
AWS Classification	E 410 NiMo	ER 410 NiMo
Temperature range in °C (°F)		
Preheat & Interpass Temperature Range	100-315 (210-600)	100-315 (210-600)
Stress relief	565-620 (1050-1150)	565-620 (1050-1150)

Note:

1 Equivalent specifications, such as for flux cored filler metals, may be used.

TABLE 5
Parameters for Welding of Grade CA-15 Stainless Steel

Filler Metal [1]	*Shielded Metal Arc Welding*	*Gas Metal and Gas Tungsten Arc Welding*
AWS Specification	A5.4	A5.9
AWS Classification	E 410	ER 410
Temperature range in °C (°F)		
Preheat & Interpass Temperature Range	205-315 (400-600)	205-315 (400-600)
Stress relief	660-790 (1220-1450)	660-790 (1220-1450)

Note:

1 Equivalent specifications, such as for flux cored filler metals, may be used.

TABLE 6
Parameters for Welding of Grade CB-6 Stainless Steel

Filler Metal (1)	*Shielded Metal Arc Welding*
Specification	DIN 8556
Grade	E 17 6 B 20+
Temperature range in °C (°F)	
Preheat & Interpass Temperature Range	150-200 (300-400)
Stress relief	595-625 (1100-1160)

Note:

1 Equivalent specifications, such as for gas metal arc, gas tungsten arc, and flux cored arc welding filler metals, may be used.

17.15 Repair of Intergranular Corrosion

i) *Intergranular corrosion less than 1.6 mm ($^1/_{16}$ in.) in depth*. If the intergranular corrosion is found to extend less than or equal to 1.6 mm ($^1/_{16}$ in.) beneath the surface of the propeller, repair is to be carried out by surface grinding to remove all the affected material.

ii) *Intergranular corrosion greater than 1.6 mm ($^1/_{16}$ in.) in depth*. If the intergranular corrosion is found to extend more than 1.6 mm ($^1/_{16}$ in.) beneath the surface of the propeller, repair is to be carried out by welding.

iii) *Inspection after repair of intergranular corrosion*. Propellers are to be inspected after repair of intergranular corrosion in accordance with 9.11. All suspect areas are to be examined to confirm that all surfaces of the propeller are free from intergranular corrosion.

iv) *Marking*. After intergranular corrosion welding repair, the propeller is to be marked in accordance with 23.

v) *Preparation for storage*. Propeller surfaces are to be protected after intergranular corrosion welding repair in accordance with 9.15.

17.17 Extent of Testing – Weld Repair Procedure Qualification and Welder Qualification

17.17.1 General

Refer to 2-3-14/11.17.1.

17.17.2 Weld Repair Procedure Qualification

Refer to 2-3-14/11.17.2, except for tensile test results which are to meet the requirements indicated in 7 TABLE 2.

17.17.3 Welder Qualification

Refer to 2-3-14/11.17.3.

17.17.4 Re-testing

Refer to 2-3-14/11.17.4.

17.17.5 Range of Approval

All the conditions of validity stated below are to be met independently of each other. Changes outside of the ranges specified are to require a new welding procedure qualification.

i) *Base Metal*. The range of approval for stainless steel cast propeller is limited to stainless steel grade used in qualification test.

ii) *Welding Position*. Approval for a test made in any position is restricted to that position in qualification test. If a range of qualification is required, welding is to be performed in the highest heat input and lowest heat input positions.

iii) *Welding Process*. The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run process to a single run process and vice versa.

iv) *Filler Metal*. The approval is valid solely for the filler metal designation used in the welding procedure qualification test.

v) *Heat Input*. The upper limit of heat input approval is 15% greater than that used in qualification test. The lower limit of heat input approved is 15% lower than that used in qualification test.

vi) *Preheating and Interpass Temperature*. The minimum preheating temperature is not to be less than that used in the qualification test. The maximum interpass temperature is not to be higher than that used in the qualification test.

vii) *Post Weld heat Treatment*. The heat treatment used in the qualification test is to be specified in WPS, soaking time may adjusted as a function of thickness.

viii) *Thickness*. The range of qualification related to thickness shown below.

Thickness of the Test Piece, t (mm)	*Range of Approval, mm*
$15 < t \leq 30$	3 to 2t
$30 \leq t$	½t to 2t or 200, whichever greater

19 Straightening *(2024)*

19.1 Major and Minor Straightening Repairs

Minor straightening repairs include the repair of edges on the outer $^{1}/_{3}$ of the propeller diameter and are to be limited to the repair of sections under 32 mm (1¼ in.) thick. All other repairs, including repairs to the critical area of high skew propellers, are considered to be major repairs.

19.3 Straightening Procedure

19.3.1 Grade CF-3 and CF-8 Austenitic Stainless Steel

i) Procedures for straightening repairs are subject to special approval when the inner radius of the blade deformation is less than ten times the section thickness.

ii) Other straightening repairs may be conducted by cold or hot straightening and by dynamic or pressure loading at the preference of the facility and in accordance with 21.11 TABLE 7.

iii) Hot straightening is not to exceed 455°C (850°F).

19.3.2 Grade CA-6NM, CA-15, and CB-6 Martensitic Stainless Steel

i) Cold straightening is to be conducted only by pressure loading and only for minor straightening repairs.

ii) Hot straightening by means of dynamic or pressure loading may be used for all straightening repairs.

iii) Stress relief treatments after straightening are to be conducted as per 17.7 and 21.11 TABLE 7.

19.5 Hot Straightening

i) The portion of the propeller which is being hot straightened is to be kept within the target temperature range during the straightening by soft gas torches or strip heaters or moving oxyacetylene torches used with proper precaution to avoid local overheating.

ii) A generous area surrounding the portion to be straightened is to be heated through its entire thickness to the target temperature.

iii) After straightening, the propeller may be slowly and uniformly cooled to ambient temperature. If the propeller is to be subjected to stress relief, it is not necessary to first cool to ambient temperature.

19.7 Cold Straightening

The minimum straightening temperature on the areas to be straightened is to be min. of 15°C (60°F).

19.9 Inspection After Straightening

After straightening repair and stress relief (if applicable), the propeller is to be inspected in accordance with 13.

19.11 Marking

Marking to be as 23.3.

19.13 Preparation for Storage

Propeller surfaces are to be protected after straightening operations when required by 9.15.

21 Repitching *(2024)*

21.1 General

Repitching of a propeller is subject to special approval, unless the change in pitch measured at 0.7 radius is less than 5%, and the repitching is accomplished with uniform deformation and outside the blade of 0.4 radius.

No repitching of a propeller that has been repitched previously is to be undertaken without special approval of ABS, unless the cumulative absolute change in pitch is less than 5% and the above provisions are complied with.

21.3 Repitching by Pressure Loading

i) Slowly applied uniform loads is to be conducted within the temperature ranges indicated in 21.11 TABLE 7.

ii) Repitching by means of dynamic loading is not to be used.

iii) The portion of the propeller which is being repitched is to be kept within the required temperature range during the repitching process by soft gas torches or strip heaters or by means of moving oxyacetylene torches used with proper precaution to avoid local overheating.

iv) A generous area surrounding the portion to be repitched is to be heated through its entire thickness to the required temperature.

v) After the repitching has been completed, the propeller may be slowly and uniformly cooled to ambient temperature. If the propeller is to be stress relieved, it is not necessary to first cool to ambient temperature.

21.5 Stress Relief

Stress relief is to be carried out as 17.7 and 17.13 TABLE 3 through 17.13 TABLE 6 and 21.11 TABLE 7 after repitching.

21.7 Inspection After Repitching

After repitching operations and stress relief (if applicable) have been performed, the propeller is to be inspected in accordance with 2-3-14/13 as applicable.

21.9 Marking

After repitching and final inspection, the propeller is to be marked in accordance with 23.3.

21.11 Preparation for Storage

Propeller surfaces are to be protected after repitching when required by 9.15.

TABLE 7
Temperatures for Straightening and Repitching Stainless Steel Propellers

	Grades CF-3 and CF-8	*Grade CA-6NM and CB-6*	*Grade CA-15*
Temperature for Minor Straightening in °C (°F)			
Dynamic Loading	15-455 (60-850)	565-620 (1050-1150)	675-730 (1250-1350)

	Grades CF-3 and CF-8	*Grade CA-6NM and CB-6*	*Grade CA-15*
Pressure Loading	15-455 (60-850)	15-620 (60-1150)	15-730 (60-1350)
Temperature for Major Straightening in °C (°F)			
Dynamic Loading	15-455 (60-850)	565-620 (1050-1150)	675-730 (1250-1350)
Pressure Loading	15-455 (60-850)	565-620 (1050-1150)	675-730 (1250-1350)
Temperature for Repitching in °C (°F)			
Pressure Loading	15-455 (60-850)	565-620 (1050-1150)	675-730 (1250-1350)
Temperature for Stress Relief After Straightening or Repitching in °C (°F)			
	None	565-620 (1050-1150)	660-790 (1220-1450)

23 Marking of Propellers *(2024)*

23.1 New Propellers

i) The manufacturer is to adopt a system for the identification of all castings, to enable the casting to be traced to its original cast.

ii) Each finished cast propeller is to be marked by the manufacturer at least with the following particulars:

a) The manufacturer's name

b) Heat number

c) Grade of cast material

d) Report number

e) Ice class symbol, where applicable

f) Skew angle for high skew propellers

g) Date of final inspection

iii) Propellers are to be stamped on the hub between the blades and preferably in line with the filling plugs, if present.

iv) For separately cast blades a marking location inside the flange area is preferred.

v) Grade CF-3, CF-8, CA-6NM, CB-6 and CA-15 castings are to be stamped **AB/CF-3**, **AB/S/CF-8**, **AB/S/CA-6NM**, **AB/S/CB-6** and **AB/S/CA-15**, respectively.

vi) Stainless steel propellers and separately cast blades, produced to specifications other than the alloys covered herein are to be stamped **AB/S** followed by the manufacturing specification.

23.3 Repaired Propellers

Repaired propellers are to be marked at appropriate locations, preferably adjacent to the existing markings as per 23.1 to confirm that repair has been performed.

These provisions relative to marking are not applicable to repairs normally accomplished during the manufacture of a new propeller.

The marking and information are to be stamped as follows:

i) RECON followed by stamping which indicates the type of repair.

a) "W" for welding repair

b) "S" for straightening repair

c) "RP" for repitching.

ii) Report Number

iii) Date

iv) Diameter

v) Pitch

25 Manufacturer's Certificate *(2024)*

For each propeller, the manufacturer is to supply to the Surveyor a certificate containing the following details:

i) Purchaser and order number

ii) Vessel identification or shipbuilding project number, if known

iii) Description of the casting with drawing number

iv) Diameter, number of blades, pitch, direction of turning

v) Grade of alloy, heat number and chemical composition

vi) Heat or casting number

vii) Final weight

viii) Results of mechanical tests

ix) Casting identification number

x) Details of time and temperature of heat treatment

xi) Skew angle for high skew propellers

xii) Result of non-destructive tests and details of test procedure where applicable

xiii) Details of weld repairs including location, or by reference to the sketches required as in 15.

PART 2

CHAPTER 3
Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 16
Seamless Copper Piping *(1998)*

Note:

In substantial agreement with ASTM B42.

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection, and certification of seamless copper pipes intended for boiler feed, heat exchangers/condensers and piping systems.

Requirements for ABS grade pipes and tubes are in 2-3-16/27. Alternatively, pipes complying with recognized national standards or proprietary specifications may be accepted by ABS, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified.

7 Marking

7.1 Manufacturer's Marking *(2024)*

The name or brand of the manufacturer, the applicable grade (ABS or other), and the test pressure are to be legibly marked by stamping or stenciling on each length of pipe. On small-diameter pipe, which is bundled, this information may be marked on a tag securely attached to each bundle.

7.3 ABS Markings

The ABS 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 2-3-16/7.1.

9 Chemical Composition *(2024)*

Chemical composition is to meet requirements of the ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

10 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-16/27 or recognized national standard or proprietary specification.

11 Tension Test

11.1 Tension Test Specimens *(2024)*

Tension test specimens are to be a full section of the pipe. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the pipe in accordance with ASTM E8.

11.3 Tensile Properties *(2024)*

Tension tests are performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

13 Expansion Test *(2024)*

When applicable, expansion tests are performed and meet requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

15 Flattening Test *(2024)*

When applicable, flattening tests are performed and meet requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

17 Hydrostatic Test

17.1 General *(2024)*

When applicable, hydrostatic tests are performed and meet requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

17.3 Affidavits of Tests

Where each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

19 Number of Tests *(2024)*

Test specimens are to be in accordance with requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

20 Microscopical Examination *(2024)*

When required, microscopical examination is to be performed and meet requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

21 Retests *(2024)*

If the results of the test on one of the specimens, made to determine the physical properties, do not meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests are 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.

23 Permissible Variations in Dimensions *(2024)*

The permissible variations in wall thickness diameter and other dimensions are based on the ordered thickness and are to conform to that given in the applicable ASTM designation for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of such prior acceptance.

25 Nondestructive Examination *(2024)*

When applicable, nondestructive examination is to be performed and meet requirements of the applicable ABS grade in 2-3-16/27 or other recognized national standard or proprietary specification.

27 ABS Grade Seamless Copper Pipes *(2024)*

ABS grade seamless copper pipes are to be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in 2-3-17/27 TABLE 1 to meet the design requirements. Tensile properties are identified in 2-3-18/27 TABLE 2.

TABLE 1
ABS Grade Seamless Copper Pipes *(2024)*

ABS Designation	*ASTM Specification*	*UNS number*
C2	ASTM B42	C10200
C3	ASTM B42	C10300
C4	ASTM B42	C10800
C5	ASTM B42	C12000
C6	ASTM B42	C12200

TABLE 2
Tensile Properties of ABS Grade Seamless Copper Pipes *(2024)*

Temper Designation		*Yield Strength, N/mm² (kgf/mm², ksi)*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)*
Code	*Name*		
O60[(1)]	Soft Anneal	62 (6, 9)	205 (21, 30)
H55[(2)]	Light-drawn	205 (21, 30)	250-325 (24.5-33, 36-47)
H80[(2)]	Heavy-drawn	275 (28, 40)	310 (31.6, 45)

Notes:

1 For bending applications, the pipe is to be furnished with an annealed temper (O60).

2 Other drawn tempers (H55) or heavy-drawn temper (H80) may be furnished for other applications.

29 Pipe Testing and Inspection *(2024)*

i) 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.

ii) The pipes are to be examined by the Surveyor when requested by the purchaser.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 17

Seamless Red-brass Piping *(2024)*

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Part 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope

This section provides requirements for manufacture, testing, inspection and certification of seamless red-brass piped intended for boiler and piping system.

Requirements for ABS grade boiler and pressure vessel tubes are provided in 2-3-17/27. Alternatively, pipes which comply with recognized national standards or proprietary specifications may be considered by ABS, provided such specifications give reasonable equivalence to these requirements and meet the specified requirements.

2 Process of Manufacture *(2009)*

i) The material is to be produced by either hot or cold working or both. It is to be finished, unless otherwise specified, by cold working and annealing or heat treatment as may be necessary to meet the properties specified.

ii) All pipes are usually 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 specified by the purchaser.

3 Marking

3.1 Manufacturer's Marking *(2024)*

The name or brand of the manufacturer, the applicable grade (ABS or other), and the test pressure is to be legibly marked by stamping or stenciling on each length of pipe. On small-diameter pipe, which is bundled, this information may be marked on a tag securely attached to each bundle.

3.3 ABS Marking

The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be marked on the material near the markings specified in 2-3-17/3.1.

5 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

7 Chemical Composition *(2024)*

Chemical composition is to meet requirements of the ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

Analysis is regularly to be made only for the elements specifically mentioned in this table. If, however, the presence of other elements is suspected 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.

9 Expansion Test *(2024)*

When applicable, an expansion tests are performed and is to meet the requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

11 Flattening Test *(2024)*

When applicable, a flattening tests are performed and is to meet the requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

13 Mercurous Nitrate Test *(2024)*

When applicable, a Mercurous Nitrate test is to be performed and is to meet the requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

15 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 one and one-half times the inside diameter of the pipe, without cracking on the outside of the bent portion. This test is to apply only to sizes 50.8 mm (2 in.) and under in outside diameter.

17 Hydrostatic Test

17.1 General *(2024)*

When applicable, a hydrostatic tests are performed and is to meet the requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

17.3 Affidavits of Tests

Where each pipe is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

19 Number of Tests *(2024)*

Test specimens are to be in accordance with requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

21 Retests

If the results of the test on one of the specimens, made to determine the physical properties, do not meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results of both of these tests are 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.

23 Permissible Variations in Dimensions *(2024)*

The permissible variations in wall thickness, diameter and other dimensions are based on the ordered thickness and are to conform to that given in the applicable ASTM for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of any prior acceptance.

25 Nondestructive Examination *(2024)*

When applicable, nondestructive examination is to be performed and is to meet the requirements of the applicable ABS grade in 2-3-17/27 or other recognized national standard or proprietary specification.

27 ABS Grade Red-Brass Pipes *(2024)*

ABS grade pipes are to be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in the table below and are to meet the design requirements.

TABLE 1
ABS Grade Red-Brass Pipes *(2024)*

ABS Designation	*Specification*	*Temper*	*Yield Strength, N/mm^2 (kgf/mm^2, ksi)*	*Ultimate Tensile Strength, N/mm^2 (kgf/mm^2, ksi)*	*Minimum % Elongation 50 mm (2 in.)*
RB	ASTM B43	061 Annealed	85 (9, 12)	275 (28, 40)	35

29 Pipe Testing and Inspection *(2024)*

i) All pipes for working pressures over 10 bar (10.5 kgf/cm^2, 150 psi) are to be tested and inspected at the mills to the satisfaction of the Surveyor.

ii) The pipes are to be examined by the Surveyor when requested by the purchaser.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 18

Seamless Copper Tube *(2024)*

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of seamless copper tubes for boiler and piping systems.

Requirements for ABS grade copper tubes are provided in 2-3-18/27. Alternatively, tubes which comply with recognized national standards or proprietary specifications may be considered by ABS, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

The material is to be produced by either hot or cold working operations, or both. It is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified.

7 Marking

7.1 Manufacturer's Marking *(2024)*

The name or brand of the manufacturer, the applicable grade (ABS or other), and the test pressure are to be legibly marked by stamping or stenciled on each length of tube. On small-diameter tube, which is bundled, this information may be marked on a tag securely attached to each bundle.

7.3 ABS Markings

The ABS 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 2-3-18/7.1.

9 Chemical Composition *(2024)*

Chemical composition is to meet requirements of the ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

10 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-5/41 or other recognized national standard or proprietary specification.

11 Tension Test

11.1 Tension Test Specimens *(2024)*

Tension test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8.

11.3 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

13 Expansion Test *(2024)*

When applicable, expansion tests are to be performed and meet the requirements of the applicable ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

15 Flattening Test

When applicable, a flattening tests are to be performed and meet the requirements of the applicable ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

17 Hydrostatic Test

17.1 General *(2024)*

When applicable, hydrostatic tests are to be performed and meet the requirements of the applicable ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

17.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

19 Number of Tests *(2024)*

Test specimens are to be in accordance with requirements of the applicable ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

21 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, do not meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results 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.

23 Permissible Variations in Dimensions *(2024)*

The permissible variations in wall thickness and diameter and other dimensions are based on the ordered thickness and are to conform to that given in the applicable ASTM for acceptance, but the minimum thickness for all pipe is not to be less than that required by the Rules for a specific application, regardless of any prior acceptance.

25 Nondestructive Examination *(2024)*

When applicable, nondestructive examination is to be performed and meet the requirements of the applicable ABS grade in 2-3-18/27 or other recognized national standard or proprietary specification.

27 ABS Grade Seamless Copper Tubes *(2024)*

ABS grade seamless copper tubes are to be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in 2-3-18/27 TABLE 1 to meet the design requirements. Tensile properties are identified in 2-3-18/27 TABLE 2.

TABLE 1
ABS Grade Seamless Copper Tubes *(2024)*

ABS Designation	*ASTM Specification*	*UNS Number*
CA	ASTM B75	UNS C10100
CB	ASTM B75	UNS C10200
CC	ASTM B75	UNS C10300
CD	ASTM B75	UNS C10800
CE	ASTM B75	UNS C12000
CF	ASTM B75	UNS C12200

TABLE 2
Tensile Properties of ABS Grade Seamless Copper Tubes *(2024)*

Temper Designation		*Yield Strength, N/mm² (kgf/mm², ksi)*	*Ultimate Tensile Strength, N/mm² (kgf/mm², ksi)*
Code	*Name*		
O60[1]	Soft Anneal	62 (6, 9)	205 (21, 30)
H55[2]	Light-drawn	205 (21, 30)	250-325 (24.5-33, 36-47)
H80[2]	Heavy-drawn	275 (28, 40)	310 (31.6, 45)

Notes:

1 For bending applications, the tube is to be furnished with an annealed temper (O60).

2 Other drawn tempers (H55) or heavy-drawn temper (H80) may be furnished for other applications.

29 Tube Testing and Inspection *(2024)*

i) All tubes for working pressures over 10 bar (10.5 kgf/cm^2, 150 psi) are to be tested and inspected at the mills to the satisfaction of the Surveyor.

ii) The tubes are to be examined by the Surveyor when requested by the purchaser.

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 19

Condenser and Heat Exchanger Tube *(1998)*

Note:

In substantial agreement with ASTM B111.

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of seamless copper nickels tubes for condensers, evaporators and heat exchangers.

Requirements for ABS grade copper nickel tubes are provided in 2-3-19/27. Alternatively, tubes which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

The product is to be produced by either hot or cold working operations and worked to the finished size, and subsequently annealed, straightened, trimmed, or undergo other processes, when required, to meet the temper properties specified.

7 Marking

7.1 Manufacturer's Marking *(2024)*

Identification markings are to be legibly stenciled, or suitably marked on each length of tube, except that in the case of smaller-diameter tube 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:

- Name or brand of the manufacturer
- Name and type of material grade (ABS or other)
- Heat number
- Temper number
- Tube diameter
- Wall thickness
- Test Pressure, or the letters NDET
- ABS markings by the Surveyor

7.3 ABS Markings *(2024)*

The ABS 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 2-3-19/7.1.

9 Chemical Composition

9.1 Chemical Requirements *(2024)*

Chemical composition is to meet requirements of the ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

9.3 Chemical Analysis Sampling

Samples may be taken at the time the metal is cast or may be taken from semi-finished product, or from finished product in accordance with sampling in 2-3-19/21.

10 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

11 Tension Test

11.1 Tension Test Specimens *(2024)*

Tension test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8.

11.3 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 2-3-19/27 TABLE 2 or other recognized national standard or proprietary specification.

13 Expansion Test *(2024)*

When applicable, expansion test is to be performed and meet the requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

15 Flattening Test *(2024)*

When applicable, flattening test is to be performed and meet the requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

17 Nondestructive Electric Test (NDE) *(2024)*

When applicable, nondestructive examination is to be performed and meet the requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

19 Hydrostatic Test

19.1 General *(2024)*

When applicable, hydrostatic test is to be performed and meet the requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

19.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

21 Number of Tests *(2024)*

Test specimens are to be in accordance with requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

Chemical analyses, where required, tensile tests, expansion tests, flattening tests, dimensional examinations and visual examinations are to be made 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.

23 Retests

If the results of the test on one of the specimens, made to determine the mechanical properties, do not meet the requirements, this test is to be repeated on each of two additional specimens taken from different pieces and the results 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.

25 Workmanship, Finish and Appearance *(2024)*

Workmanship, surface finish and appearance of the tubes are to be in accordance with requirements of the applicable ABS grade in 2-3-19/27 or other recognized national standard or proprietary specification.

27 ABS Grade Seamless Copper Nickel Tubes *(2024)*

Tubes selected for testing are to be measured and examined for dimensions and tolerances.

TABLE 1
ABS Grade Seamless Copper Nickel Tubes *(2024)*

ABS Designation	ASTM Specification	UNS Number
CNA	ASTM B111	UNS C70600
CNB	ASTM B111	UNS C71500

TABLE 2
Tensile Properties of ABS Grade Seamless Copper Nickel Tubes *(2024)*

Grade	Temper Designation		Tensile Strength, min. N/mm^2 (kgf/mm^2, ksi)	Yield Strength, min. N/mm^2 (kgf/mm^2, ksi) (1)	Elongation in 2 in., min %
	Code	Name			
CNA	061	Annealed	275 (28,40)	105 (11, 15)	=
CNA	H55	Light Draw	310 (32,45)	240 (25, 35)	=
CNB	061	Annealed	360 (36,52)	125 (13, 18)	=
CNB	HR50	Drawn and Stress Relieved	495 (51,72)	345 (35, 50)	12 (2);15 (3)

Notes:

1 At 0.5% extension under load

2 For wall thickness 1.21 mm (0.048 in.) and less

3 For wall thickness over 1.21 mm (0.048 in.).

29 Inspection *(2024)*

i) The tubes are to be examined by the Surveyor when requested by the purchaser.

ii) All tubes are to be round, straight, clean, smooth and free from harmful defects and deleterious films in the bore.

SECTION 20
Copper-Nickel Tube and Pipe *(1998)*

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 Goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.

Functional Requirement No.	*Functional Requirements*
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of seamless and welded copper-nickel tube and pipe intended piping applications requiring seawater corrosion resistance.

Requirements for ABS grade tubes and pipes are specified in 2-3-20/29. Alternatively, tubes and pipes which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

The material is to be produced by hot extrusion or piercing and subsequent cold working for seamless pipes and tubes. In the case of welded pipes and tubes, cold working is to be performed after welding and prior to the heat treatment. The material is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified in 2-3-20/29.

6 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

7 Marking

7.1 Manufacturer's Marking *(2024)*

Identification markings are to be legibly marked by stamping or stenciled on each piece of tubular. For material with small outside diameter which is bundled this information may be marked on a tag securely attached to each bundle. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- Name and type of material grade (ABS or other)
- UNS Alloy Number
- Heat number or manufacturer's number by which the heat can be identified
- Temper designation

- Tube diameter/NPS Designation
- Wall thickness (specify minimum or nominal)/NPS schedule
- Test pressure
- NDET if so tested

7.3 ABS Markings *(2024)*

The ABS 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 2-3-20/7.1.

9 Chemical Composition *(2024)*

Chemical composition is to meet requirements of the ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

11 Tension Test

11.1 Tension Test Specimens

Tension test specimens are to be a full section of the tube. For larger sizes, tension test specimens are to consist of longitudinal strips cut from the tube in accordance with ASTM E8, for Tension Testing of Metallic Materials.

11.3 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet requirements of the applicable ABS grade in 2-3-20/29 or a recognized national standard or proprietary specification.

13 Expansion Test *(2024)*

When applicable, expansion test is to be performed in accordance with ASTM B153 or other nationally recognized standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

15 Flattening Test *(2024)*

When applicable, flattening test is to be performed in accordance with ASTM B968 or other nationally recognized standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

17 Nondestructive Examination

17.1 General *(2024)*

When applicable, nondestructive examination is to be performed in accordance with ASTM E243 or other nationally recognized standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

19 Hydrostatic Test

19.1 General *(2024)*

When applicable, hydrostatic test is to be performed in accordance with ASTM B466 or B467 or other nationally recognized standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

19.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

21 Number of Tests *(2024)*

Test specimens are to be in accordance with requirements of the applicable ABS grade in 2-3-20/29 or recognized national standard or proprietary specification.

23 Retests *(2024)*

If the results of the test on one of the specimens, made to determine the mechanical properties, fails to meet the requirements of the applicable ABS grade in 2-3-20/29, this test is to be repeated on each of two additional specimens taken from different pieces and the results 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.

25 Workmanship, Finish and Appearance *(2024)*

Tubes selected for testing are to be examined for finish and workmanship. Tubes are to be free from cracks, injurious surface flaws and similar defects to the extent determinable 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.

27 Dimensions and Tolerances *(2024)*

The following dimensions of finished seamless and welded tubes is to be performed in accordance with ASTM B466 and B467, respectively or other recognized national standards as agreed with ABS,

i) Wall Thickness

ii) Outside Diameter

iii) Length

iv) Ends Cut

v) Straightness

vi) Roundness

29 ABS Grade Copper-Nickel Tube and Pipe *(2024)*

ABS grade tubes and pipes may be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in 2-3-20/29 TABLE 1 to meet the design requirements.

TABLE 1
ABS Grade Copper Nickel Tube and Pipe *(2024)*

ABS Designation	*ASTM Specification*	*UNS Number*
Seamless		
CN1	ASTM B466	UNS C70600
CN2	ASTM B466	UNS C71500
Welded		
CN3	ASTM B467	UNS C70600
CN4	ASTM B467	UNS C71500

TABLE 2
Tensile Properties of ABS Grade Copper Nickel Tube and Pipe *(2024)*

<table>
<tr><th colspan="2">Temper Designation</th><th>Yield Strength, N/mm2 (ksi)</th><th>Ultimate Tensile Strength, N/mm² (ksi)</th><th>Rockwell B Hardness 30 T</th></tr>
<tr><td colspan="5">Seamless</td></tr>
<tr><td>Annealed (060)</td><td>CN1
CN2</td><td>90 (13)
125 (18)</td><td>260 (38)
360 (52)</td><td>45 max
51 max</td></tr>
<tr><td colspan="2">Light Drawn (H55) CN1</td><td>240 (35)</td><td>310 (45)</td><td>45-70</td></tr>
<tr><td colspan="5">Welded</td></tr>
<tr><td rowspan="2">As-Welded and Annealed (WO61)</td><td>CN3</td><td>105 (15) ≤ 114 mm dia
90 (13) > 114 mm dia</td><td>275 (40)
260 (38)</td><td>25</td></tr>
<tr><td>CN4</td><td>140 (20) ≤ 114 mm dia
105 (15) > 114 mm dia</td><td>345 (50)
310 (45)</td><td>30</td></tr>
<tr><td>As-welded (WO50) CN3</td><td>CN4</td><td>205 (30) ≤ 114 mm dia</td><td>310 (45)</td><td>-</td></tr>
</table>

PART 2

CHAPTER 3

Materials for Machinery, Boilers, Pressure Vessels, and Piping

SECTION 21

Monel Pipe and Tube *(1999)*

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Scope *(2024)*

This section covers requirements for manufacture, testing, inspection and certification of seamless and welded nickel-copper (Monel) pipes and tubes intended piping applications requiring superior seawater corrosion resistance.

Requirements for ABS grade pipes and tubes are provided in 2-3-21/31. Alternatively, tubes which comply with recognized national standards or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements and meet the design requirements.

5 Process of Manufacture *(2024)*

The material is to be produced by cold working operations for seamless and for welded pipes and tubes after welding and prior to the heat treatment. The material is to be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified.

6 Heat Treatment *(2024)*

Heat treatment is to be carried out in furnaces which are maintained and have means for control and recording of temperature. Heat treatment is to be in accordance with the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

7 Marking

7.1 Manufacturer's Marking *(2024)*

Identification markings are to be legibly stenciled, or marked on each length of pipe and tube. The marking fluid is not to be harmful to the pipe and tube and is not to rub off or smear 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. In the case of small-diameter tube or pipe with an outside diameter less than 19.0 mm ($^3/_4$ in.) which is bundled or boxed, the required markings are to be placed on a tag securely attached to the bundle or box, or on the box. The markings are to be arranged and are to include the following information:

- Name or brand of the manufacturer
- Grade (ABS or Other)
- UNS Alloy Number
- Heat number or manufacturer's number by which the heat can be identified
- Temper designation
- Tube diameter/NPS Designation
- Wall thickness (specify minimum or nominal)/NPS schedule
- Test pressure
- NDET if so tested

7.3 ABS Markings *(2024)*

The ABS 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 2-3-21/7.1.

9 Chemical Composition *(2024)*

Chemical composition is to meet requirements of the ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

11 Tension Test

11.1 Tension Test Specimens

Tension test specimens are to be a full section 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.

11.3 Tensile Properties *(2024)*

Tension tests are to be performed to determine yield strength, ultimate tensile strength, elongation and reduction of area. The results are to meet the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

13 Flattening Test *(2024)*

When applicable, flattening test is to be performed in accordance with ASTM B751 or other recognized national standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

15 Flare Test *(2024)*

When applicable, flare test is to be performed in accordance with ASTM B829 or ASTM B751 or other recognized national standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

17 Flange Test *(2024)*

When applicable, flange test is to be performed in accordance with ASTM B751 or other recognized national standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

19 Number of Tests *(2024)*

Test specimens are to be in accordance with requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

21 Hydrostatic Test

21.1 General *(2024)*

When applicable, hydrostatic test is to be performed in accordance with ASTM B829 or ASTM B751 or other recognized national standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

21.3 Affidavits of Tests

Where each tube is hydrostatically tested as a regular procedure during process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

23 Nondestructive Examination *(2024)*

23.1 General *(2024)*

When applicable, nondestructive examination is to be performed in accordance with ASTM B829 or ASTM B751 or other recognized national standards as agreed with ABS. The results are to meet the requirements of the applicable ABS grade in 2-3-21/31 or other recognized national standard or proprietary specification.

23.3 Affidavits

When each tubular is subjected to an approved nondestructive electrical test as a regular procedure during the process of manufacture, an affidavit covering this test may be accepted by the Surveyor.

25 Retests *(2024)*

If the results of the test on one of the specimens made to determine the mechanical properties, do not meet the requirements of the applicable ABS grade in 2-3-12/41 or other recognized national standard or proprietary specification, this test is to be repeated 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 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.

27 Workmanship, Finish and Appearance *(2024)*

Pipe or tube selected for testing is to be examined 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.

29 Dimensions and Tolerances *(2024)*

The following dimensions of finished seamless and welded tubes are to be in accordance with ASTM B829 or ASTM B751, respectively or other recognized national standards as agreed upon by ABS,

i) Wall Thickness

ii) Outside Diameter

iii) Length

iv) Ends Cut

v) Straightness

31 ABS Grade Monel Pipes and Tubes *(2024)*

ABS grade tubes may be manufactured in accordance with all the applicable requirements of the ASTM grade referenced in 2-3-21/31 TABLE 1 to meet the design requirements.

TABLE 1
ABS Grade Monel Pipes and Tubes *(2024)*

ABS Designation	ASTM Specification	UNS Number
Seamless Pipes and Tubes		
M1	ASTM B165	UNS N044003
M2	ASTM B165	UNS N044003
Welded Pipes and Tubes		
M3	ASTM B730	UNS N04400
M4	ASTM B730	UNS N04400

TABLE 2
Tensile Properties of ABS Grade Monel Tubes and Pipes *(2024)*

Temper Designation	Yield Strength, N/mm^2 (ksi)	Ultimate Tensile Strength, N/mm^2 (ksi)	Elongation %
Seamless Pipes and Tubes			
Annealed	195 (28) ≤ 127 mm dia	480 (70)	35
170 (25) ≥ 127 mm dia			
Stressed Relieved	380 (55)	585 (85)	15
Welded Pipes and Tubes			
Annealed	195 (28) ≤ 127 mm dia 170 (25) ≥ 127 mm dia	480 (70)	35
Stressed Relieved	380 (55)	585 (85)	15

PART 2

CHAPTER 4

Welding and Fabrication

CONTENTS

PART 2

CHAPTER 4

Welding and Fabrication

SECTION 1

Hull Construction *(1 July 2021)*

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Welding and fabrication are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope *(2024)*

1.2.1 Hull Welding *(1 July 2021)*

Welding in hull construction is to comply with the requirements of this section, unless specially approved otherwise. It is recommended that appropriate permanent markings be applied to the side shell of welded vessels to indicate the location of bulkheads for reference. In all instances welding procedures and filler metals are to produce sound welds having strength and toughness comparable to the base material. For weld design, see Section 3-2-19 of the *Marine Vessel Rules.*

In cases where welding is proposed with water backing, refer to Appendix 2-4-1-A1, which includes requirements for qualification of weld procedures with water backing.

1.3 Plans and Specifications *(2024)*

The plans submitted 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 detail drawings or in separate specifications submitted for approval which are to distinguish between manual and automatic welding. The shipbuilders are to prepare and file with the Surveyor a planned procedure to be followed in the erection, welding, and inspection of the important structural members.

1.5 Workmanship and Supervision *(2024)*

The Surveyor is to satisfy himself that all welders and welding operators to be employed in the construction of vessels to be classed are properly qualified and are experienced in the work proposed. The Surveyor is also to be satisfied as to the employment of a sufficient number of skilled supervisors to provide a thorough supervision and control of all welding operations. Inspection of welding assemblies, parameters, qualification tests, and welds employing methods outlined in 2-4-1/5.17 is to be carried out to the satisfaction of the Surveyor.

1.7 Welding Procedures *(2024)*

Welding procedures are to be qualified in accordance with to Part 2, Appendix 9 or to equivalent recognized standards such as AWS, EN, ISO, ASME, MIL and JIS as agreed upon with ABS.

Procedures for the welding of all joints are to be established, qualified, and approved before construction for the welding processes, base materials, types of electrodes, joint design and edge preparations, welding techniques, and positions proposed. See 2-4-3/5. Details of proposed welding procedures and sequences may be required to be submitted for review depending on the intended application.

1.9 TMCP Plates - Note to Users *(1996)*

When considering thermo-mechanically controlled steels for further heating for forming or stress relieving, or for high heat input welding, the attention of the fabricator is drawn to the possible reduction in the mechanical properties. A procedure test using representative material is to be considered.

3 Preparation for Welding

3.1 Edge Preparation and Fitting *(2024)*

The edge preparation is to be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved joint detail with suitable access to the weld root. All means adopted for correcting improper fitting are to be to the satisfaction of the Surveyor. The Surveyor may accept a welding procedure for build up of each edge that does not exceed 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 subject to ABS Technical assessment and, provided the Surveyor is notified of such cases before the members are welded together. The built up or buttered weld areas on steels with SMYS > 420 MPa are to be 100% inspected by MT or PT before welding the groove. Where plates to be joined differ in thickness and have an offset on either side of more than 4 mm (0.16 in.), a suitable transition taper is to be provided. For 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 taper length is to be not less than three times the offset. The transition may be formed by tapering the thicker member or by specifying a weld joint design which will provide the required transition or a combination of both.

For weld joints of Class II or Class III structure, or Special or Primary structure, edge preparation is to be performed prior to welding, as follows:

i) Sheared material thicker than 12.5 mm (0.5 in.)

ii) Rolled edges of plates (other than universal mill plates) thicker than 9.5 mm (3/8 in.)

iii) Toes of angles or rolled shapes (other than wide flange sections) thicker than 15.9 mm (5/8 in.)

3.3 Alignment

Means are to be provided for maintaining the parts to be welded in correct position and alignment during the welding operation. Strong backs, or other appliances used for this purpose are to be so arranged 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.

3.5 Cleanliness *(2023)*

All surfaces to be welded are to be free from moisture, grease, loose mill scale, paint, and excessive rust. Primer coatings of ordinary thickness, thin coatings of linseed oil, or equivalent coatings may be used, provided it is demonstrated that their use has no adverse effect in the production of satisfactory welds. Weld procedures with shop primer are to be qualified in accordance with 2-A9-1/7.1.4. Slag and scale are to be removed not only from the edges to be welded but also from each pass or layer before the deposition of subsequent passes or layers. Weld joints prepared by arc-air gouging may require additional preparation by grinding or chipping and wire brushing prior to welding to minimize the possibility of excessive carbon on the scarfed surfaces. Compliance with these cleanliness requirements is of prime importance in the welding of higher-strength steels, especially those which are quenched and tempered.

3.7 Tack Welds and Temporary Attachments Welds *(2024)*

Tack welds and temporary attachment welds are to made with qualified weld procedures and certified welders. Welds of consistently good quality, made with a suitable grade of filler metal as intended for production welding and deposited in such a manner as not to interfere with the completion of the final weld, need not be removed, provided they are found upon examination to be thoroughly clean and free from cracks or other defects.

Tack welds that are incorporated into the final welds are to be cleaned prior to incorporation and with no objectionable changes in weld surface appearance.

Preheat may be necessary prior to tack welding when the materials to be joined are highly restrained. ABS technical assessment is to be given to use the same preheat as specified in the qualified welding procedure when tack welding higher-strength steels, particularly those materials which are quenched and tempered. These same precautions are to be followed when making any permanent welded markings. When RT is to be performed, no tack welds are allowed in the test area.

Commentary:

In cases where the yards have satisfactory experience with temporary attachments on rolled products, where qualified weld procedures and certified welders are employed, follow up surface NDE may be omitted on agreement with the attending ABS Surveyor.

End of Commentary

3.9 Run-on and Run-off Tabs, Spacers and Backing Bars *(2024)*

When used, run-on and run-off tabs are to be designed to minimize the possibility of high-stress concentrations and base-metal and weld-metal cracking. The tabs and backing bars are to be of qualified steel. When spacers are used, they are to be of the same material as the base metal.

Commentary:

In case of welding of steels with SMYS greater than or equal to 100 ksi with wide gap, the backing bars are to be equivalent to the base material.

End of Commentary

3.11 Stud Welding *(2024)*

Stud welding procedures are to be qualified. Refer to Part 2-A9-1/3.11. 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. Stud welded attachment to quenched and tempered steel is to be specifically approved. At the Surveyor's discretion, trial stud welds may be tested to demonstrate that the base material in way of the stud welds is free from cracking and excessively high hardness. The use of stud welding for structural attachments is subject to ABS technical assessment and may require procedure tests appropriate to each application.

3.13 Forming *(1 July 2013)*

Steel is not to be formed between the upper and lower critical temperatures; forming of ordinary-strength and higher-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) is to be avoided. If it is intended to form within these ranges for either of the above steels, the manufacturer is to be consulted prior to forming. If the forming temperature exceeds 650°C (1200°F) for as-rolled, controlled 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, mechanical tests are to be made to confirm that these temperatures have not adversely affected the mechanical properties of the steel. See 2-4-1/1.9.

For applications where toughness is of particular concern (such as Class III in 3-1-2/3.1 TABLE 2A of the *Marine Vessel Rules*), 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 the impact properties meet minimum requirements after forming. 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. Rule steels of 2-1-2/15.9 TABLE 5 and 2-1-3/7.3 TABLE 5 or equivalent steels used for radius gunwales (in accordance with 3-1-2/3.1 TABLE 1 of the *Marine Vessel Rules*) may be cold formed to a minimum radius of 15t without requiring stress relieving or other supporting data.

$$\text{* Calculated on the basis of \% strain} = \frac{65 \times \text{plate thickness}}{\text{outer radius}}$$

5 Production Welding

5.1 Environment

Proper precautions are to be taken so that all welding is done under conditions where the welding site is protected against the deleterious effects of moisture, wind and severe cold.

5.3 Sequence *(2024)*

Welding is to be planned to progress symmetrically so that shrinkage on both sides of the structure will be equalized by limiting the time material is at high temperatures (above the liquidus temperature), leading to residual stress. The ends of frames and stiffeners are to be left unattached to the plating at the subassembly stage until 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 specifically approved.

Joints expected to shrink and distort are to be welded before those joints expected to have less shrinkage. When welding joints with significant shrinkage restraint, the joint is not to be allowed to cool below the minimum preheat specified until the weld is completed to prevent cracking. In case preheat has not been maintained, surface NDI (DP, MT) is to be performed (to verify no defects) prior to re-initiating welding.

The direction of welding is to be from a relatively fixed part towards the part with greater relative freedom of movement to minimize residual stress in welding.

The welding process, material thickness, fit-up and edge preparation, fixturing type, preheat, weld deposition technique and weld design are to be considered when planning weld sequence to control heat input and high shrinkage stresses by limiting the time material is at a high temperature.

For efficient control of weld residual stress, an approved procedure with a weld sequence plan is required to minimize the effect of volumetric changes produced during heating and cooling of the weld. In cases where a systemic issue has been identified which requires extensive/multiple weld repairs, weld sequence specification is to be available upon request, in addition to the approved weld procedure specification. Branch weld repairs on offshore structural joints are to be welded in sequence to minimize distortion on the tubulars.

5.5 Preheat and Interpass Temperature Control *(2024)*

Preheat and interpass temperatures are to be in accordance with the approved welding procedure specification; that is appropriate to the alloy chemistry and thickness.

Commentary:

An increase in specified preheat is to be considered during the weld procedure qualification for steels with specific property requirements, such as, high toughness, extra high strength, crack arrest and enhanced corrosion resistance to prevent welds from cracking.

End of Commentary

The minimum preheat temperature is to be maintained throughout all welding operations, including tack welds and temporary attachment welds.

The minimum and maximum interpass temperatures are to be maintained within the qualified WPS ranges throughout all welding operations, including tack welds and temporary attachment welds.

In all cases, preheat and interpass temperature control are to be sufficient to maintain dry surfaces, slow cooling and minimize the possibility of the formation of fractures.

When welding is performed 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 20°C (70°F) or as specified in the WPS, whichever is the higher.

Particular close attention to control, with verification by the ABS Surveyor, of preheat and interpass temperature (using calibrated equipment) is to be applied when welding high and extra-high-strength steels, forgings and castings, and materials of thick cross-section or materials subject to high restraint, for example, cruciform T butt welds.

If any of the following apply, an increase in preheat temperature is to be considered:

i) Structural members in critical areas

ii) Members such as cruciform joints which have high restraint

iii) Increased material thickness as combined thickness; over 25 mm (1 in.), over 50 mm (2 in.), over 70 mm (2.8 in.), over 100 mm (4.0 in.)

iv) Welding connections of castings to thick rolled plates or large structures, which could act as heat sinks

v) Any weld repairs

vi) Higher Carbon content or high Carbon equivalent

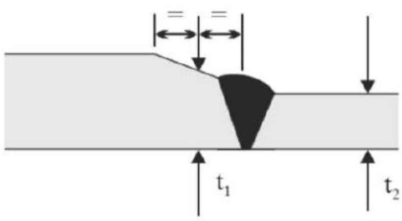
vii) Hydrogen content of weld metal

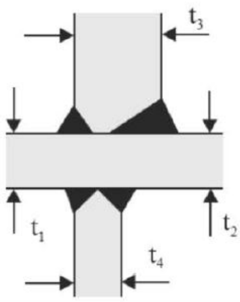
Note:

Depending upon the welding code applied (e.g., AWS D1.1, ASME IX), a requalification of a WPS with a higher preheat might be required.

Calculation of Combined Thickness below:

Combined thickness $t_{comb} = t_1 + t_2 + t_3 + t_4$, see figure





Preheating may be performed by gas burners, oxy-gas torch, electric blankets, induction heating, or by heating in a furnace.

All specified preheat and interpass temperatures are to be measured or verified by appropriate temperature measuring devices in close proximity to weld and in all directions from the point of welding. (Typically 75 mm (3 inches) from the weld).

Preheat is to be applied in such a manner as to allow for the complete material thickness to reach the required temperature.

If a torch is used to preheat welds, including tack or short welds, it is to be manipulated around the surrounding joint area to produce uniform heating. Intense, non-uniform heating is to be avoided and may be detrimental, leading to distortion, high residual stress, undesirable metallurgical phases and do little to retard weld cooling.

Preheat and interpass temperature are to be checked just prior to initiating the arc for each pass.

When welding materials with different preheat requirement, the minimum preheat is to be based on the highest minimum preheat. For quenched and tempered steel, care is to be taken when preheating since the steels may have restricted minimum and maximum interpass temperatures.

Preheating may also be necessary before thermal cutting operations.

5.6 Post Weld Heat Treatment (PWHT) *(2024)*

PWHT may be required depending on grade, delivery condition, product form, thickness and application. Where needed, PWHT is to be applied during the weld procedure qualification.

Commentary:

i) Local regulations may require a PWHT of welds with thickness greater than 40 mm for nodes or 50 mm for other cases. An engineering criticality assessment (ECA) may be performed on the weld joint in accordance with recognized standards such as BS 7910 or API 579-1/ASME-FFS-1, with CTOD testing on the weld procedure qualification.

ii) Stress relief after welding may cause problems if the structure being welded is restrained (such as a stern frame in an existing vessel). Stress relieving may be carried out locally across an entire cross-section however, with some precautions. The temperature should be about 620°C + 25°, and held for about one hour per inch of thickness of cross-section at weld. Heating and cooling should be slow to avoid excessive gradient stresses. Post weld stress relief should usually be omitted on repairs to castings on existing vessels where they are in restraint positions.

End of Commentary

5.7 Low-hydrogen Electrodes or Welding Processes

5.7.1 Welding of Ordinary and Higher Strength Steel *(2024)*

The use of low-hydrogen electrodes or welding processes is to be used for welding all higher-strength steel and may also be considered for ordinary-strength steel weldments subject to high restraint. When using low-hydrogen electrodes or processes, proper precautions are to be taken to confirm that the electrodes, fluxes and gases used for welding are clean and dry. Electrodes that have been wet, contaminated by rust, oil grease or deleterious materials are not to be used unless properly reconditioned. Flux used for SAW is to be dried and free from contamination such as oil, dirt, and other foreign material.

5.7.2 Welding of Quenched and Tempered Steels *(2024)*

Unless approved otherwise, matching strength, low-hydrogen electrodes or welding processes are to be used for welding quenched and tempered steels and overmatching is to be avoided. When welding quenched and tempered steels to other steels, the welder 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. In all cases, filler metal strength is to be no less than that of the lowest strength member of the joint unless otherwise. The Surveyor is to be satisfied that the procedures for storage, handling and baking filler metals and fluxes are commensurate with the low-hydrogen practices appropriate to the highest strength steel and in conformance with the manufacturer's recommendation. Electrodes are not to be rebaked more than once.

5.9 Back Gouging *(2024)*

Except as permitted in 2-4-1/7.3, chipping, grinding, arc-air gouging or other suitable methods are to be employed at the root or underside of the weld to obtain sound metal before applying subsequent beads for all full-penetration welds. Carbon arc gouging is to be followed by grinding to remove any carburized layer before welding. After grinding, weld is to be inspected by magnetic particle testing to confirm no crack before depositing subsequent weld beads. When arc-air gouging is employed, a selected technique is to be used so that carbon buildup and burning of the weld or base metal is minimized. Quenched and tempered steels are not to be flame gouged.

5.11 Peening *(2024)*

Peening, when used to correct distortion, is to be effected immediately after depositing and cleaning each weld pass. Manual slag hammers, chisels and lightweight vibrating tools for slag remover are not to be used for peening. Peening is not recommended to be used for single-pass welds, the root or cover passes on multipass welds, or on the base metal at the edges of the weld except as provided in 2-4-1/5.12 to enhance fatigue life.

5.12 Weld Profiling *(2024)*

For fatigue life enhancement for life extension or for areas where fatigue has been found to be a problem in service, weld profiling may be carried out (e.g., in critical areas). Welds may be profiled using grinding, TIG dressing, or peening, at weld toes to the satisfaction of the attending Surveyor.

5.13 Fairing and Flame Shrinking *(2024)*

Fairing by heating or flame shrinking and other methods of correcting distortion or defective workmanship in fabrication of main strength members within the midship portion of the vessel and other plating which may be subject to high stresses is to be carried out only with the express approval of the Surveyor. These corrective measures are to be kept to an absolute minimum when the higher-strength steels are involved, due to high local stresses and the possible degradation of the mechanical properties of the base material. See 2-4-1/1.9. Flame straightening is to be performed in accordance with an agreed procedure. Measures are to be taken to minimize degradation of material surface properties, and also to prevent accelerated cooling of the steel above 315°C (600°F).

5.15 Surface Appearance and Weld Soundness

5.15.1 Surface Appearance *(2024)*

The surfaces of welds are to be visually inspected and are to be regular and uniform with a minimum amount of reinforcement and reasonably free from incomplete penetration, root concavity, melt-through, undercut and overlap. 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:

- Surfaces are to be free of all loose and lightly adhering weld spatter.
- Surfaces are to be dressed (e.g., by grinding) to remove irregular and sharp-edged profiles.
- Surfaces are to be free from slag.
- Surfaces are to be free from sharp or deep undercut.
- Surface pores are to be sufficiently open to allow penetration of paint or are to be dressed out.
- End craters are to be free from sharp edges.

5.15.2 Weld Soundness

Welds are to be sound, crack free throughout the weld cross section, and fused to the base material to the satisfaction of the attending Surveyor and are to be considered on the basis of 2-4-1/1.5 "Workmanship and Supervision", 2-4-1/1.7 "Welding Procedure Qualification", and 2-4-1/5.17 "Nondestructive Inspection of Welds".

5.17 Inspection of Welds *(2020)*

Inspection of welded joints in important locations is to be carried out by an approved nondestructive test method such as radiographic, ultrasonic, magnetic-particle or dye-penetrant inspection. ABS's separately issued *Guide for Nondestructive Inspection* or an approved equivalent standard is to be used in evaluating radiographs and ultrasonic indications. Evaluation of radiographs and ultrasonic indications is one of the factors in assessing shipyard weld quality control. Radiographic or ultrasonic inspection, or both, is to be used when the overall soundness of the weld cross section is to be evaluated. Magnetic-particle or dye-penetrant inspection or other approved methods are to be used when investigating the outer surface of welds or may be used as a check of intermediate weld passes such as root passes and also to check back-gouged joints prior to depositing subsequent passes. Surface inspection of important tee or corner joints in critical locations, using an approved magnetic particle or dye penetrant method, is to be conducted to the satisfaction of the Surveyor. Extra high-strength steels, [415-960 N/mm^2 (42-98 kgf/mm^2, 60,000-139,000 psi) minimum yield strength] may be susceptible to delayed cracking. When welding these materials, the final nondestructive testing is to be delayed sufficiently to permit detection of such defects in accordance with 1/2.5 of the ABS *Guide for Nondestructive Inspection*. 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 method is to indicate the presence of defects that could jeopardize the integrity of structure, removal and repair of such defects are to be to the satisfaction of the attending Surveyor.

5.19 Repair Welding *(2024)*

Defective welds and other injurious defects, including base metal defects, as determined by visual inspection, nondestructive test methods, or leakage are to be excavated in way of the defects to sound metal and corrected by rewelding, using a suitable repair welding procedure to be consistent with the material being welded. Removal by grinding of minor surface imperfections such as scars, tack welds and arc strikes may 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 thicker than approximately 19 mm (3/4 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. Repair welding in the same area is to be performed no more than two times. Further repairs in the same area are subject to ABS Technical assessment. All weld repairs are to be re-inspected by the original NDT method and technique used, and with the same acceptance criteria.

5.19.1 Repair to Casting Defect Identified after Machining or During Assembly *(2017)*

After it has been agreed, by the attending Surveyor, that a casting can be repaired by welding, full details of the extent and location of the repair are to be submitted for approval together with the qualified welding procedures, welders' qualifications, heat treatment (if applicable) and subsequent inspection procedures.

Defects are to be removed to sound metal, and the excavation is to be investigated by suitable approved nondestructive examination methods to confirm that the defect has been removed. Corrective welding is to be associated with the use of preheat.

Temporary welds made to castings (for operations such as lifting, handling, staging etc) are to be carried out to qualified welding procedures and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

5.21 Fillet Weld Ends *(2018)*

The ends of continuous fillet welds is to be seal welded (wrapped) at terminations of structural members and in way of cut-outs or holes and along all edges of any provided brackets.

5.23 Post Weld Heat Treatment of Welds in Dissimilar Materials *(2011)*

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, requires the prior approval of ABS Materials.

7 Additional Requirements *(2024)*

7.1 Manual Welding Using Covered Electrodes

Manual welding using covered electrodes may be ordinarily employed for butt welds in members not exceeding 6.5 mm ($^1/_4$ in.) in thickness without beveling the abutting edges. Members exceeding 6.5 mm ($^1/_4$ in.) are 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. For welds made from both sides, the root of the first side welded is to be removed to sound metal by an approved method before applying subsequent weld passes on the reverse side. Where welding is to be deposited from one side only, using ordinary welding techniques, appropriate backing (either permanent or temporary) is to be provided. The backing is to be fitted so that spacing between the backing and the members to be joined is in accordance with established procedures. Unless specially approved otherwise, splices in permanent backing strips are to be welded with full penetration welds prior to making the primary weld.

7.3 Submerged-arc Welding *(2024)*

Submerged-arc welding, using wire-flux combinations for butt welds in members not exceeding 16 mm ($^5/_8$ in.) in thickness, may be ordinarily employed without beveling the abutting edges. Members exceeding 16 mm ($^5/_8$ 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. When it is determined that sound welds can be made without back gouging, the provisions 2-4-1/5.9 are not applicable. Where the metal is to be deposited from one side only, using ordinary welding techniques, backing (either permanent or temporary) is to be provided and the members are to be beveled and fitted in accordance with established procedures. The granular submerged-arc welding flux is to be kept from moisture to prevent porosity and underbead cracking. Also, the weld width-to-depth ratio is to be controlled and in accordance with the qualified procedure to prevent solidification cracking. For multi-pass welds, thorough cleaning of the slag from each weld pass is to be done prior to deposition of additional passes to reduce the occurrence of slag inclusion.

Commentary:

i The submerged-arc welding flux is to be kept from moisture in accordance with manufacturers recommendations.

ii The weld width-to-depth ratio is to be controlled and in accordance with the qualified procedure to prevent solidification cracking.

iii For multi-pass welds, thorough cleaning of the slag from each weld pass is to be done prior to deposition of additional passes to reduce the occurrence of slag inclusion.

End of Commentary

7.5 Gas Metal-arc and Flux Cored-arc Welding *(2024)*

Semiautomatic or mechanized gas metal-arc welding and flux cored-arc welding using wire-gas combinations and associated processes may be ordinarily employed utilizing the conditions as specified in 2-4-1/7.1, except that specific joint designs may differ between processes.

Short circuit gas metal arc welding (GMAW-S) is to be restricted to welding thickness up to 6.5 mm ($^1/_4$ in.) and out-of-position welding unless specifically approved otherwise (see 2-4-3/11.3 for special requirement for welder qualification). The shielding gas flow rate is to be controlled and within the qualified range to prevent porosity caused by drawing atmospheric gases into the weld zone.

7.7 Electroslag and Electrogas Welding *(2024)*

The use of electroslag and electrogas welding processes will be subject to specifically consideration ABS technical assessment, depending upon the specific application and the mechanical properties of the resulting welds and heat-affected zones. See 2-4-1/1.9. The electroslag and electrogas welding processes are not to be used for welding quenched and tempered steel, as these processes are associated with high heat input known to cause grain growth and deterioration of mechanical properties in the heat-affected zones.

7.9 Special Welding Processes and Techniques *(2024)*

Special welding techniques employing any of the basic welding processes mentioned in 2-4-1/7.1 through 2-4-1/7.7 will also be subject to ABS technical assessment, depending upon the extent of the variation from the generally accepted technique. Such special techniques include narrow-gap welding, tandem-arc welding and consumable guide electroslag welding. In addition, the use of gas tungsten arc welding will be subject to ABS technical assessment, depending upon the application and whether welding is manual or mechanized. Welding processes such as friction stir welding, electron beam welding, plasma arc welding, laser and hybrid laser welding or other special welding process will be subject to ABS technical assessment.

PART 2

CHAPTER 4
Welding and Fabrication

SECTION 1
Appendix 1 - Welding In Way of Water Backing *(1 July 2021)*

1 General

1.1 Objective *(2024)*

1.1.1 Goals *(2024)*

Welding and fabrication are to be suitable for the intended application in accordance with the following goals and is support of the Tier 1 Goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements *(2024)*

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance *(2024)*

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

Note: This Appendix is not required to be applied for cases where a cofferdam is installed on the shell plating to remove water as backing.

1.2 Weld Procedure Qualification Requirements

Procedure qualification testing is to be carried out to qualify for welding against water backing. Butt welds with backing plate, fillet welds or weld build-up (in corroded/pitted areas) - qualification testing is to be carried out, with welding and testing as indicated below to the satisfaction of the attending Surveyor.

i) Base material used in the qualification testing is to be representative of the plate(s) in production welding. Factors that need to be considered during selection of base material are chemical analysis, Carbon content, Carbon equivalent (refer to 2-1-3/7.1), cold cracking susceptibility (refer to 2-1-3/7.3), tensile and impact properties and delivery condition.

ii) Weld procedure qualification test assembly and set-up is to simulate the actual welding environment. The qualification should include setting the plate to be welded against a water backing, Water should be flowing during welding and the water temperature is to be cooled and circulated to maintain a temperature lower than the actual production weld water temperature.

iii) All moisture is to be removed from the weld prep before welding. Preheat is to be appropriate for the steel grade to be welded. If preheat is required, the minimum preheat temperature it is to be maintined during qualification and production welding. Preheat is to extend to at least 100 mm (4 in.) beyond the weld area or four times the base metal thickness, whichever is greater. If the water temperature is less than 5°C, preheat is to be applied during qualification and production welding.

iv) Low Hydrogen welding consumables are to be used.

v) Qualification test assembly is to be carried out in each position intended for production.

vi) Welding heat input is to be at least 1600 J/mm (40 kJ/in). Welding heat input is determined as follow;

$$Heat \quad Input \quad (J/in) = \frac{60 \quad \times Volts \quad \times Amps}{Travel \quad Speed \quad (in/min)}$$

Note that in the case of fillet weld qualification testing, only the water backed member need to comply with this section.

1.3 Alternative Requirements

Alternative weld procedures qualified to other recognized standards such as MIL-STD-1689A, which specifically includes requirements for water back welding, may be applied provided full complaince with the standard is maintained. The weld procedure is to be submitted for review and acceptance by ABS Materials Department.

Upon review, established weld procedures qualified with water backing, previously reviewed by ABS Materials Department, may be accepted by ABS provided they are suitable and the procedure is supported by proven results.

2 Weld Procedure with Water Backing *(2024)*

2.1 Scope *(2024)*

This section is intended to provide requirements for qualification of weld procedures with water as backing. Some examples include,

i) Where the vessel or offshore structure is in water, fillet welds on shell plating below the waterline are considered welding with water backing.

ii) Where the vessel or offshore structure is in water, weld build-up on shell plating below the waterline is considered welding with water backing.

iii) Where the the vessel or offshore structure is in water, full penetration welds with a backing plate on shell plating below the waterline is considered welding with water backing (backing plate arrangement prevents water seepage to the root of the weld).

The primary problem encountered in welding steels against water backing is the tendency towards reduced elongation and toughness in the weld metal resulting from the relatively rapid cooling. Special measures are required during production welding, so weld procedures are to be specifically qualified.

Prior to beginning welding a preliminary welding procedure specification (pWPS) is to be submitted to ABS Materials Department for review. After satisfactory testing, the weld procedure (weld procedure specification (WPS) and supporting procedure qualification record (PQR)) are also to be submitted to ABS Materials Department for review.

Note: This Appendix is not required to be applied for cases where a cofferdam is installed on the shell plating to remove water as backing.

2.3 Requirements for Qualification of Weld Procedure with Water Backing *(2024)*

Welding on hull plating below the waterline of vessels afloat is restricted to only normal and high strength structural steels with specified yield strength not exceeding 355 MPa. Welding of other steels with higher yield strength is subject to special consideration by ABS. Procedure qualification testing is to be carried out to qualify for welding against water backing. For butt welds with backing plate, fillet welds or weld build-up (in corroded/pitted areas) qualification testing is to be carried out, with welding and testing as indicated below to the satisfaction of the attending Surveyor.

i) Base material used in the qualification testing is to be representative of the plate(s) in production welding. Factors that need to be considered during selection of base material are chemical composition, Carbon content, Carbon equivalent (refer to 2-1-3/7.1), cold cracking susceptibility (refer to 2-1-3/7.3), tensile and impact properties and delivery condition.

ii) Weld procedure qualification test assembly and set-up is to simulate the actual welding environment. The qualification is to include setting the plate to be welded against a water backing. Water is to be flowing during qualification of the welding procedure and the water temperature is to be cooled and circulated to maintain a temperature lower than the actual production weld water temperature.

iii) All moisture is to be removed from the weld preparation before welding. Preheat and method of preheat is to be appropriate for the steel grade to be welded to prevent rapid cooling and condensation that may pose risk of hydrogen cracking. If preheat is required, the minimum preheat temperature is to be maintained during qualification and production welding. Preheat is to extend to at least 100 mm (4 in.) beyond the weld area or four times the base metal thickness, whichever is greater. If the water temperature is less than 5°C, preheat is to be applied during qualification and production welding.

iv) Low Hydrogen welding consumables are to be used.

v) Weld qualification is to have more than one weld pass. Multiple weld passes will help in tempering previously deposited beads.

vi) Welding heat input is determined as follows:

$$Heat \quad Input \quad (J/in) = \frac{60 \quad \times Volts \quad \times Amps}{Travel \quad Speed \quad (in/min)}$$

Note that in the case of fillet weld qualification testing, only the water backed member needs to comply with this section.

2.3.1 Alternative Requirements

Alternative weld procedures qualified to other recognized standards such as MIL-STD-1689A, which specifically includes requirements for water backed welding, may be applied provided full compliance with the standard is maintained. The weld procedure is to be submitted for review and acceptance by the ABS Materials Department.

Upon review, established weld procedures qualified with water backing, previously reviewed by the ABS Materials Department, may be accepted by ABS provided they are suitable, and the procedure is supported by proven results.

3 Qualification Tests for Welding Procedure with Water Backing *(2024)*

3.1 General

Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor. 2-4-1-A1/3.3 FIGURE 1 below provides an illustration of setup to qualify weld procedures with water backing.

3.3 Butt Weld Testing *(2024)*

i) Base metal thickness is to be similar to the full thickness of that being repaired in production.

ii) The test assembly is to be a butt weld with backing plate. The separation between the faying surfaces of butt joints landing on a backing is not to exceed 1.5 mm ($^{1}/_{16}$ in.). The backing plate should be the same grade as the base metal. Alternatively, the test assembly can represent the production repair joint configuration, such as a weld buildup of a corroded/pitted plate where a depression or groove can be ground out in the test plate to a specified depth representing the actual repair. In all cases, tolerances for the weld preparation and joint fit-up are to be developed during welding procedure qualifications and defined in the welding procedure.

iii) The thickness of the backing plate or the remaining plate thickness is to be the minimum remaining thickness of production plate after removal of corrosion pitting or imperfection. Weld repair with water backing is not permitted when the remaining plate thickness is less than 6 mm (0.24 in.) due to the risk of burn through plate cracking, and embrittlement. Special consideration may be given to procedures that addresses each of these risks.

iv) Qualification testing is to include the following (Refer to 2-A9-1/7.3.2 FIGURE 2 for test sampling);

- One all-weld metal tensile test. Refer to 2-A9-1/7.3.2(c).
- Two transverse weld tensile test. Refer to 2-A9-1/7.3.2(b).

- Four bend test. Refer to 2-A9-1/7.3.2(d).
- Hardness traverse (included the hardness at the backing plate or the remaining plate). Refer to 2-A9-A2.

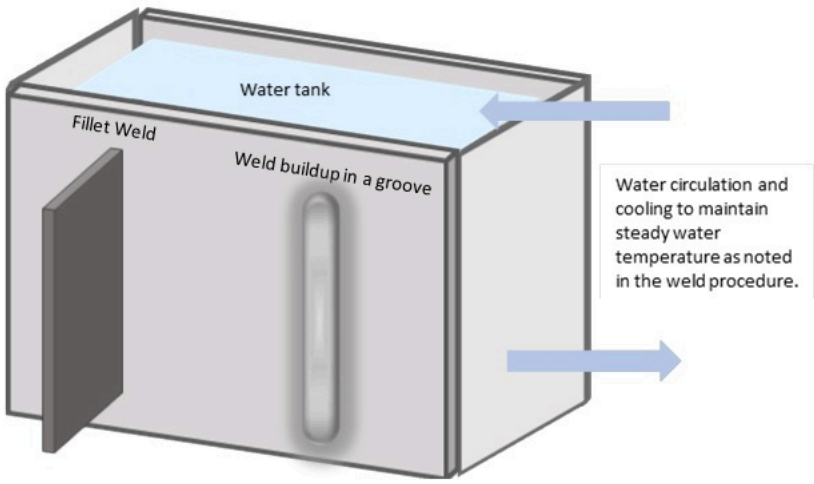
v) Charpy V-notch tests are to be carried out in accordance with 2-A9-A1and 2-A9-1/7.3.2(e). Test temperature is to be in accordance with 2-A9-1/7.3.2(e).i TABLE 1. Qualification test welds are to be examined by visual, surface and volumetric inspection in accordance with the ABS *Guide for Nondestructive Inspection*. Inspection of the welds is to be delayed by at least 24 hours, for steels with minimum yield strength less than 415 MPa (60 ksi). For all other steels, inspection is to be in accordance with guidance in the ABS *Guide for Nondestructive Inspection*.

Commentary:

In cases where weld repair with water backing is not permitted when the remaining plate thickness is less than 6 mm (0.24 in.), use of an external cofferdam with the water evacuated is a safer solution.

End of Commentary

FIGURE 1
Illustration of Setup to Qualify Weld Procedures with Water Backing



Notes:

1 For qualification of butt weld procedures with water backing, thickness of the plate for the water tank is to be the thickness of the backing plate used during production

2 The above illustration can be used for qualification of weld procedure for weld build-up, where the thickness of the plate for the water tank is to represent the minimum thickness of the corroded or pitted plate.

3 In case of qualification for fillet weld, the fillet is to be welded on the plate forming the water tank. The thickness of the water tank plate is to be the thickness of the shell plating on the vessel or offshore structure.

3.5 Fillet Weld Testing *(2024)*

The requirements of fillet weld testing is intended to demonstrate that weld penetration, weld size, and elongation properties are achieved.

i) Test assemblies, one for each filler metal size to be used in production welding.

ii) The thickness of the water backed member is to be same as the thinnest shell plate in way of proposed repairs. The same applies as for butt welds in that it is not recommended to attempt to perform a fillet weld where the water backed plate is less than 6 mm (0.24 in.) thick.

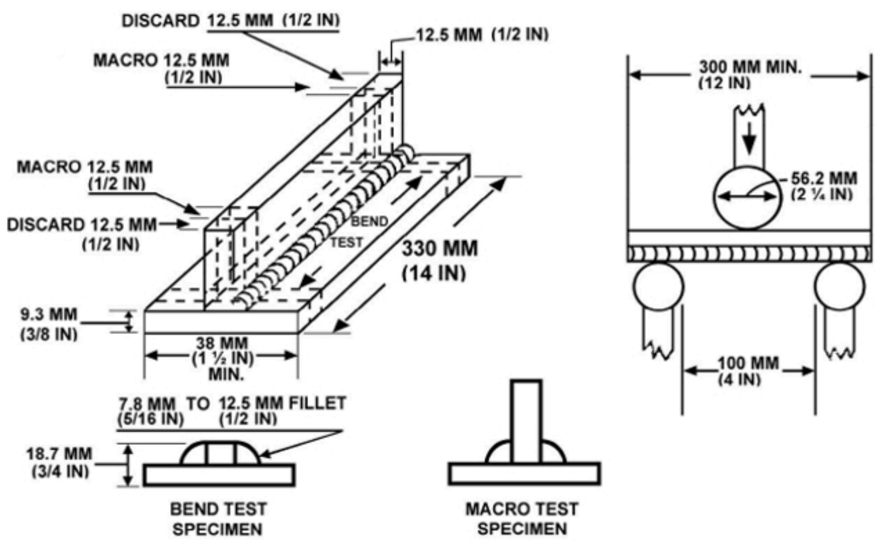
iii) Qualification testing is to include the following;

- Macro Examination - 2 macros are required. Macro examination is to include approximately 10 mm unaffected base metal.
- One longitudinal fillet weld guided bend test.
- Hardness Traverse, refer to 2-9/Annex 2.

iv) Qualification test welds are to be examined by visual and surface inspection in accordance with the ABS *Guide for Nondestructive Inspection*. Inspection of the welds is to be delayed by at least 24 hours, for steels with minimum yield strength less than 415 MPa (60 ksi). For all other steels, inspection is to be in accordance with guidance in the ABS *Guide for Nondestructive Inspection*.

For sample preparation and evaluation of the macro examination and longitudinal guided bend test specimens, refer to 2-4-1-A1/Figure 2. Alternative arrangements that meet the technical intent for testing a completed fillet weld can be specifically agreed with ABS.

FIGURE 2
Fillet Weld Test Specimen



3.7 Acceptance Criteria

3.7.1 Butt Weld

i) All-weld metal and transverse weld tensile test value is to at least meet the base metal minimum tensile strength.

ii) After the 180 degree bend test, the weld is to be free of cracks.

iii) Hardness value are to be in accordance with 2-A9-1/7.3.2(g).

iv) Charpy V-notch test results are to be in accordance with 2-A9-1/7.3.2(e).i TABLE 1.

3.7.2 Fillet Weld

i) Macro examination is to reveal fusion at the root of the weld. The weld metal and heat affected zone (HAZ) are to be free of cracks.

ii) After the 180 degree bend test, the fillet weld is to be free of cracks.

iii) Hardness values are to be in accordance with 2-A9-1/7.5.3(c).

3.9 Approval Range *(2024)*

i) The minimum qualified base metal thickness of a water backed weld is limited to the thickness of the water backed test plate or remaining plate thickness (if a grooved out plate). Water backed plate higher than the thickness of the water backed test plate can be welded provided the applied welding code maximum thickness ranges are not exceeded.

ii) The qualified base metal grade is limited to the grade and delivery condition used in the qualification test.

iii) Minimum preheating temperature is not to be less than that used in the qualification test.

iv) Maximum interpass temperature is not to be higher than that used in the qualification test.

v) Separate weld procedure qualification tests are required for each position. Ideally the production position qualified should be the position of welding during qualificaiton. If a range of qualification is required, procedures are to be qualified in the highest and lowest heat input welding positions.

vi) A change in the welding process would require a new weld procedure qualification test.

vii) A change in welding consumable would require ABS approval.

viii) In case of flux cored arc welding (FCAW), a change in filler metal manufacturer or manufacturer's trade name will require a new weld procedure qualification test.

ix) The upper and lower limit of heat input approved is plus/minus 10% used in the qualification test.

x) Other variables may also be considered in determining the range of approval subject to ABS technical assessment and approval.

PART 2

CHAPTER 4

Welding and Fabrication

SECTION 2

Boilers, Unfired Pressure Vessels, Piping and Engineering Structures*

(1 July 2021)

Note:

* *(2016)* The piping requirements in this Section are applicable to piping for applications other than for installation on vessels to be built in accordance with the ABS *Rules for Building and Classing Marine Vessels (MVR)*, the ABS *Rules for Building and Classing Mobile Offshore Units (MOU)*, and the ABS *Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)*. For piping for installation on vessels to be built in accordance with the ABS *Rules for Building and Classing Marine Vessels (MVR)* or the ABS *Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)*, see Section 2-4-4.

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Welding and fabrication are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, welding and fabrication of boilers, unfired pressure vessels, piping and engineering structures are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Fabrication *(2024)*

Drums or shells, other pressure parts of boilers, unfired pressure vessels, pipes and pipe connections, and other engineering structures may be fabricated, using ABS grades identified in Part 2, Chapter 2, by means of an approved process of fusion welding in accordance with the following requirements, provided they comply in all other respects with the applicable requirements of Part 4, Chapter 4 and Part 4, Chapter 6 respectively.

Alternatively, other design standards or welding codes may be considered, provided such standards are applied in full give reasonable equivalence to these requirements and meet the design requirements.

1.3 Welding Approval *(2024)*

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 the welding process the manufacturer proposes are capable of meeting the design requirements. Welding procedures, welders, and welding operators are to be duly qualified for the work intended. The Surveyor is to verify that the weld procedures (weld procedure specification (WPS) and supporting procedure qualification records (PQR) are reviewed by the ABS Materials Department for Group I and Group II Pressure Vessels and Boilers, as part of the design approval package. Weld procedures (WPS and PQRs) for other equipment (excluding Group I and Group II Pressure Vessels and Boilers) are to be to the satisfaction of the Surveyor. Refer to MVR 4-4-1/1.13.5.

1.5 Grouping of Welded Structures

Welding and tests are to be executed in accordance with the requirements of this section, the Rules vary according to the application in each case and the work is therefore divided into the following groups for the purpose of these Rules.

Category	*Service*	*Limitations*		
		Pressure	*Temperature*	*Max. Metal Thickness (See Note 1)*
Boilers and Group I Pressure Vessels	Boilers: All pressure parts.	Over 3.4 bar (3.5 kgf/cm^2, 50 psi)	All	None
	Unfired Pressure Vessels for:			
	a Vapors or Gases **b** Liquids	Over 41.4 bar (42.2 kgf/ cm^2, 600 psi) Over 41.4 bar (42.2 kgf/ cm^2, 600 psi)	Over 371°C (700°F) Over 204°C (400°F)	None None
Group II Pressure Vessels	Unfired Pressure Vessels for:			
	a Vapors or Gases **b** Liquids	41.4 bar (42.2 kgf/cm^2, 600 psi) and under 41.4 bar (42.2 kgf/cm^2, 600 psi) and under (See Note 2)	371°C (700°F) and under 204°C (400°F) and under	38.1 mm(1.5 in.) 38.1 mm(1.5 in.)

Notes:

1 The maximum metal thickness does not apply to heads made from a single plate.

2 Pressure limit does not apply to hydraulic pressure at atmospheric temperature.

1.5.1 Boilers and Pressure Vessels

The group designation of a pressure vessel is determined by the design pressure or temperature or material thickness in accordance with the table above.

1.5.2 Pipe Connections

1.5.2(a) Application - General.

Group I in general includes all piping intended for working pressures or temperatures in various services as follows:

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 includes all piping intended for working pressures and temperatures at or below those stipulated under Group I, cargo-oil and tank-cleaning piping, and, in addition, such open-ended lines as drains, overflows, vents and boiler escape pipes.

1.5.2(b) Application - Rules for Building and Classing Marine Vessels (MVR), Rules for Building and Classing Mobile Offshore Units (MOU) and Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)

For piping intended for vessels and structures to be built in accordance with *MVR*, *MOU*, and *LHSNV*, the pipe classes are as defined in 4-6-1/5 TABLE 1 of the *Rules for Building and Classing Marine Vessels*, and the welding and fabrication requirements are to be in accordance with Section 2-4-4 of this Chapter.

1.5.3 Engineering Structures

Group I includes turbine casings, valve bodies, manifolds and similar constructions which normally would come under Group I Pressure Vessels with the same requirements for workmanship tests, except that where there is no longitudinal seam, no test plates will be required. See also 4-6-2/5.5 of the *Marine Vessel Rules*. Group I also includes gear elements, gear casings and diesel engine entablatures, frames, bedplates and other load support structures.

Group II includes turbine casings, valve bodies, manifolds and similar constructions which normally would come under Group II Pressure Vessels and are to meet the same requirements, except that where there is no longitudinal seam, no workmanship tests are required; Group II includes also engine frames, base plates and other machinery parts not exposed to internal pressures or direct load support. See also 4-6-2/5.15 of the *Marine Vessel Rules*.

1.7 Weld Repairs to Ductile (Nodular) Iron

Weld repairs to ductile (nodular) iron castings are subject to special approval. For applications where reduced strength and ductility are permitted, welds which demonstrate satisfactory tensile strength and soundnessin procedure tests may be approved.

3 Plans and Specifications

3.1 Details

All details regarding the process and extent of welding proposed for use in the fabrication of the pressure parts of boilers, unfired pressure vessels, piping and engineering structures, together with the types of joints and welds and the proposed method of procedure are to be clearly shown on the plans and specifications submitted for approval.

3.3 Base Materials *(2024)*

All base materials used in fusion-welding construction are to conform to the specifications approved for the design in each case and in ordinary carbon steels, the carbon content is not to exceed 0.35% unless specifically approved otherwise. Attachments welded directly to boilers, pressure vessels and piping are to be made of compatible material with qualified weld procedures.

5 Workmanship and Supervision

5.1 Construction *(2024)*

Construction is to be carried out in accordance with approved plans and in compliance with Rule requirements. Manufacturers, in all cases, are to be responsible for the quality of the work, and where special supervision is required as stipulated in the applicable section of the Rules, the Surveyor is to verify that procedure and workmanship, as well as the material used, are in accordance with the Rule requirements and approved plans. Inspection of welds is to be carried out to the satisfaction of the Surveyor in accordance with the acceptance criteria of 2-4-3/9and/or applicable design standards.

5.3 Joint Tolerance

Plates, shapes or pipes which are to be joined by fusion welding are to be accurately cut to size, and where forming is necessary, this is to be done by pressure and not by blows. A tapered transition having a length not less than three times the offset between the adjacent surfaces of abutting sections is to be provided at joints between sections that differ 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 partly or entirely 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, where *t* is the nominal thickness of the thinner section at the joint.

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 ($^1/_8$ in.)	$^1/_4 t$
Over 19 (0.75) to 38 (1.5), incl.	3.2 ($^1/_8$ in.)	4.8 ($^3/_{16}$ in.)
Over 38 (1.5) to 51 (2.0), incl.	3.2 ($^1/_8$ in.)	$^1/_8 t$
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 is to be faired at a 3 to 1 taper over the width of the finished weld or, if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

5.5 Surfaces of Parts

The surfaces of parts to be welded are to be cleaned of scale, rust and grease for at least 12.5 mm (0.50 in.) from the welding edge. When it is necessary to deposit metal over a previously welded surface, any scale or slag is to be removed to prevent the inclusion of impurities; if for any reason the welding is stopped, special care is to be taken in restarting to secure thorough fusion.

5.7 Out of Roundness

The cylinder or barrel or drum 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 reheated, rerolled or reformed. In fabrications of plates of unequal thickness, the measurements are to be corrected for the plate thickness as they may apply, to determine the diameters at the middle line of the plate thickness.

7 Details of Joints *(2024)*

Weld joint details and configuration for pressure and non-pressure parts are to meet the design requirements and are to be in accordance with a qualified welding procedure. Evaluation of any joint misalignment that may result from the joint geometries is to be included in the joint design. Alternative joint details may be used provided they are acceptable to the design and are qualified by a weld procedure.

7.1 Dimensions and Shape

The dimensions and shape of the edges to be joined are to be such as to insure thorough fusion and complete penetration at the root of the joint.

7.3 Double-welded Butt Joints

In this type of 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 chipping, grinding or otherwise cleaning out, so as to secure sound metal at the base of the weld metal first deposited, before 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 2-4-2/23.1.1.

7.5 Single-welded Butt Joints

This type of joint is a butt joint with the filler metal 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 indicated in 2-4-2/7.3. In the case of boilers, backing strips used at longitudinal welded joints are to be removed.

7.7 Joint Finish *(2024)*

Butt joints are to have complete joint penetration. Edges of the fillet and groove weld deposits are to blend smoothly with the base metal and are to be free from overlaps or abrupt ridges or grooves and reasonably free from undercuts. The reinforcements permitted for both double-and single-welded butt joints may be removed upon completion to provide a smooth finish. Backing strips that may result in corrosion of the base material are to be removed.

7.9 Lap Joints *(2024)*

Where lapped joints are permitted, they are to be made with an overlap of the edges not less than four times the thickness of the thinner plate, except as noted in 2-4-2/25.7 FIGURE 1. For fillet welded joints, the weld metal is to be deposited such that complete penetration into the base metal is achieved at the root of the weld. Reduction of base metal thickness at the edges is to not exceed $^1/_{32}$ in. or 10% of the nominal base metal thickness at the adjoining surface, whichever is less.

7.11 Head to Shell Attachments

7.11.1 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 less than 25 mm (1 in.) for heads or furnace openings not over 610 mm (24 in.) in external diameter and not less than 38 mm (1.5 in.) for heads or furnace openings over 610 mm (24 in.) in diameter. For unfired pressure vessels, see 2-4-2/25.7 FIGURE 1 for details.

7.11.2 Inserted Heads

When dished heads are fitted inside or over a shell, they are to have a driving fit before welding.

7.11.3 Connections

Acceptable types of fusion-welded connections of heads to shells are illustrated in 2-4-2/25.7 FIGURE 1, subject to the tabulated limitations in 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*.

7.13 Bending Stresses in Welds

The design of a Group I or II welded container is to be such that the weld will not be subjected to direct bending stresses [see 2-4-2/25.7 FIGURE 1]. Corner welds are not to be used unless the plates forming the corner are supported independently of the welds.

7.15 Connections *(2024)*

All welding for fusion-welded connections is to be equivalent to that required for the joints of the vessel to which they are attached. A uniform tapered transition is to be used for sections that differ in thickness by more than one-fourth of the thinner section or more than $^1/_8$ inch in thicknesses. See 2-4-2/25.7 FIGURE 1(k).

7.17 Nozzles

Acceptable types of fusion-welded nozzle connections are illustrated in 2-4-2/25.7 FIGURE 2 and are to comply with the following.

7.17.1 2-4-2/Figure 2(a) and (b)

Necks abutting the vessel wall are to be attached by a full penetration groove weld.

7.17.2 2-4-2/Figure 2(c) through (h)

Necks inserted into or through a hole cut in the vessel wall and without additional 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.

7.17.3 2-4-2/Figure 2(l), (m), (n), (o) and (p)

Inserted type necks having added reinforcement in the form of one or more separate reinforcing plates are to be attached by welds at the outer edge of the reinforcing plate and at the nozzle-neck periphery. The welds attaching the neck to the vessel wall and to the reinforcement plate are to consist of one of the following combinations.

7.17.3(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. See 2-4-2/25.7 FIGURE 2(n) and (p).

7.17.3(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. See 2-4-2/25.7 FIGURE 2(m) and (o).

7.17.3(c) A full penetration groove weld in each reinforcement plate, and a fillet, single-bevel, or single-J weld in the shell plate. See 2-4-2/25.7 FIGURE 2(l).

7.17.4 2-4-2/Figure 2(k), (q), (r), (s) and (t)

Nozzles with integral reinforcement 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.

7.17.5 2-4-2/Figure 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. See 2-4-2/25.7 FIGURE 2(u), (v), (w) and (x). Internally threaded fittings not exceeding 89 mm OD (3 in. NPS) may be attached by a fillet groove weld from the outside only. See 2-4-2/25.7 FIGURE 2(w-3).

For all cases, the strength of the welded connection is to be in accordance with the requirements of 4-4-1-A1/7.9.3.ii. of the *Marine Vessel Rules*.

7.19 Limitations *(2024)*

The use of various types of welded construction is subject to the limitations of the welded structure group for which it is intended as well as the limitations tabulated in 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*.

9 Forms of Welded Joints Required

9.1 Boilers and Group I Pressure Vessels

Joints are to be in accordance with the following details.

9.1.1 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. See 2-4-2/7.5.

9.1.2 Nozzles and Other Connections

Some acceptable types of welded nozzles and other connections to shells, drums and headers are shown in 2-4-2/25.7 FIGURE 2.

9.1.3 Closing Plates

Closing plates of headers for boilers and superheaters as well as flat heads of other pressure vessels may be attached by welding as indicated in 2-4-2/25.7 FIGURE 1(g) or (h) and 4-4-1-A1/5.7.2 FIGURE 7 of the *Marine Vessel Rules*.

9.3 Group II Pressure Vessels

Joints are to be the same as Group I, except as noted below.

9.3.1 Single-welded

Butt joints welded from one side, with or without backing strips, are subject to the tabulated limitations in 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*. When backing strips are used, they may be left in place or removed.

9.3.2 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 4-4-1-A1/21 TABLE 1. See also 2-4-2/25.7 FIGURE 1.

9.5 Group I Pipe Welded Joints

Welded joints are to be in accordance with the following.

9.5.1 Pipes Over 89 mm OD (3 in. NPS)

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 include backing. The depth of weld is to be not less than the minimum thickness permitted by the applicable material specifications for the particular size and thickness of the pipe used.

9.5.2 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. For sleeve joints, the inside diameter of the sleeve is not to exceed the outside diameter of the pipe by more than 2.0 mm (0.080 in.). The fit and fillet weld sizes are to be in accordance with an applicable recognized standard (e.g., ANSI B16.11 for socket-type joints, ASTM F682 for sleeve-type joints and ANSI B31.1 for fillet weld sizes). The depth of insertion of the pipe into the sleeve or socket fitting is to be at least 9.5 mm (0.375 in.). A minimum gap of approximately 2.0 mm (0.080 in.) is to be provided between the ends of the pipe for a sleeve joint or between the pipe and socket shoulder for socket-type joints prior to welding. The fittings are to be reasonably centered around the pipe.

9.5.3 Flanges *(2024)*

ANSI slip-on flanges may be attached to piping by double-fillet welds for applications with a service rating no higher than ANSI 300 Class, 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 limited to sizes not exceeding 114 mm OD (4 in. NPS) and the throats of fillet welds is not to be less than 0.7 times the thickness of the part to which the flange is attached. Slip-on flanges for higher ratings which comply with ASME or other recognized standards will be subject to special consideration are subject to ABS technical assessment and approval.

Socket-type flanges up to and including ANSI 600 Class may be used in piping 89 mm OD (3 in. NPS) or less and up to and including the ANSI 1500 Class in piping 73 mm OD (2.5 in. NPS) pipe size or less.

9.5.4 Backing

Backing for grooved joints may be omitted in pipes under 33 mm OD (1 in. NPS). Backing is to be used for welding pipes on shipboard for all sizes 33 mm OD (1 in. NPS) and above when welded with single butt joints.

9.5.5 Welding *(2024)*

Welding in pipe lines is to be done in the shop, as far as practicable, and joints made in the installation onboard ship are to be in positions accessible for proper welding and in accordance with qualified weld procedures.

9.7 Group II Pipe Welded Joints

The type of welded joints in the construction of piping under this Group is to be similar to those in Group I except for the following modifications. For 2-4-2/9.7.1, 2-4-2/9.7.2 and 2-4-2/9.7.3 below, full penetration welds are required.

9.7.1 Single-groove

Single-groove welded-butt joints may be without backing in all sizes if the weld is chipped or ground off flush on the root side.

9.7.2 Backing

Backing may also be dispensed with, without grinding the root of the weld, in such services as tank-vent and overflow pipes.

9.7.3 Square-groove Welds

Square-groove welds may be used in lieu 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.).

9.7.4 Sleeves

Sleeves fitted over the joint and attached by fillet welds or socket-type joints with a fillet weld will be acceptable in all sizes. The fit and fillet weld sizes are to be in accordance with an applicable 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 2-4-2/9.5.2. The fittings are to be reasonably centered around the pipe.

9.9 Low-temperature Piping Systems [Below -18°C (0°F)]

For service temperatures lower than -18°C (0°F), each welding procedure is to be approved in accordance with the requirements of 2-4-3/5 and Part 5C, Chapter 8 of the *Marine Vessel Rules*. All piping systems over 10.3 bar (10.5 kgf/cm^2, 150 psi) are to be considered Group I piping systems, except that socket-weld joints, slip-on flanges, single-welded butt joints with backing strips left in place, pipe-joining sleeves and threaded joints are not to be used, except where permitted by Part 5C, Chapter 8 of the *Marine Vessel Rules*.

9.11 Engineering Structures *(2024)*

The type of welded joints used in either Group I or II in this class of construction is subject to ABS technical assessment and approval to special consideration in connection with the design in each case

11 Preheat *(2024)*

Some parts may require preheating. The need for preheat temperature is dependent on several factors such as environmental factors, chemical composition, degree of restraint of the parts being joint, material thicknesses and elevated physical properties. The welding procedure for material being welded is to specify the minimum preheat requirements in accordance with the qualified welding procedure. For parts where preheating is not required by the weld procedure, preheat may be applied during welding to aid in completion of a satisfactory welded joint.

11.1 Boilers, Pressure Vessels, and Group I Piping *(2024)*

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 less than 10°C (50°F). Higher preheat is required for material composition, degree of restraint of the parts being joined thicknesses, and carbon content in accordance with the following paragraphs.

11.1.1 General *(2024)*

The thicknesses referred to are nominal at the weld for the parts to be joined. Where the qualification procedure specifies a higher preheat, this higher preheat is to be used. Where different materials having different preheat requirements are joined by welding, the higher preheat is to be used. For materials, refer to Section 2-3-2, Section 2-3-5 and Section 2-3-12.

11.1.2 Preheat Temperatures for ABS Grades *(2024)*

Welds joining pressure parts or attachments to pressure parts are to be preheated to not less than the following temperatures.

Preheat requirements for steels with ABS grade notation used for boilers and pressure vessels in the form of plate, tube and pipe are provided in 2-4-2/25.7 TABLE 2. Alternatively, preheat requirements for other material grades complying with recognized national standards, and provided welding is performed in accordance with a qualified weld procedure, may be accepted. Note that a higher preheat temperature than those listed in 2-4-2/25.7 TABLE 2 may necessary depending on factors such as environmental factors, chemical analysis, degree of restraint of the parts being joint, material thicknesses and elevated physical properties.

11.1.2(a) ABS 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. 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.).

11.1.2(b) ABS Plate Grades H, I, J, Tube Grades K, L, M and Pipe Grades 6 and 7. to 79°C (175°F) for material which has either a specified minimum tensile strength in excess of 485 N/mm2 (49 kgf/mm^2, 70,000 psi) or a thickness at the joint in excess of 16.0 mm (0.625 in.).

11.1.2(c) ABS Tube Grades N and O and Piping Grades 11 and 12. to 121°C (250°F) for material which has a thickness at the joint in excess of 12.5 mm (0.5 in.).

11.1.2(d) ABS Tube Grade P and Piping Grade 13. to 149°C (300°F) regardless of thickness.

11.3 Group I Pipe Connections

All Group I pipe connections defined in 2-4-2/2.5.2 are to be preheated in accordance with 2-4-2/11.

13 General Requirements for Postweld Heat Treatment

13.1 General

Prior to the application of the following requirements, satisfactory weld-procedure qualifications of the procedures to be used are to be performed in accordance with all the essential variables of Section 2-4-3, including conditions of postweld heat treatment or lack of postweld heat treatment and other restrictions as listed in the following paragraphs.

13.3 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 postweld 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 postweld heat treatment is to be that specified for the material requiring the higher postweld temperature. When nonpressure parts are welded to pressure parts, the postweld-heat-treatment temperature of the pressure part is to control.

15 Fusion-welded Boilers - Postweld Heat Treatment of ABS Grades *(2024)*

15.1 General *(2024)*

All boilers of plate, pipe and tube materials listed in Section 2-3-2, Section 2-3-5 and Section 2-3-12 are to be given a post-weld heat treatment after all pads, flanges or nozzles have been welded in place. Postweld heat treatment is to be as follows:

Grades	*Minimum * Holding Temperature*	*Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)*	
		Up to 51 mm (2 in.)	*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 (1 in.) 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 (1 in.) 15 min. minimum	1 hr/25 mm (1in.) 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 (1 in.) 15 min. minimum	1 hr/25 mm (1 in.) to 127 mm (5 in.) plus 15 min. for each additional 25 mm (1 in.)

* Maximum temperature is to be at least 28°C (50°F) below base material tempering temperature.

15.3 Lower Temperatures - Carbon and Carbon Molybdenum Steels *(2024)*

When it is impractical to postweld heat-treat materials listed in 2-4-2/15.5 and 2-4-2/15.7 at the temperature specified in 2-4-2/15.1, it is permissible to heat-treat at lower temperatures for longer periods, as follows.

Lower Min. Temp. degrees °C (°F)	*Min. Holding Time at Decreased Temp. in hr/25 mm (hr/in.)*
566 (1050)	2
538 (1000)	4
510 (950)	10 (Note 2)
482 (900)	20 (Note 2)

15.5 Heat-treatment Exceptions for Fusion-welded Boilers - ABS 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

Postweld heat treatment of these materials and other equivalent pipe, plate and tube material is not required under the following conditions:

15.5.1 Circumferential Welds

For circumferential welds in pipes, tubes or headers where the pipe, tube or header complies with a nominal wall thickness of 19.1 mm (0.75 in.) or less at the joint.

15.5.2 Fillet Welds

For fillet welds, attaching nonpressure parts to 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).

15.5.3 Heat-absorbing Surfaces

For welds used to attach extended heat-absorbing surfaces to tubes and insulation attachment pins to pressure parts.

15.5.4 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.

15.5.5 Studs

For studs welded to pressure parts for purposes not included in 2-4-2/15.5.3, 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.).

15.7 Heat-treatment Exceptions for Fusion-welded Boilers - ABS Plate Grades H, I, J, Tube Grades K, L, M, and Group I Piping Grades 6 and 7

Postweld heat treatment of these materials and other equivalent pipe, plate and tube material is not required under the following conditions:

15.7.1 Circumferential Welds

For circumferential welds in pipes, tubes or headers where the pipes, tubes or headers comply 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%.

15.7.2 Fillet Welds

For fillet welds attaching nonpressure 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 15.9 mm (0.625 in.).

15.7.3 Heat-absorbing Surfaces

For welds used to attach extended heat-absorbing surfaces to tubes and insulation attachment pins to pressure parts.

15.7.4 Tubes

For tubes or pressure-retaining handhole 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.).

15.7.5 Studs

Postweld heat treatment is not mandatory for studs welded to pressure parts for purposes not included in 2-4-2/15.7.3 and which have a specified maximum carbon content of not more than 0.25%, 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.).

15.9 Heat Treatment Exceptions for Fusion-welded Boilers - ABS Tube Grades N, O and Group I Pipe Grades 11 and 12

Postweld heat treatment of these materials and other equivalent pipe and tube material with 0.15% carbon maximum is not required under the following conditions:

15.9.1 Circumferential Welds

For circumferential welds where the pipe or tubes comply with all of the following.

15.9.1(a) a maximum outside diameter of 101.6 mm (4 in.)

15.9.1(b) a maximum thickness of 16 mm (0.625 in.)

15.9.1(c) a minimum preheat of 121°C (250°F)

15.9.2 Fillet Welds

For fillet welds attaching nonpressure 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 2-4-2/15.9.1(a) and 2-4-2/15.9.1(b).

15.9.3 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 2-4-2/15.9.1(a) and 2-4-2/15.9.1(b).

15.9.4 Tubes

For tubes or pressure retaining handhole 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.

15.11 Heat Treatment Exceptions for Fusion Welded Boilers - ABS Tube Grade P and Group I Pipe Grade 13

Postweld heat treatment of this material and other equivalent pipe and tube material with 0.15% carbon maximum is not required under the following conditions:

15.11.1 Circumferential Welds

For circumferential welds where the pipe or tube complies with all of the following.

15.11.1(a) a maximum outside diameter of 101.6 mm (4 in.)

15.11.1(b) a maximum thickness of 16 mm (0.625 in.)

15.11.1(c) a minimum preheat of 149°C (300°F)

15.11.2 Fillet Welds

For fillet welds attaching nonpressure parts that have a specified throat thickness of 12.5 mm (0.5 in.) or less, provided the pressure part meets the requirements of 2-4-2/15.11.1(a) and 2-4-2/15.11.1(b).

15.11.3 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 2-4-2/15.11.1(a) and 2-4-2/15.11.1(b).

15.11.4 Tubes

For tubes or pressure retaining handhole 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.

15.13 Other Materials *(2024)*

Postweld heat treatment of other materials for boilerplate and tubes will be subject to ABS technical assessment and approval.

15.15 Other Welded Connections

Nozzles or other welded attachments for which postweld heat treatment is required may be locally postweld heat-treated by heating a circumferential band around the entire vessel with the welded connection located 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 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 2-4-2/15.1 for post-weld heat treatment.

15.17 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 three times the width of the widest part of the welding groove, but in no case less than twice the width of the weld reinforcement.

17 Fusion-welded Pressure Vessels - Postweld Heat Treatment of ABS Grades *(2024)*

17.1 Postweld Heat Treatment

17.1.1 General

All pressure vessels and pressure-vessel parts are to be given a postweld heat treatment at a temperature not less than that specified in 2-4-2/15.1 and 2-4-2/15.3 when the nominal thickness, including corrosion allowance of any welded joint in the vessel or vessel part exceeds the limits as noted in 2-4-2/17.3 and 2-4-2/17.5. In addition, postweld heat treatment is required for the following.

17.1.1(a) For all independent cargo tanks where required by Part 5C, Chapter 8 of the *Marine Vessel Rules*.

17.1.1(b) For all carbon or carbon manganese steel pressure vessels and independent cargo pressure vessels not covered by 2-4-2/17.1.1(a), when the metal temperature is below -29°C (-20°F).

17.1.1(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.

17.1.2 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 2-4-2/25.7 FIGURE 1.

17.3 Heat-treatment Exceptions - ABS Plate Grades MA, MB, MC, MD, ME, MF, MG, K, L, M, N and Tube Grades D, F, G, H, J

Postweld heat treatment of these materials is not required under the following conditions:

17.3.1 38.1 mm (1.5 in.) and Under

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.

17.3.2 Over 38.1 mm (1.5 in.)

For material over 38.1 mm (1.5 in.) thickness, all welded connections and attachments are to be postweld heat-treated except that postweld heat treatment is not required for:

17.3.2(a) Nozzle Connections.

Fillet welds with a throat not over 12.7 mm (0.50 in.) and groove welds not over 12.7 mm (0.50 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.

17.3.2(b) Nonpressure Attachments.

Fillet welds having a throat not over 12.7 mm (0.5 in.), or groove welds not over 12.7 mm (0.50 in.) in size, used for attaching nonpressure 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.).

17.5 Heat-treatment Exceptions - ABS Plate Grades, H, I, J and Tube Grades K, L, M

Postweld heat treatment of these materials is not required under the following conditions:

17.5.1 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.

17.5.2 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 postweld heat-treated, except that postweld treatment is not required for:

17.5.2(a) Nonpressure Attachments.

Attaching to pressure parts which have a specified maximum carbon content of not more than 0.25% and nonpressure parts with fillet welds that have a throat thickness of 12.7 mm (0.50 in.) or less, provided preheat to a minimum temperature of 80°C (175°F) is applied.

17.5.2(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 (0.50 in.) or less, and a specified maximum carbon content of not more than 0.25%.

17.7 Heat-treatment Exceptions - Attachments

On pressure vessels which do not require postweld heat treatment as a whole, connections and other attachments after being attached by fusion welding need not be postweld heat-treated. See also 2-4-2/17.3.2(a) for nozzles or other welded attachments for which postweld heat treatment is not required.

17.9 Other Materials *(2024)*

Postweld heat treatment of other materials for boiler plate and tubes will be subject to ABS technical assessment and approval.

17.11 Welded Connections

Nozzles or other welded attachments for which postweld 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.

19 Pipe Welded Joints and Engineering Structures - Postweld Heat Treatment *(2024)*

19.1 Group I Pipe Welded Joints

All Group I Pipe welded joints, defined in 2-4-2/2.5 are to be postweld heat-treated in accordance with 2-4-2/15 or the American National Standard ANSI B31.1.

19.3 Group II Pipe Welded Joints

Unless specially required, welded joints in Group II piping need not be postweld heat-treated.

19.5 Group I Engineering Structures

All welded structures under this group are to be postweld heat-treated in accordance with the applicable requirements of 2-4-2/17.

19.7 Group II Engineering Structures *(2024)*

Postweld heat treatment of structures under this group depends on the type and purpose of the construction, and the matter will be subject to ABS technical assessment and approval in connection with the approval of the design.

19.9 Low-temperatures Piping Systems [Below -18°C (0°F)]

In general, all piping weldments except socket-weld joints and slip-on flanges, where permitted, are to be postweld heat-treated. Exceptions will be considered for specific materials where it can be shown that postweld heat treatment is unnecessary.

21 Additional Guidance - Postweld Heat-Treatment Details *(2024)*

21.1 Boilers and Pressure Vessels

The weldment is to be heated uniformly and slowly to the temperature and time specified in 2-4-2/15.1, and is to be allowed to cool slowly in a still atmosphere to a temperature not exceeding 427°C (800°F). The postweld heat treatment may be done either by heating the complete welded structure as a whole or by heating a complete section containing the parts to be postweld heat-treated. The postweld-heat-treatment temperature is to be controlled by at least two pyrometric instruments to avoid the possibility of error.

21.3 Pipe Connections

In the case of welded pipe connections requiring postweld 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.

21.5 Other Steels *(2024)*

The postweld heat treatment of other steels not specifically covered in Part 2, Chapter 3 will be subject to ABS technical assessment and approval.

21.7 Clad Pressure Vessels *(2024)*

Pressure vessels or parts of vessels with weld metal overlay clad or applied corrosion resistant lining material are to be postweld heat treated when the base material requires postweld heat treatment. Alternatively, where different material thicknesses, linings such as Type 405 or Type 410S, and welds made using Austenitic electrodes, will be subject to ABS technical assessment and approval.

21.9 Opening Connections

Welded connections may be added to a vessel after post-weld heat treatment without requiring repostweld heat treatment, provided the following conditions are met.

21.9.1 Size of Weld

The inside and outside attachment welds do not exceed 9.5 mm (0.375 in.) throat dimension.

21.9.2 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.

21.9.3 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 postweld heat-treated.

21.11 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 in accordance with these Rules.

23 Radiography

23.1 General

23.1.1 Welded-joint Preparation

All welded joints to be radiographed are to be prepared as follows: The weld ripples or weld surface irregularities, on both the inside and outside, are to be removed by any suitable mechanical process to such a degree that the resulting radiographic contrast due to any irregularities cannot mask or be confused with the image of any objectionable defect. Also, the weld surface is to 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 to exceed the following thickness.

Plate Thickness, in mm (in.)	*Thickness of Reinforcement, in mm (in.)*
Up to 12.7 (0.5) incl.	1.6 ($^{1}/_{16}$)
Over 12.7 (0.5) to 25.4 (1.0)	2.4 ($^{3}/_{32}$)
Over 25.4 (1.0) to 50.8 (2.0)	3.2 ($^{1}/_{8}$)
Over 50.8 (2.0)	4.0 ($^{5}/_{32}$)

23.1.2 Radiographic Examination with Backing Strip

A single-welded circumferential butt joint with backing strip may be radiographed without removing the backing strip, provided it is not to be removed subsequently and provided the image of the backing strip does not interfere with the interpretation of the resultant radiographs.

23.1.3 Details of Radiographic Search

See 2-4-3/9 for further details of radiographic search of finished joints.

23.3 Boilers

All circumferential, longitudinal, and head joints are to be examined for their full length by radiography except that parts of boilers fabricated of pipe material, such as drums, shells, downcomers, risers, cross-pipes, headers, and tubes are to be nondestructively examined as required by 2-4-2/23.7.

23.5 Other Pressure Vessels

23.5.1 Full Radiography

Double-welded butt joints or their equivalent are to be examined radiographically for their full length under any of the following conditions.

23.5.1(a) Joint Efficiency.

Where the design of the vessel or vessel section is based on the use of the joint efficiency tabulated in column (a) of 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*.

23.5.1(b) Material Used.

Complete radiographic examination is required for each butt-welded joint in vessels built of Steel Plate for Boilers and Pressure Vessels ABS 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 ABS Grades H, I and J having a thickness in excess of 19 mm (0.75 in.). Other steels not specifically covered in Part 2, Chapter 3 will be subject to ABS technical assessment and approval.

23.5.2 Spot (Random) Radiography

All longitudinal and circumferential double-welded butt joints or their equivalent which are not required to be fully radiographed in 2-4-2/23.5.1 are to be examined by spot (random) radiography where the pressure vessel or pressure vessel section is based on the use of the joint efficiency tabulated in column (b) of 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules*. The extent of spot radiography is to compare favorably with accepted practice such as that specified in the ASME Boiler and Pressure Vessel Code and is to be the satisfaction of the Surveyor.

23.7 Group I Pipe Connections *(1999)*

Group I pipe connections are to be radiographically examined according to either of the conditions indicated below, as applicable.

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 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.

23.9 Group II Pipe Connections*(1999)*

Spot (random) radiographic or ultrasonic examination of welded joints with an outer diameter greater than 101.6 mm (4.0 in) may be required by the Surveyor when further inspection deems it necessary.

23.11 Low Temperature Piping Connections [Below -18°C (0°F)]

In all carbon and alloy steel piping with a service temperature below -18°C (0°F) and an inside diameter of more than 75 mm (3 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 pipe 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.

23.13 Group I Engineering Structures

Group I Engineering Structures are to meet the same radiographic requirements as Group I Pressure Vessels.

23.15 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.

23.17 Engine Bedplates

Bedplates for main propulsion internal-combustion engines with cylinders 458 mm (18 in.) in diameter and over are to be examined radiographically or ultrasonically in way of principal welds.

23.19 Miscellaneous

23.19.1 Alloy and Clad Pressure Vessels *(2024)*

The radiographic examination of vessels or parts of vessels constructed of alloy, integrally clad or applied corrosion-resistant lining materials, will be subject to ABS technical assessment and approval.

23.19.2 Nozzles, Sumps, etc.

Butt welds of inserted-type nozzles are to be radiographed 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 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules* 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 4-4-1-A1/21 TABLE 1 of the *Marine Vessel Rules* 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.

25 Hydrostatic Test *(2024)*

All completed pressure vessels, boilers, or piping are to be subjected to hydrostatic pressure testing.

25.1 Boilers and Pressure Vessels *(2024)*

Hydrostatic tests are to be conducted in accordance with 4-4-1/7.11 and 4-4-1-A1/21 of the *Marine Vessel Rules*. All pressure tests are to be carried out after postweld heat treatment.

25.3 Piping

Hydrostatic tests are to be conducted in accordance with 2-4-2/25.3 TABLE 1 below:

TABLE 1
Hydrostatic Testing of Piping

*MVR**			*MOU**	
Class I	*Class II*	*Class III*	*Group I*	*Group II*
4-6-2/7.3	4-6-2/7.3	4-6-2/7.3.1	7-1-4/41	7-1-4/41
4-6-7/7.7				

Note:
*
MVR – Rules for Building and Classing Marine Vessels
MOU – Rules for Building and Classing Mobile Offshore Units

For conditions of hydrostatic testing in other Rules and Guides, see the requirements within the relevant Rules or Guides.

25.5 Defects

Pinholes, cracks or other defects are to be repaired only by chipping, machining or burning out the defects and rewelding. Boiler drums and vessels requiring stress relieving are to be stress-relieved after any welding repairs have been made.

25.7 Retest

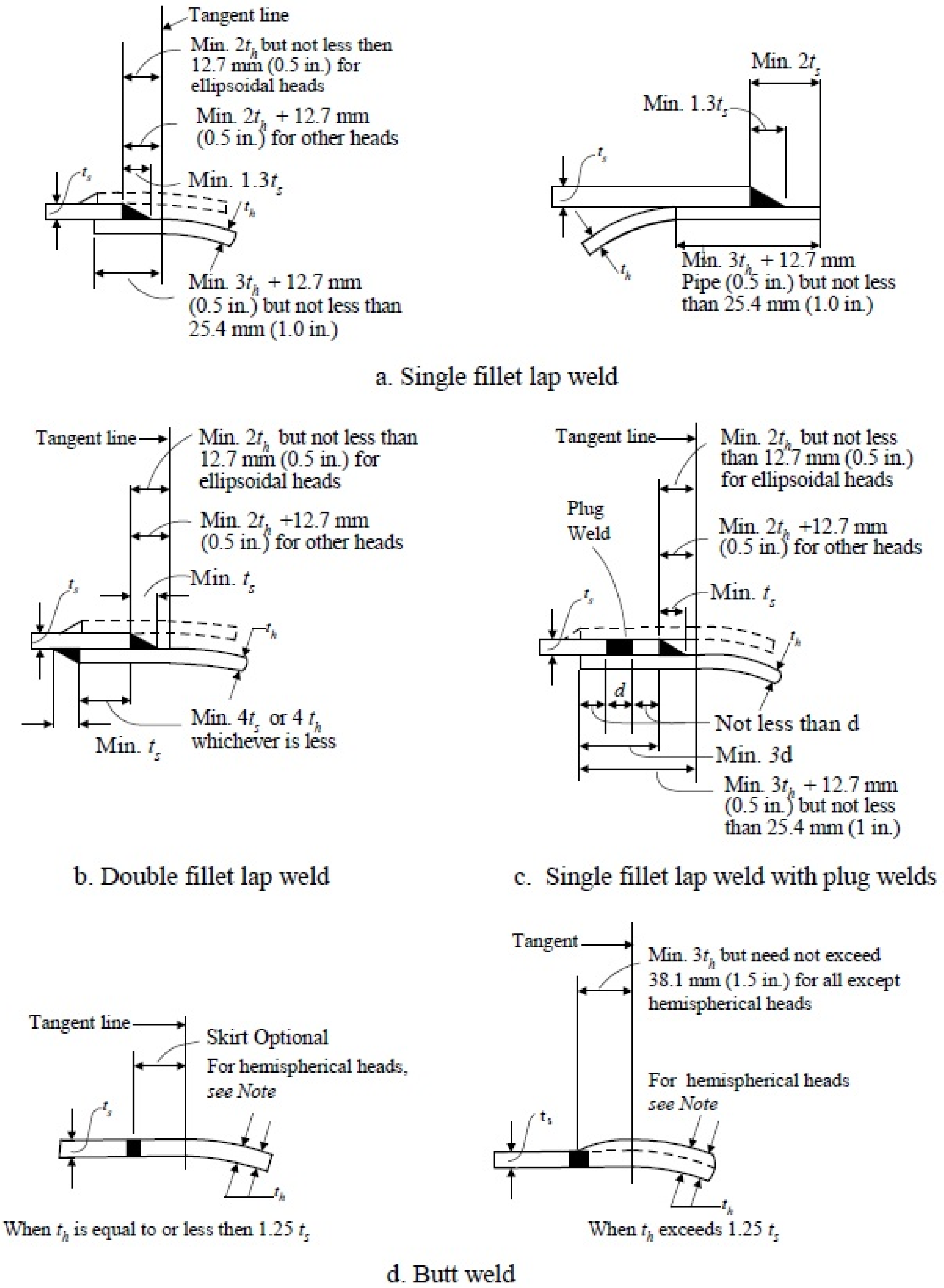
After repairs have been made, the drum, vessel or piping is to be again subjected to the hydrostatic test required in 2-4-2/25.1 through 2-4-2/25.3, inclusive.

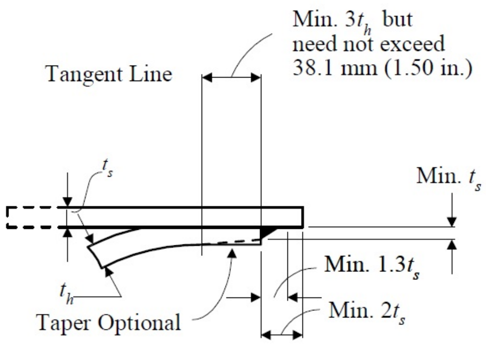
TABLE 2
Preheat Requirement and Postweld Heat Treatment Exemption for ABS Grade Plates, Tubes and Pipes used in Fabrication of Boilers and Pressure Vessels
(2024)

ABS Grade Notation	*Preheat Temperature, °C (°F)*	*Postweld Heat Treatment Temperature, °C (°F)*	
		Boilers	*Pressure Vessels*
ABS Grade Plates (2-3-2)			
MA	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
MB	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
MC	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
MD	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
ME	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
MF	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
MG	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
K	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
L	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
M	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
N	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
H	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/17.5
I	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/17.5
J	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/17.3
ABS Grade Tubes (2-3-5)			
D	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
F	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
H	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
J	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/17.3
K	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/17.5
L	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/17.5
M	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/17.5
N	121 (250) See 2-4-2/11.1.2(c)	See 2-4-2/15.9	N/A
O	121 (250) See 2-4-2/11.1.2(c)	See 2-4-2/15.9	N/A
P	149 (300) See 2-4-2/11.1.2(d)	See 2-4-2/15.11	N/A
ABS Grade Pipes (2-3-12)			
1	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19
2	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19
3	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19

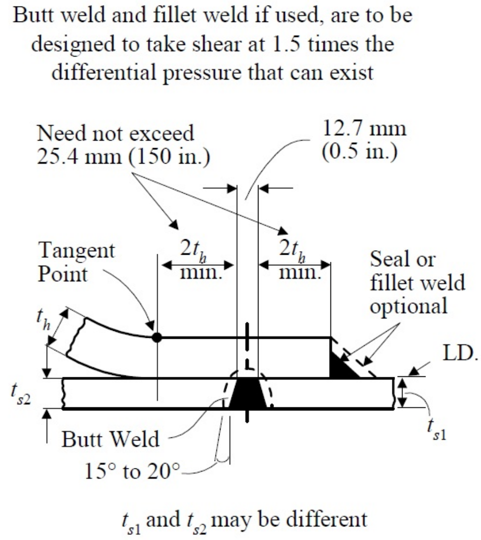
ABS Grade Notation	*Preheat Temperature, °C (°F)*	*Postweld Heat Treatment Temperature, °C (°F)*	
		Boilers	*Pressure Vessels*
4	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19
5	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19
6	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/19
7	79 (175) See 2-4-2/11.1.2(b)	See 2-4-2/15.7	See 2-4-2/19
8	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19
9	79 (175) See 2-4-2/11.1.2(a)	See 2-4-2/15.5	See 2-4-2/19
11	121 (250) See 2-4-2/11.1.2(c)	See 2-4-2/15.9	See 2-4-2/19
12	121 (250) See 2-4-2/11.1.2(c)	See 2-4-2/15.9	See 2-4-2/19
13	149 (300) See 2-4-2/11.1.2(d)	See 2-4-2/15.11	See 2-4-2/19
Other Materials			
Preheat and Postweld heat treatment of other material grades for boiler and pressure vessels will be subjected to ABS Technical Assessment and Approval.			

FIGURE 1
Head to Shell Attachments *(2024)*

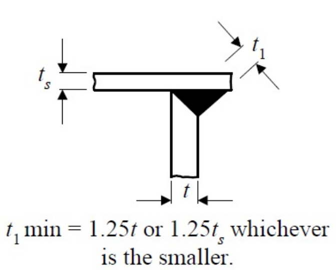




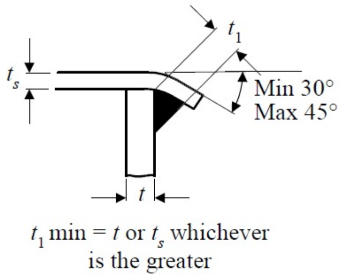
e. Single fillet lap weld



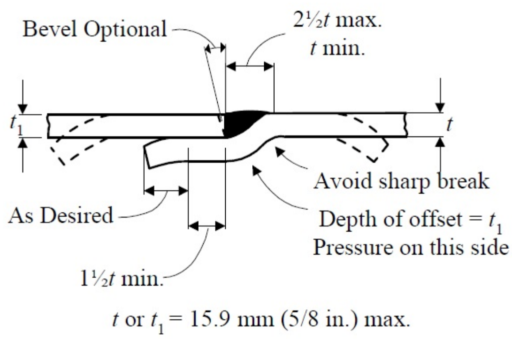
f. Intermediate head



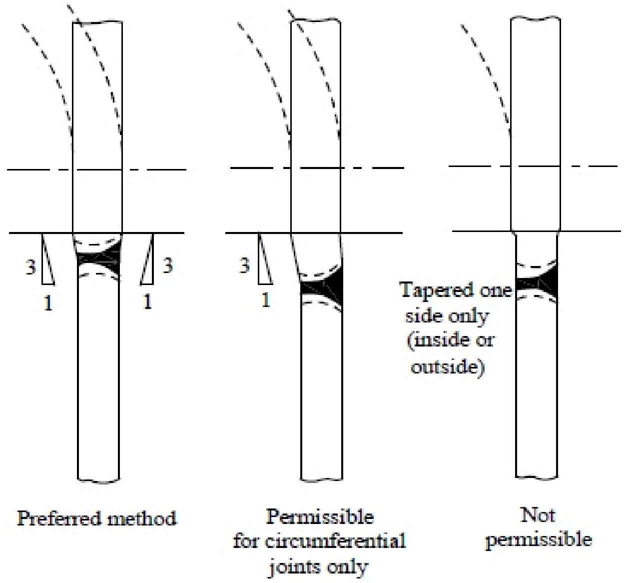
g.



h.



j. Butt weld with one plate edge offset



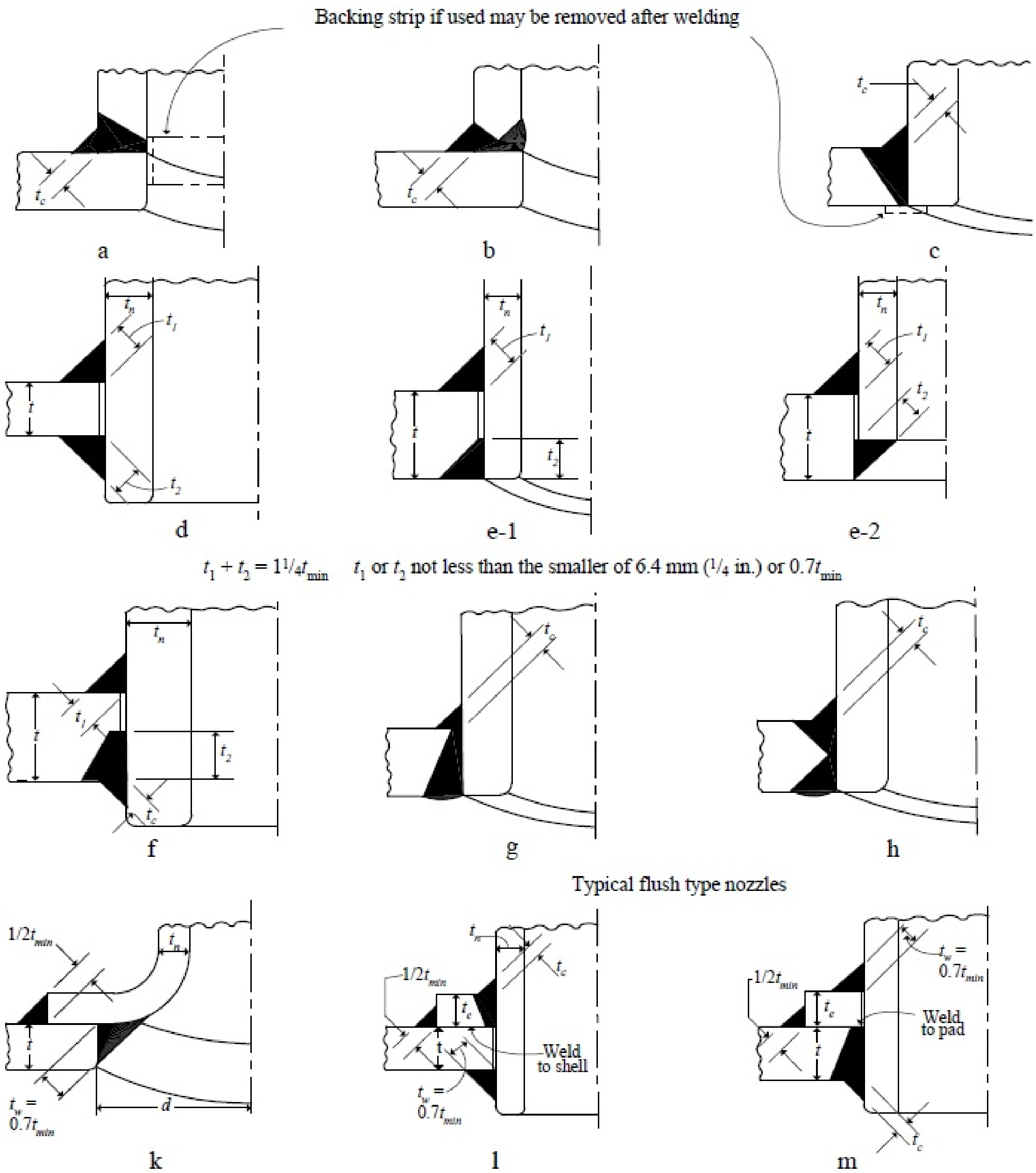
k. Butt welding of plates of unequal thickness

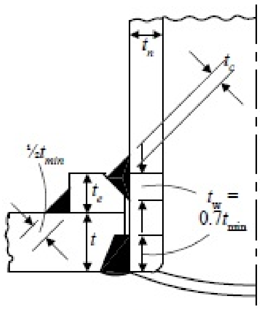
m. Example of corner weld subject to bending stress (not permissible)

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 2
Types of Fusion-welded Construction Details





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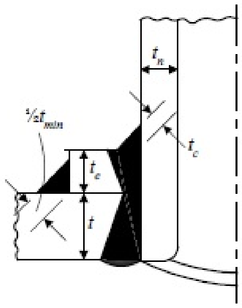

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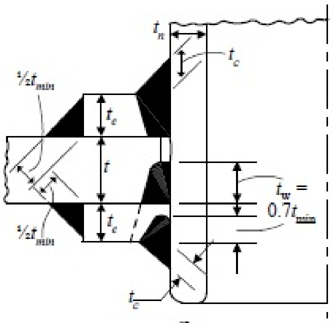

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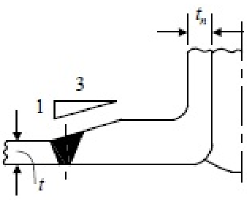
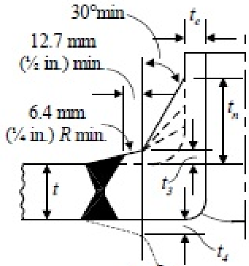
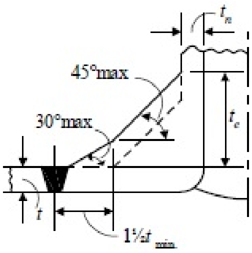


q-1

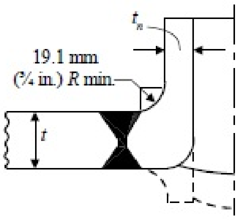


q-3

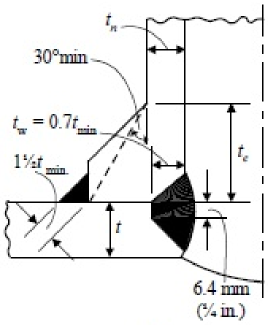
$t_3 + t_4 \leq 0.2t$ but not greater than 6.4 mm ($^1/_4$ in.)



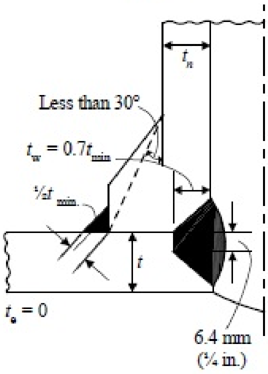
q-2



q-4



r-1



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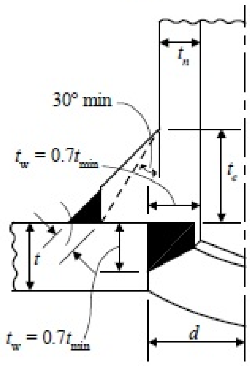

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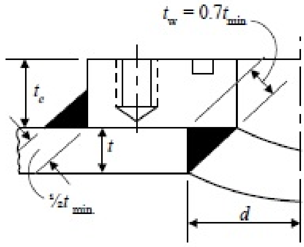
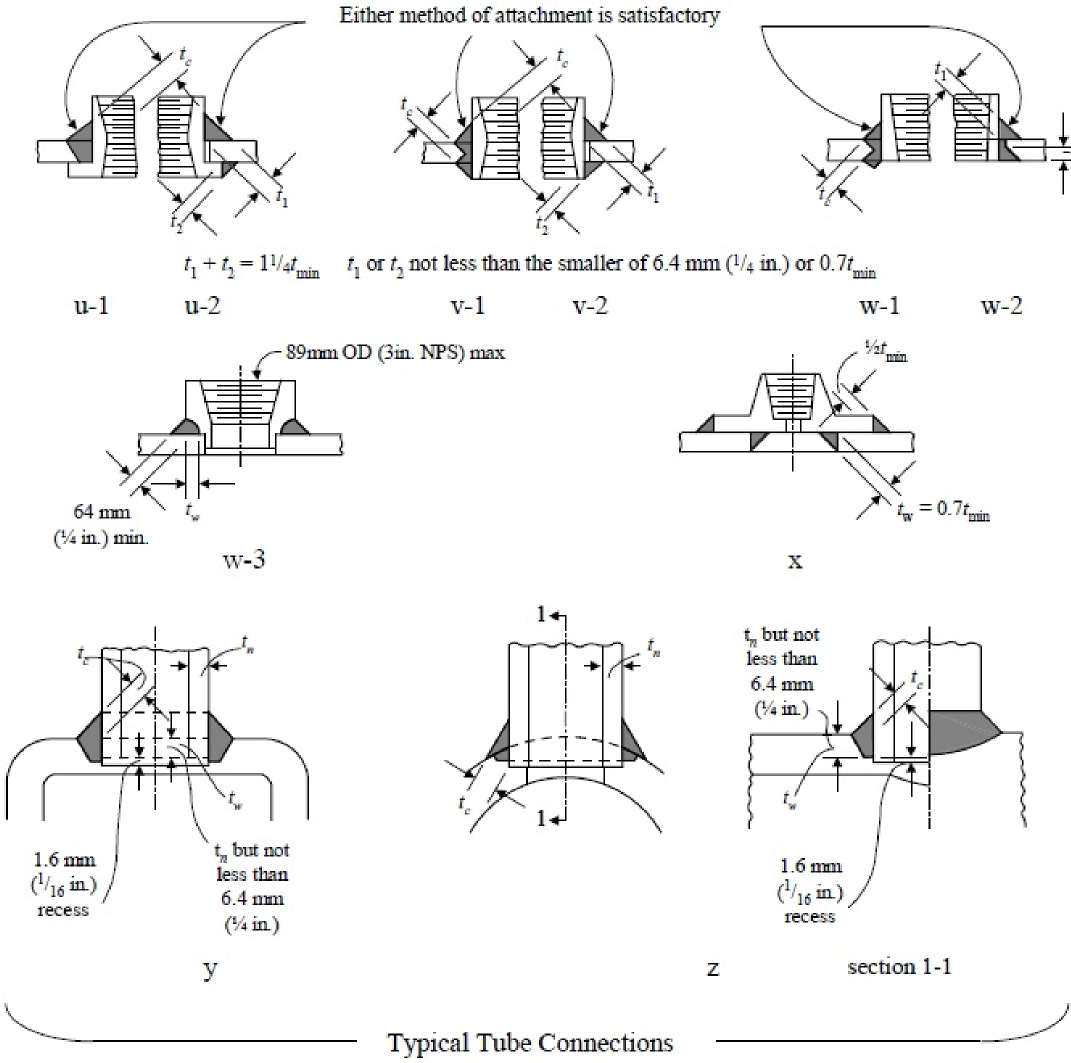


t



(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 ($^1/_4$ in.) 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 ($^3/_4$ in.) or the thickness of either of the parts joined by a fillet, single-bevel, or single-J weld, mm (in.)

PART 2

CHAPTER 4
Welding and Fabrication

SECTION 3
Weld Tests

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Welded and fabrication are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope *(2024)*

The steps to be taken in obtaining approval by ABS of electrodes, filler metals, and welding procedures for qualifying welders and for demonstrating satisfactory workmanship are given below.

1.3 Weld Groups *(2024)*

The various groups of welds are designated by index letters and numbers, by which they are referred to in subsequent paragraphs, as follows.

Hull Construction	H	All hull structures
Boilers, etc. Group I	B1	
Unfired Pressure Vessels Group II	B2	
Piping Group I	P1	As defined in 2-4-2/1.5
Piping Group II	P2	As defined in 2-4-2/1.5
Engineering Structures Group I	E1	As defined in 2-4-2/1.5
Engineering Structures Group II	E2	As defined in 2-4-2/1.5

3 Filler Metals

3.1 General *(2024)*

Filler metals are to be a type suitable to produce sound welds that have chemical composition, strength and toughness comparable to the materials being welded. ABS maintains a separately issued list of approved filler metals entitled, “Approved Welding Consumables” in the ABS web site, www.eagle.org. This list, together with Part 2, Appendix 3, indicates the grade, and general application for which such filler metals are to be employed. It is intended that these lists will serve as useful guides in the selection of suitable filler metals for various welding applications.

3.3 Approval Basis *(2005)*

Filler metals will be approved and listed, subject to tests conducted at a manufacturer's plant or alternatively, at a location outside of the manufacturer's plant under the supervision of the manufacturer. Upon satisfactory completion of tests, a certificate will be issued for general approval, indicating, where applicable, the ABS Grade, operating characteristics and limits of application. Test assemblies are to be prepared in the presence of the Surveyor and all tests are to be carried out in the Surveyor's presence and to the Surveyor's satisfaction. Procedure and testing are to comply with either of the following standards.

3.3.1 ABS Standards

Approval of filler metals for welding vessels and other engineering structures will be granted upon compliance with the Requirements for the Approval of Filler Metals contained in Part 2, Appendix 2.

3.3.2 Standards of Other Agencies

Filler metals will be considered for approval based upon tests conducted to standards established by The American Welding Society or other recognized agencies.

3.3.3 Special Approval

Under circumstances where exact specifications have not been established, ABS will consider approval on the basis of a filler metal manufacturer's guaranteed requirements. Qualified approvals will also be considered, with and without classifying as to grade, for special applications with reliance upon procedure tests at a user's plant.

5 Approval of Welding Procedures

5.1 Approved Filler Metals *(2024)*

The type of approved filler metals used on ABS-classed weldments will depend upon the specific application for which the filler metal is intended. Procedure tests may be required at the discretion of the attending Surveyor to determine the shipyard or fabricator's capability in the application of the proposed filler metal to the base material. The extent of such tests may vary depending upon the intended application, but are to follow those tests outlined in 2-4-3/5.8.

For steels shown in 2-1-2/15.9 TABLE 4, 2-1-3/7.3 TABLE 4, and 2-1-8/5.11 TABLE 5A , approved filler metals appropriate to the grades shown in Part 2, Appendix 3 may be used.

5.3 Surveyor's Acceptance

The Surveyor may, at his discretion, accept a filler metal, welding procedure, or both, in a shipyard or fabricator's plant where it is established to the Surveyor's satisfaction that they have been effectively used for similar work under similar conditions.

5.5 New Procedures and Methods *(2024)*

Weld tests using new welding techniques procedures and materials similar to those intended for production welding are required to be prepared by each shipyard or fabricator when new or unusual methods, base metals or filler metals are proposed. All tests are to be made in the presence of the Surveyor and carried out to the Surveyor's satisfaction.

5.7 Qualification of Weld Procedures *(2024)*

5.7.1 Hull Construction

Weld procedures for hull structure are to be qualified to Part 2, Appendix 9 or to an equivalent recognized national standards such as AWS, EN, ISO, MIL and JIS as agreed upon by ABS.

Weld procedures for structural tubulars or TKY Joints are to be qualified to AWS D1.1 or to an equivalent recognized national standards as agreed upon by ABS.

5.7.2 Boilers and Pressure Vessels

Weld procedures for boilers and pressure vessels are to be qualified to ASME IX or the applicable design standards such as PD5500 or EN as agreed upon by ABS.

5.7.3 Piping

Weld procedures for piping are to be qualified to ASME IX or the applicable design standards such as ASME B31.3 or EN as agreed upon by ABS.

5.7.4 Engineering Structures (as defined in 2-4-2/1.5.3)

Weld procedures for engineering structures are to be qualified to ASME IX or the applicable design standards such as AWS or EN as agreed upon by ABS.

5.8 Review of Weld Procedures *(2024)*

All weld procedures are to be reviewed by ABS. When deemed necessary or when required by the applicable rules, the weld procedures are to be submitted to ABS Materials Department for review.

Weld procedures for the following are to be submitted for review by ABS Materials Department,

i) Welding of extra high strength steels (including rack to chord and rack to rack welds)

ii) Weld procedures for TKY joints

iii) Weld procedures for Nickel Steels

iv) Weld procedures for high ductility steels

v) Weld procedures for steels with enhanced corrosion resistance properties (refer to Section 2-1-8)

vi) Weld procedures for steels with minimum specified yield strength higher than 100 ksi (690 MPa)

vii) Weld procedures qualified for use with water-backing (refer to Appendix 2-4-1-A1)

viii) Weld procedures for underwater welding (wet and dry) (refer to 2-4-3/5.13)

5.9 Special Tests *(2024)*

All weld-metal tension, Charpy V-notch impact, macro-etch or other relevant tests may be required for certain applications, such as higher-strength steels, electroslag welding, one-side welding, etc., and the results submitted for ABS technical assessment. Refer to 2-A9-1/7.3.2(e) Charpy V-notch impact tests.

5.9.1 Weld Metal and HAZ Toughness - Criteria for ABS Grade of Steels *(2024)*

Where CVN impact tests for weld metal and HAZ may be required as per 2-4-3/5.9, 5C-8-6/5.3.4 of the *Marine Vessel Rules*, or 4/5.5 of the ABS *Guide for Application of Higher-strength Hull Structural Thick Steel Plates in Container Carriers*, the minimum weld metal and HAZ CVN impact values for ABS grade steels are as indicated in 2-4-3/11.5.4 TABLE 1.

5.9.2 Weld Metal and HAZ Toughness - Criteria for Other Steels *(2024)*

Weld metal and HAZ is to exhibit Charpy V-notch toughness values at least equivalent to transverse base metal requirements ($^2/_3$ of the longitudinal base metal requirements).

5.11 Repair and Cladding of Rudder Stock, Stern Tube and Tail Shafts *(2024)*

Weld repairs and cladding on rudder stocks, stern tube shafts and tail shafts are to be performed in an approved facility.

Approval of welding procedures for the repair or cladding of rudder stocks, stern tube shafts and tail shafts is to be in accordance with 2-3-7-A1

5.13 Underwater Welding Procedures *(2024)*

Use of underwater welding procedures is subject to ABS technical assessment and approval on a case-by-case basis. Underwater welding procedures are to be qualified in accordance with AWS D3.6.

7 Workmanship Tests *(2024)*

At the discretion of the Surveyor, the following tests may be requested to demonstrate satisfactory workmanship. These tests are in addition to the weld procedure qualification tests or welder qualification tests.

7.1 Hull Construction

The Surveyor may, when it is considered desirable, require welders to prepare specimens for Fillet-weld Tests (Test No. 3) for the positions involved. Details of the specimen are shown in 2-4-3/11.5.4 FIGURE 8.

7.3 Boilers and Group I Pressure Vessels

7.3.1 Required Tests *(2024)*

The following tests are to be conducted/performed using equivalent material of the same thickness as the boiler or pressure vessel. Refer to test assembly as shown in 2-4-3/11.5.4 FIGURE 1. The results required are stated with the applicable figures and in 2-4-3/9.3.

- **Test No. 1** Reduced-section Tension Test (2-4-3/11.5.4 FIGURE 3 or 2-4-3/11.5.4 FIGURE 4)
- **Test No. 2** Guided Bend Test, (2-4-3/11.5.4 FIGURE 5 or 2-4-3/11.5.4 FIGURE 6). The bending jig and test requirements are indicated in 2-4-3/11.5.4 FIGURE 7.
- **Test No. 3** Radiographic Search of Welds on Finished Joint

7.3.2 Test Exceptions

Test Nos. 1 and 2 are not required for cylindrical pressure parts of Boilers and Group I Pressure Vessels constructed of ABS Steel Plate for Boilers and Pressure Vessels Grades A through G inclusive and Grades K through N inclusive whose welded joints are fully examined by radiography.

7.3.3 Attached Test Plates

Structures made in accordance with the requirements of Group B1 of materials other than those given in 2-4-3/7.3.2 are to have test plates attached as shown in 2-4-3/11.5.4 FIGURE 2 to permit the longitudinal joint of the shell and test plates to be welded continuously. The test plate is to be of sufficient length to provide two specimens for each of Tests Nos. 1 and 2 detailed above. One specimen is to be tested; the other specimen is for use in retesting, if necessary.

7.3.4 Separate Test Plates

Circumferential joints of a boiler or pressure vessel need not be provided with test plates unless there be no longitudinal welded joint, in which case, test plates are required to be welded separately.

7.3.5 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 the joints are welded by the same operators and the same welding method. Shells having no longitudinal joints may be considered as being of the same design 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.).

7.3.6 Test-plate Heat Treatment and Retests

In all cases, the welded test plates are to be treated as to stress relieving, etc., in the same manner as the work which they represent. In case any of the tests fail, one retest is to be made for each failure; and in case the retest also fails, the welding represented is to be chipped or gouged out and rewelded and new test plates provided.

7.5 Other Pressure Vessels

Workmanship test plates are not required for structures in this Group. Test No. 3 is to be carried out when required in 2-4-2/23.3.

7.7 Group I Pipe Connections

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 the requirements of this group are to be subjected to 100% Radiographic Search - Test No. 3, or to other approved method of test, where the former is not applicable.

7.9 Group II Pipe Connections

No workmanship tests are required.

7.11 Group I Engineering Structures

Group I Engineering Structures are to meet the same requirements as 2-4-3/7.3, except that where there is no longitudinal joint, no test plates will be required.

7.13 Group II Engineering Structures

Welds in structures in this group which correspond in service requirements to Group B2 are to be tested in the same manner as Group B2, except that where there is no longitudinal joint, no tests will be required.

9 Radiographic or Ultrasonic Inspection

9.1 Hull Construction

Where radiographic or ultrasonic inspection is required, such testing is to be carried out in accordance with ABS's separately issued *Guide for Nondestructive Inspection*.

9.3 Boilers, Pressure Vessels, Machinery and Piping *(2014)*

9.3.1 General

When radiographic examination of the finished joint is required, as indicated in 2-4-3/7.3, 2-4-3/7.5, 2-4-3/7.7 and 2-4-3/7.11, the radiographs are to be obtained by means of an approved technique and are to compare favorably with accepted standards.

9.3.2 Acceptability of Welds-Full Radiography

Sections of weld that are shown by full radiography to have any of the following types of imperfections are to be considered unacceptable and are to be repaired.

9.3.2(a) Incomplete Fusion or Penetration.

Any type of crack or zone of incomplete fusion or penetration

9.3.2(b) 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.)
$^1/_3t$ 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.)

9.3.2(c) 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

9.3.2(d) Porosity Standards.

Porosity in excess of that permitted by accepted porosity standards such as given in the American Society of Mechanical Engineers' (ASME) Boiler and Pressure Vessel Code.

9.3.3 Acceptability of Welds-Spot (Random) Radiography

The inspection of the production welds by spot radiography is to compare favorably with accepted standards and methods, such as given in the ASME Boiler and Pressure Vessel Code.

9.3.4 Survey Report Data

In each case, a statement on the extent and the results of the radiographic examination is to accompany the Surveyor's report. The inspection procedure and technique is to be maintained on file by the manufacturer and is to compare favorably with accepted practice such as that specified in the ASME Boiler and Pressure Vessel Code.

9.3.5 Pipe-joint Exception

An approved method of test may be used in lieu of the radiographic inspection of pipe joints, where the latter cannot be applied.

11 Welders Qualification *(2024)*

11.1 General Requirements

The Surveyor is to be satisfied that the welders are proficient in 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.

11.3 <No Text>

11.5 Qualification Tests *(2024)*

11.5.1 Hull Construction *(2024)*

Welders for hull structure are to be qualified to Part 2, Appendix 11 or to an equivalent recognized national standards such as AWS, EN, ISO, MIL and JIS as agreed upon by ABS.

Welders for structural tubulars or TKY Joints are to be qualified to AWS D1.1 or to an equivalent recognized national standards as agreed upon by ABS

11.5.2 Boilers and Pressure Vessels *(2024)*

Welders for boilers and pressure vessels are to be qualified to ASME IX or the applicable design standards such as PD5500 or EN as agreed upon by ABS.

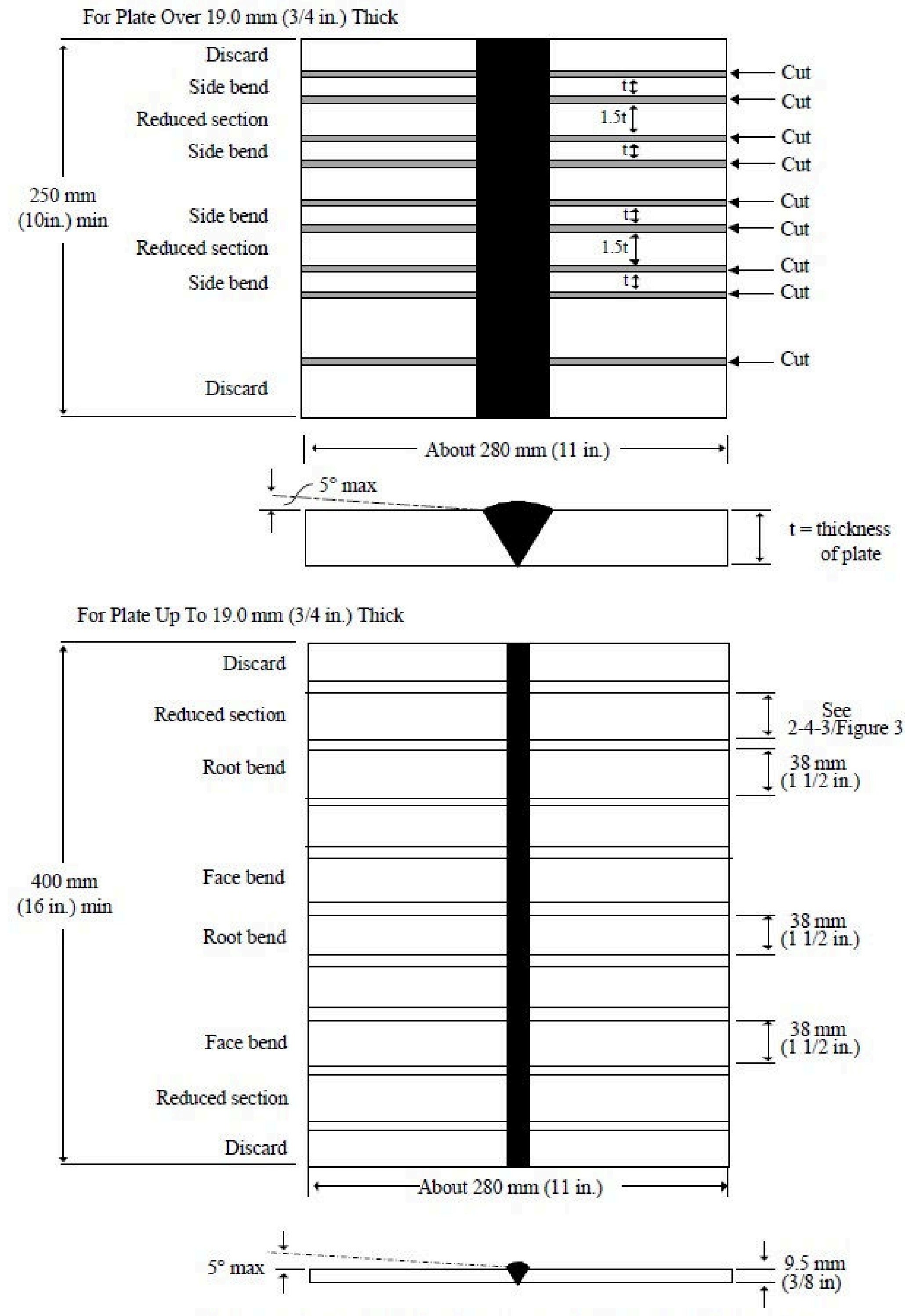
11.5.3 Piping *(2024)*

Welders for piping are to be qualified to ASME IX or the applicable design standards such as ASME B31.3 or EN as agreed upon by ABS.

11.5.4 Engineering Structures (as defined in 2-4-2/1.5.3) *(2024)*

Welders procedures for engineering structures are to be qualified to ASME IX or the applicable design standards such as AWS or EN or ISO as agreed upon by ABS.

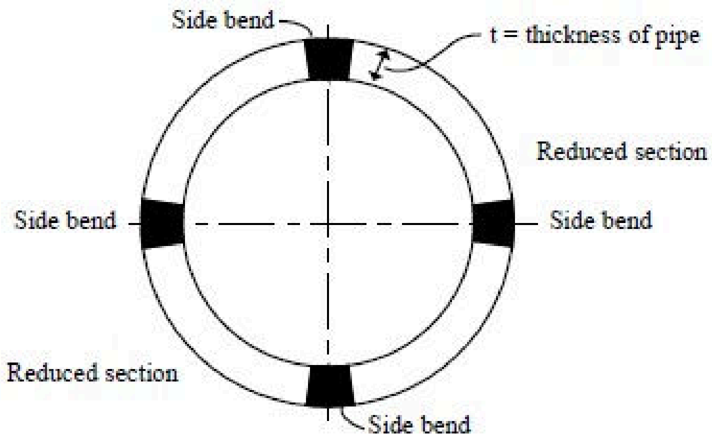
FIGURE 1
Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2



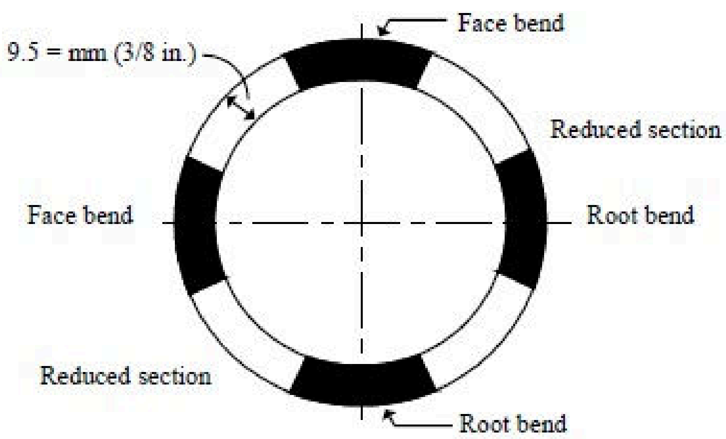
Note:

Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

For Pipe Over 19.0 mm (3/4 in.) Thick



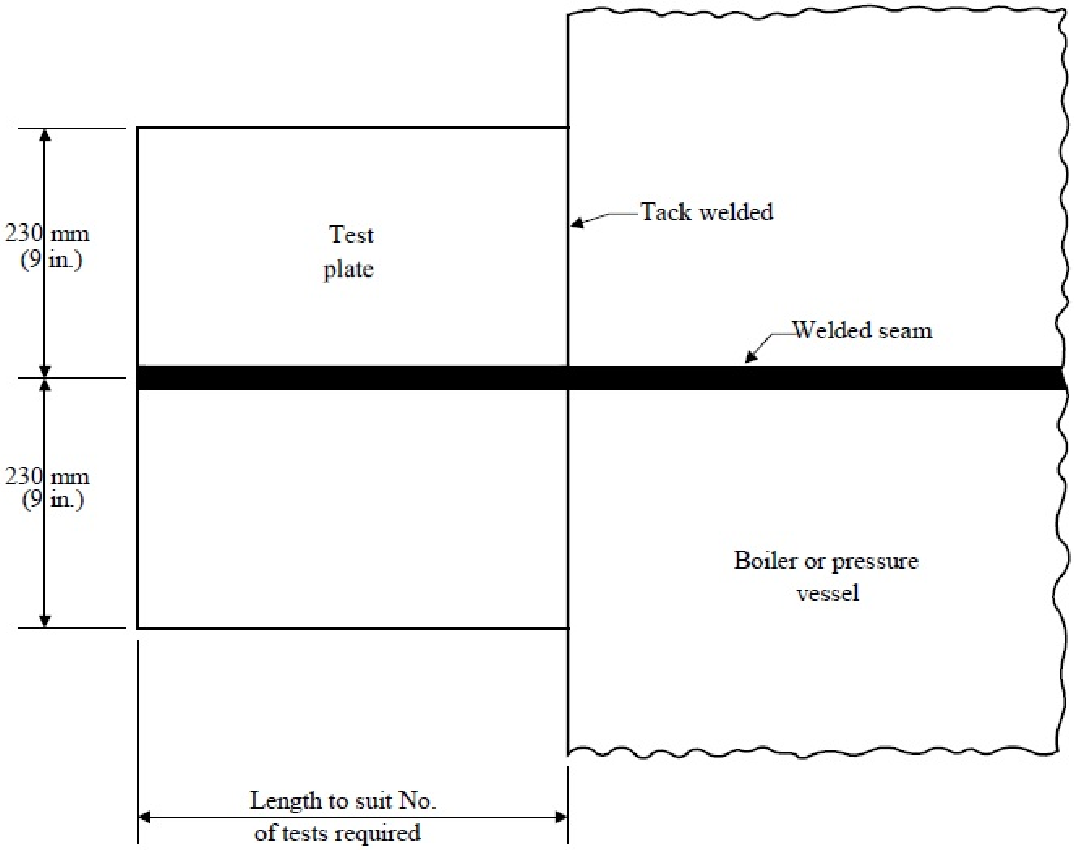
For Pipe Up To 19.0 mm (3/4 in.) Thick

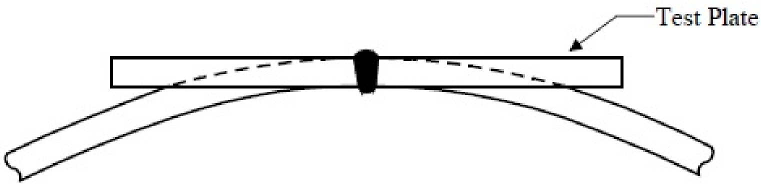


Note:

Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

FIGURE 2
Typical Arrangement of Test Plates for Workmanship Tests in Group B1

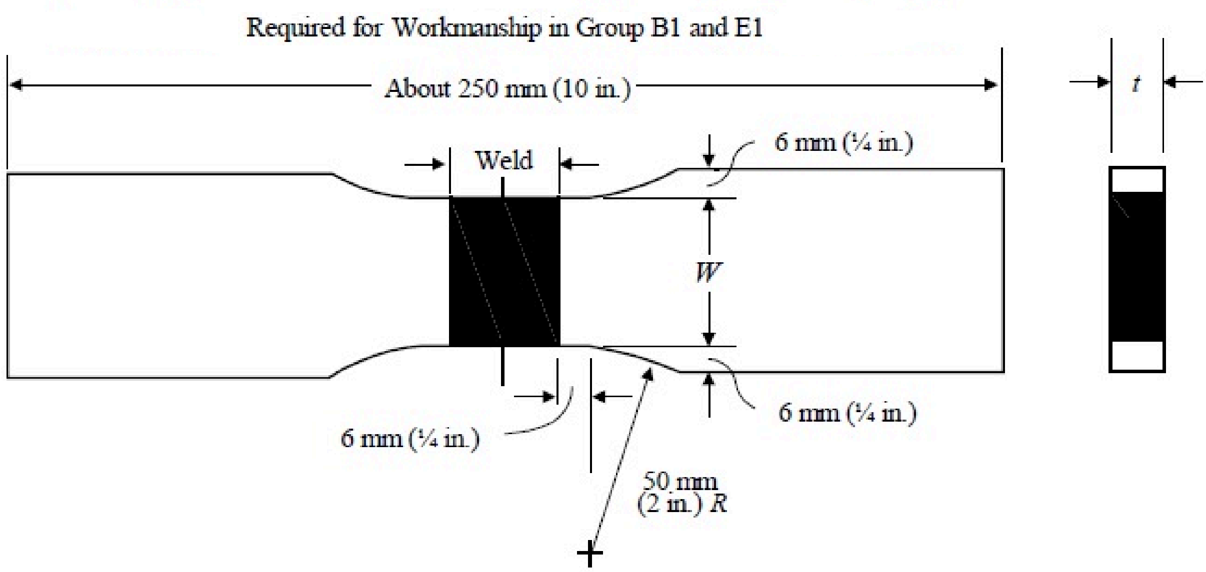




Note:

Tack weld test plates together and support test assembly so that warping due to welding does not cause deflection of more than 5 degrees. If 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 postweld heat treatment.

FIGURE 3
Test No. 1 - Reduced-section Tension Test for Plate *(2024)*



Notes:

1 Both faces of weld are to be machined flush with base metal.

2 For workmanship tests t = thickness of construction material.

3 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.).

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.

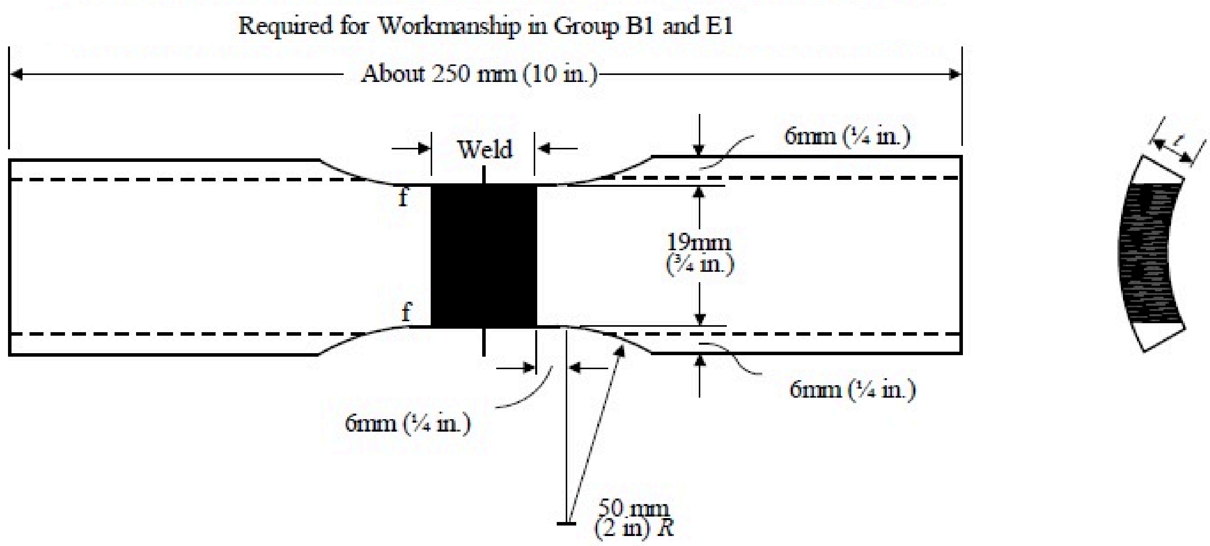
2 The tensile strength of each specimen, when it breaks in the base metal and the weld shows no signs of failure, is not to be less than 95% of the minimum specified tensile strength of the base material.

Retest Procedure (2016):

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 are to meet the test requirements.

2 If one or both of these fail, the weld test is to be rejected.

FIGURE 4
Test No. 1 - Reduced-section Tension Test for Pipe *(2024)*



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 workmanship tests t = thickness in material.
3. 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.

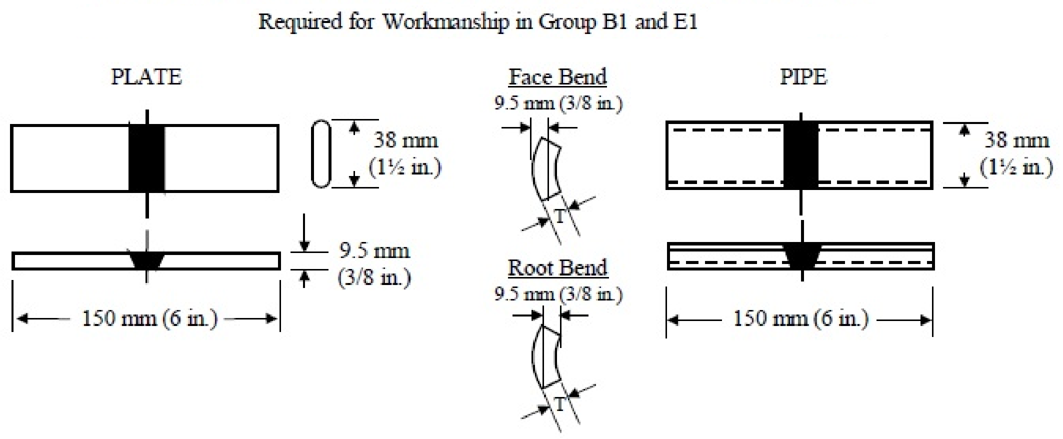
Requirements:

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 (2016):

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 are to meet the test requirements.
2. If one or both of these fail, the weld test is to be rejected.

FIGURE 5
Test No. 2 - Guided Bend Test for Root Bend and Face Bend (Plate or Pipe) *(2024)*

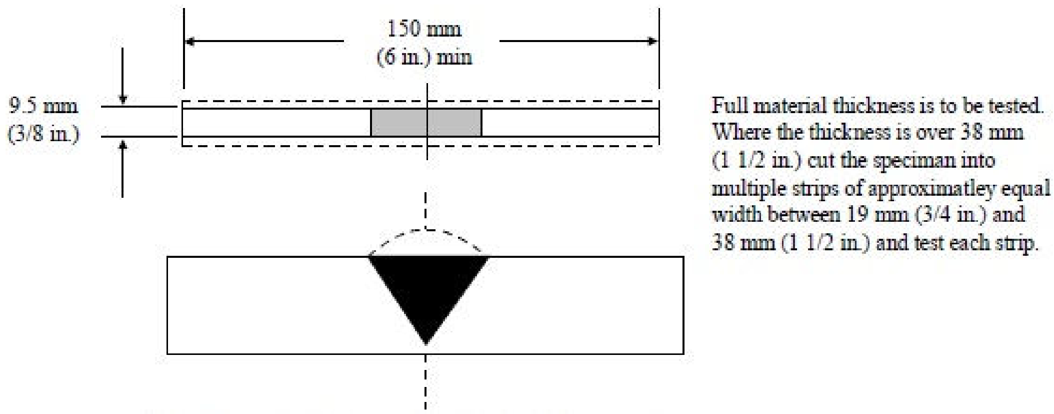


Note:

Both faces of weld to be machined flush with base metal.

On test assmeblies greater than 9.5 mm ($^3/_8$ in.) the opposite side of specimen may bemachined as shown.

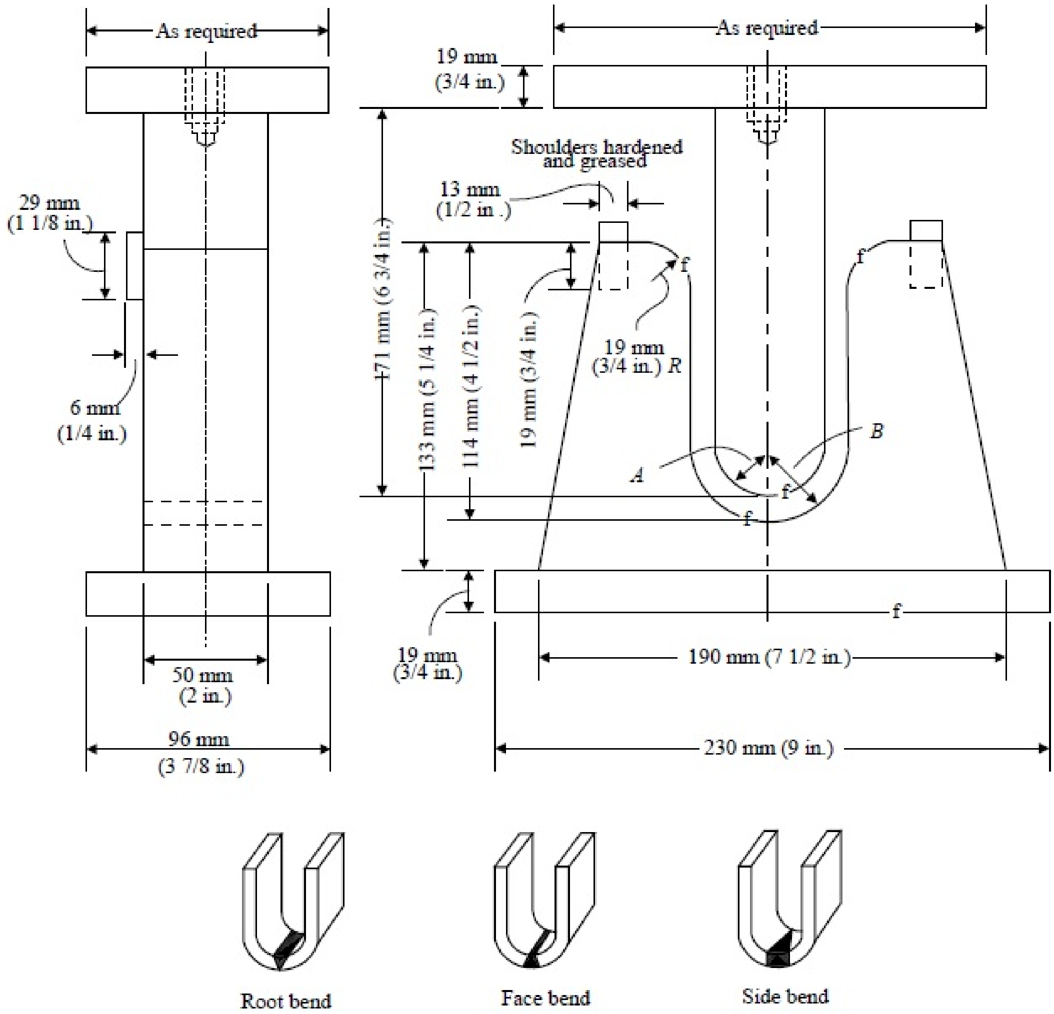
FIGURE 6
Test No. 2 - Guided Bend Test for Side Bend (Plate or Pipe) *(1996)*



Note:

Faces of weld to be machined flush with base metal.

FIGURE 7
Guided Bend Test Jig *(2016)*



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	$2t$	$3t + 1.6$ mm ($^{1}/_{16}$ in.)
Higher strength steel	$2.5t$	$3.5t + 1.6$ mm ($^{1}/_{16}$ in.)
High strength quenched and tempered steel > 620 N/mm^2 (90 ksi) YS	$3.3t$	$4.3t + 1.6$ mm ($^{1}/_{16}$ in.)

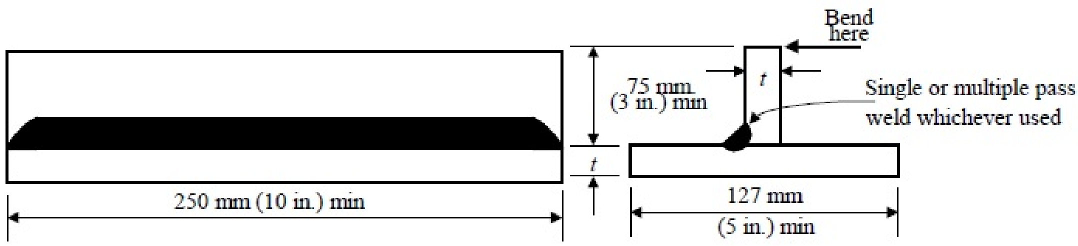
Requirements (2016):

1 After bending, the specimen is not to show any cracking or other open defect exceeding 3.2 mm ($^{1}/_{8}$ in.) on the convex side in any direction 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 is to be applied.

FIGURE 8
Test No. 3 - Fillet-weld Test *(2024)*



Notes:

1 Base and standing web is to be straight and in intimate contact and securely tacked at ends before fillet-weld is made, to insure maximum restraint.

2 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.

TABLE 1
Minimum Average Weld Metal and HAZ CVN Impact Values for ABS Grade Steels *(2024)*

Manual and Semiautomatic 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 > 50mm,
34 (25)	27 (20)	20 (68)	B > 25mm
34 (25)	34 (25)	20 (68)	AH32/36 to 12.5 mm (1/2 in.) inclusive
34 (25)	34 (25)	0 (32)	AH32/36 over 12.5 mm (1/2 in.)
47 (35)	34 (25)	0 (32)	D, DH32/36

Manual and Semiautomatic 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*
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

Manual and Semiautomatic 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*
46 (34)	46 (34)	-20 (-4)	DQ70
46 (34)	46 (34)	-40 (-40)	EQ70
46 (34)	46 (34)	-60 (-76)	FQ70

Abbreviations (2016):

F: Flat

H: Horizontal

V: Vertical

OH: Overhead

Note: For XQ91 and XQ98, Weld Metal & HAZ CVN values are to be submitted to ABS for technical assessment and approval.

PART 2

CHAPTER 4
Welding and Fabrication

SECTION 4
Piping *(2024)*

Note:

*This Section is applicable only to piping for installation on vessels to be built in accordance with the ABS *Rules for Building and Classing Marine Vessels (MVR)*, the ABS *Rules for Building and Classing Mobile Offshore Units (MOU))*, and the ABS *Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels (LHSNV)*. Piping intended for all other applications is to comply with Section 2-4-2. Additional provisions, as may be specified for piping systems of specialized carriers in Part 5C and Part 5D of the *Rules for Building and Classing Marine Vessels*, where applicable, are also to be complied with. Consideration will be given to compliance with a recognized national or international welding standard that is considered equally effective.

Commentary:

The provisions of this section are intended for welding of steel pipes in systems covered in Part 4, Chapter 6 of the *Rules for Building and Classing Marine Vessels, (MVR)*.

End of Commentary

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Welding and fabrication are to be suitable for the intended application in accordance with the following goals and support the Tier 1 Goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the welding and fabrication is to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Pipe Classes *(2024)*

Pipe classes are as defined in 4-6-1/5 TABLE 1, *(MVR)*. Classes I and II pipes are to comply with all the provisions of this Section. Class III pipes are to comply with 2-4-4/1.7, 2-4-4/3, 2-4-4/5 and 2-4-4/11.1 of this Section.

1.5 Materials

For purpose of determining welding requirements, steel pipe materials are grouped as follows:

Material group	*Description*	*Representative standards (1)*	
		ABS 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

Material group	*Description*	*Representative standards* (1)	
		ABS grade	*ASTM grade*
1Cr/0.5Mo	1.0 - 1.25% Chromium & 0.5% Molybdenum	11; 12	A335 P11; A335 P12
2.25Cr/1Mo	2.25% Chromium and 1.0% Molybdenum	13	A335 P22
1) Other materials complying with recognized national or international standards are also acceptable.			

1.7 Welding Filler Metals

All welding filler metals are to be certified by their manufacturers as complying with appropriate recognized national or international standards. Welding filler metals tested, certified and listed by ABS in its publication *Approved Welding Consumables* for meeting such a standard may be used in all cases. See Part 2, Appendix 2 for approval of filler metals. Welding filler metals not so listed may also be accepted provided that:

- They are of the same type as that proven in qualifying the welding procedure; and
- They are of a make acceptable 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 Welding Procedures and Welders

3.1 Welding Procedures *(2024)*

Before proceeding with welding, the responsible fabricator is to prove to the satisfaction of the Surveyor that the intended welding process, welding filler metal, preheat, post weld heat treatment, etc., as applicable, have been qualified for joining the base metal. The intended welding procedure is to be supported by a welding procedure qualification record (PQR) and qualification test conducted in the presence of the Surveyor. Properly documented PQR, certified by a recognized body is to be submitted to the Surveyor for acceptance. The PQR is to be conducted in accordance with a recognized standard, such as the ASME Boiler and Pressure Vessel Code, Section IX. The PQR is to be used to support those welding procedures whose welding essential and non essential variables (e.g., base metal thickness, welding parameters, preheat and postweld heat treatment, etc.) are within the ranges defined in the recognized welding standard being used. When toughness property is required by the refencing codes, standards, or specification, charpy test result is to be provided and supplemental essential variables addressed in the welding procedure specification. For class I and II steel pipes with outer diameter greater than 101.6 mm or wall thickness greater than 10 mm, Oxy-acetylene welding is not be used.

3.3 Welders and Welding Operators *(2024)*

Before proceeding with welding, the responsible fabricator is to prove to the satisfaction of the Surveyor that the welder or the welding operator is qualified in performing the intended welding procedure. The basic criterion is to determine welder’s ability to deposit wound weld metal and operator’s mechanical ability to operate the welding equipment. Welders and welding operators are to be qualified in accordance with 2-4-3/11 in the presence of the Surveyor. Properly documented welder performance qualification records (WPQ) conducted in accordance with a 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 deemed qualified, the welder or the welding operator is permitted to perform the welding as qualified, as well as other welding, provided the welding variables (e.g., position, with or without backing, pipe size, etc.) of such welding are within specified ranges defined by the recognized welding standard being used. Record of the welder and welding operator qualification is to be retained and made available to the Surveyor upon request.

5 Types of Welded Joints

5.1 Full Penetration Butt Joints

5.1.1 General *(2024)*

Full penetration butt joints for pipes are to have welds deposited on properly 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 2-4-4/5.1.2 and 2-4-4/5.1.3respectively. Joints welded without backing rings are to have complete root penetration and fusion by employing 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 2-4-4/11 such that complete root penetration is achieved and the welds do not contain unacceptable imperfection. Range of base metal thickness qualified is to be determined individually for each base metal in the test coupon. Also, where deposited weld metal is less than base metal thickness, qualified thickness range is to be determined independently for weld metal and base metal and in accordance to the applicable code/specification.

5.1.2 Edge Preparation

Dimensions of the edge-preparation are to be in accordance with recognized standards or that used in the welding procedure qualified by the responsible fabricator. The preparation of the edges is to be preferably carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching grinding or chipping back to sound metal.

5.1.3 Alignment and Fit-up *(2024)*

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:

Nominal pipe size, d		*Pipe wall thickness, t*	*Alignment Tolerance*
$d \le 150$ mm (6 in.)	or	$t \le 6.0$ mm (0.24 in.)	lesser of 1.0 mm (0.04 in.) or $t/4$
150 mm (6 in.)< $d \le 300$ mm (12 in.)	or	6.0 mm (0.24 in.) < $t \le 9.5$ mm (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 $t/4$

iii) For services where presence of backing rings may results in severe corrosion, it is required to remove backing rings and grind internal surfaces flush. Where it is not possible to remove the backing ring, welded joints are to be made without backing ring.

Where pipes of different thicknesses are to be butt welded, and if the difference in thickness is more than $^1/_4$ thickness of the thinner section or 3 mm ($^1/_8$ in.), whichever is less, a taper transition having a length not less than three times the offset between the abutting sections is to be provided at the joint.

5.3 Square-groove Butt Joint

Square groove butt joints is to be used in Class III piping systems for low pressure systems which are open to atmosphere, such as tank vent and overflow pipes. Such joints are not to be made on pipes having wall thickness greater than 4.8 mm ($^{3}/_{16}$ in.).

5.5 Fillet-welded Joints

5.5.1 Socket Welded Joints

Socket welded joints employing sockets complying with 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. See also 4-6-2/5.5.2 *(MVR)* for limitation of its use and 4-6-2/5.5.3 FIGURE 1 *(MVR)* for fit up details.

5.5.2 Slip-on Welded Sleeves Joints

Sleeves meeting dimensional and fit-up requirements in 4-6-2/5.5.3 *(MVR)* and 4-6-2/5.5.3 FIGURE 1 *(MVR)* 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.

5.7 Flange Attachment Welds *(2022)*

A weld neck flange is to be welded to the pipe with a full penetration butt weld conforming to 2-4-4/5.1. 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 for a slip-on flange or a socket-welded flange is to have a leg size not less than 1.4 times the nominal thickness of the pipe or thickness of the hub, whichever is less. For Class II and Class III flange joints, the size of the external fillet weld need not exceed 13 mm (0.531 in.) maximum. The internal weld for a slip-on welded flange is to have a leg size not less than the smaller of 6.0 mm ($^{1}/_{4}$ in.) or the nominal thickness of the pipe.

5.9 Branch Connections *(2024)*

Pipe branches made by welding branch pipe to a hole cut in the run pipe are to be designed in accordance with 4-6-2/5.3 *(MVR)*. 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. If the pipes to be joined differs in wall thickness a gradual taper transition with a slope not steeper than 1:4 is to be employed between the thicker and thinner pipe.

5.11 Tack Welding

Tack welds, where used, are to be made 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 using process and filler metal the same as or equivalent to the welding procedure to be used for the first pass. When preheating is required by 2-4-4/7, the same preheating is to be applied prior to tack welding.

5.13 Brazing *(2023)*

Brazing used in joining operations is to be carried out in accordance with brazing procedures based on an international or national standards such as ASME IX and Spec. Suitable brazing procedure specifications should be available with the basic variables being defined accordingly such as brazing technique, base metal, brazing filler metal, joint design, brazing temperature, brazing flux, and fuel gas.

All brazed joints are to be visually inspected in addition to other checks such as pressure testing on piping. When brazed pipe joints are tested in tension, the joint strength is not to be less than the tensile strength of the pipe material.

All brazing procedures, brazing operators are to be to the satisfaction of the attending ABS Surveyor.

7 Preheat *(2024)*

Dryness is to be achieved before welding; this may be attained with suitable preheating, as necessary including tack welds and repair welds. Where ambient temperatures are below 10°C (50°F), for Classes I and II pipes, the welded parts are to be heated, prior to welding, to at least 10°C (50°F). In addition, preheating is required depending on base metal thickness and chemical composition as indicated in the following table. The values given in the table below are based on the use of low hydrogen processes; consideration is to be given to using higher preheating temperatures when low hydrogen processes are not used. Consideration will be given to alternative preheat requirements based on a recognized standard and welding procedure qualification conducted thereto. The preheat temperature is to be checked in all directions from the point of welding for a distance of (3 in.) or 1.5 times the greater nominal thickness. For tack welds, base metal minimum temperature is to be at or above the specified minimum temperature for a distance of not less than (1 in.) in all directions from the point of welding. Attention is to be given to temperature control during welding such that uniform preheat is maintained uniformly in the affected or welded area.

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)

9 Post-weld Heat Treatment *(2024)*

Post-weld heat treatment is to be used in accordance with the material grouping. Specified PWHT on the qualified weld procedure is to be applied in production welds including repair welds. Where PWHT is delayed, the rate of cooling of the weldment is to be controlled to prevent detrimental effects on the weld integrity.

9.1 Procedure *(2024)*

Post-weld heat treatments are to be conducted according to a procedure acceptable to the Surveyor and as required by the qualified welding procedure. They can be carried out in furnaces or locally. Where conducted locally, the weld is to be heated in a circumferential band around the pipe having a width of at least 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. Suitable temperature and time recording equipment is to be provided.

The welded joint is to be heated slowly and uniformly to a temperature within the range indicated in the table in 2-4-4/9.3 and soaked at this temperature for a period of 1 hour per 25 mm (1 in.) of thickness, with a minimum of half an hour. Thereafter, it is to be cooled slowly and uniformly in the furnace or under insulation to a temperature not more than 400°C and subsequently cooled in a still atmosphere.

9.3 Requirement *(2024)*

Post-weld heat treatment is to be conducted on welded joints depending on base metal thickness and compositions as indicated in the following table. Consideration will be given to alternative post-weld heat treatment requirements based on a recognized standard, provided that such requirements are also applied to the welding procedure qualification.

Material group	*Thickness of the thicker joining base metal*	*Post-weld heat treatment soaking temperature (1)*
C and C/Mn	≥15 mm (2) (0.59 in.)	550-620°C (1022-1148°F)
0.5 Mo 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)

1) Maximum temperature is to be at least 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 ABS technical assessment and approval of base metal, welding process, preheat, and welding procedure qualification.

3) PWHT may be omitted for pipes having 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.

11 Nondestructive Examination

11.1 Visual Examination *(2024)*

All welded joints, including the root side, wherever possible, are to be visually examined. All visible defects, such as cracks, surface porosities, arc strikes, excessive weld reinforcement, undercuts, lack of fusion on surface, incomplete penetration where the inside is accessible, deficient size for fillet welds, etc. are to be repaired, as provided for in 2-4-4/13.

11.3 Butt Weld Joints

11.3.1 Radiographic Examination

11.3.1(a) Extent of examination.

Butt joints are to be radiographically examined as follows:

Pipe class	*Nominal size, d / 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.

11.3.1(b) Acceptance criteria. (2024)

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 2-4-4/13.

i) Any type of crack, or zones of incomplete fusion or penetration.

ii) Any elongated indication which has length greater than

6.0 mm ($^1/_4$ in.)	for $t \leq 19.0$mm ($^3/_4$ in.),
$t/3$	for 19.0 mm ($^3/_4$ in.) $< t \leq 57.0$ mm ($2^1/_4$ in.)
19.0 mm ($^3/_4$ in.)	for $t > 57.0$ mm ($2^1/_4$ 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.

11.3.1(c) Re-examination.

If the radiograph disclosed unacceptable imperfections, the weld is to be repaired and thereafter 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.

11.3.2 Ultrasonic Examination

Ultrasonic examination may be used in lieu of radiographic examination required by 2-4-4/11.3.1. Such examination technique is to be conducted in accordance with procedures and by qualified operators meeting a recognized standard and acceptable to the Surveyor.

11.5 Fillet Weld Joints *(2024)*

In Class I piping, all fillet welds attaching pipes to flanges, sockets, slip-on sleeves, pipe branches, etc. are to be examined by the magnetic particle method or other appropriate nondestructive methods. All surfaces 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.

In Class II piping, magnetic particle testing is to be performed at the discretion of the attending Surveyor.

13 Weld Repair *(2024)*

Any weld joint imperfection disclosed by examination in 2-4-4/11 and deemed unacceptable is to be removed by mechanical means or thermal gouging processes, after which the joint is to be welded on the sound metal using the appropriate qualified welding procedure by a qualified welder. Preheat and post-weld heat treatment is to be performed as indicated in 2-4-4/7 and 2-4-4/9, as applicable. Upon completion of repair, the repaired weld is to be re-examined by the appropriate technique that disclosed the defect in the original weld.

15 Pipe Forming and Bending

15.1 Cold Forming *(2024)*

Where pipe is cold bent to a mean bending radius of less than or equal to four times the outside diameter of the pipe, it is to be subjected to a stress relieving heat treatment at least equivalent to that specified in 2-4-4/9.3, except for C and C/Mn steels with ultimate tensile strength of 410 MPa (42 kgf/mm^2, 60,000 psi) or less. Cold bending is to be accomplished at a temperature below the transformation range.

15.3 Hot Forming *(2013)*

Hot forming is to be carried out in the temperature range 850–1000°C for all material groups; however, the temperature may decrease 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 2-4-4/9.3 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 following post-forming heat treatment is to be performed.

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)

17 Additional Requirements for Low Temperature Piping [below -10°C (14°F)]

17.1 Application *(2024)*

These requirements are intended for piping operating at below -10°C (14°F) that forms part of the cargo piping of specialized carriers covered in Part 5C, Chapter 8 of the *Rules for Building and Classing Marine Vessels (MVR)*or for piping intended to carry gases or other low-flashpoint fuels covered in Part 5C, Chapter 13 of the *Rules for Building and Classing Marine Vessels (MVR)*.

17.3 Welding Procedure

Welding procedures proposed for piping intended to operate below −10°C (14°F) are, in addition to the provisions of 2-4-4/3.1, to be qualified with Charpy V-notch tests as provided for in 5C-8-6/5.4 *(MVR)*.

17.5 Pipe Joints *(2024)*

All welded pipe joints are to be in accordance with 2-4-4/5.1, 2-4-4/5.5 and 2-4-4/5.9 and are subject to the limitations indicated in the table below [see also 5C-8-5/8.2 (*MVR*) or 5C-16-13/3.4 (*MVR*), as applicable].

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

17.7 Post-weld Heat Treatment *(2024)*

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, thickness, weld sizes, and design pressure and temperature, see 5C-8-5/9.2 (*MVR*) or 5C-16-13/6.2 (*MVR*), as applicable.

17.9 Nondestructive Examination *(2024)*

Butt-welded joints are to be radiographically examined as for Class I pipes indicated in 2-4-4/11.3.1(a). Butt-welded joints of smaller diameter or thickness are to have at least 10% of the joints radiographed. See also 5C-8-5/9.3 (*MVR*) or 5C-16-13/6.3 (*MVR*), as applicable.

PART 2

CHAPTER 4
Welding and Fabrication

SECTION 5
Aluminum Welding in Hull Construction *(2018)*

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR2	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR3	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR4	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR5	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Hull Welding *(2024)*

Welded construction of aluminum hulls is to comply with the requirements of this Section, unless specially approved otherwise. Welding procedures and filler metals are to be applied which will produce sound welds that have strength in accordance with 2-4-5/17 TABLE 2; the chemical compositions of the filler metals are to be generally in accordance with 2-4-5/17 TABLE 3. The selection of filler metals for welding various aluminum alloys is to be in accordance with 2-4-5/17 TABLE 4 and 2-4-5/17 TABLE 5.

Commentary:

It is recommended that appropriate permanent welded markings be applied to the side shell of the hull to indicate the location of bulkheads for reference.

End of commentary

1.3 Plans and Specifications

The plans submitted are to clearly indicate the extent to which welding is proposed to be used. The welding process, filler metal and joint design are to be shown on the detail drawings or in separate specifications submitted for approval, which are to distinguish between manual, semi-automatic and automatic welding. The shipbuilders are to prepare and file with the Surveyor a planned procedure to be followed in the erection and welding of the important structural members.

1.5 Workmanship and Supervision *(2024)*

It is the responsibility of the yard/fabricator to verify that personnel, procedures and NDT equipment used for fabrication and inspection comply with the requirements of this section. The Surveyor is to verify that all welders and welding operators to be employed in the construction are properly qualified and are experienced in the type of work proposed and in the proper use of the welding processes and procedures to be followed. The Surveyor is to be satisfied with the employment of a sufficient number of skilled supervisors to ensure a thorough supervision and control of all welding operations.

1.7 Welding Procedures and Welder Qualification *(1 July 2022)*

Procedures for the welding of all joints are to be established in writing for each welding test, process, type of electrode, edge preparation, welding technique and position proposed. Details of proposed welding procedures and sequences are required to be submitted for review. Procedure qualifications previously prepared and approved by ABS may be submitted for consideration for the current designs, if applicable.

Friction Stir welding procedures and welder qualifications refer to the ABS *Requirements for Friction Stir Welding in Aluminum*.

Welding procedures and welder qualifications for aluminum alloys are to be prepared and carried out to equivalent recognized codes and standards such as AWS, CSA, EN, ISO, ASME, MIL and JIS, as well as the additional requirements in this Section. The applicable welding code is to be in accordance with client/owner specification. In case there is no welding code specified from client/owner, the application of a recognized code or standard can be proposed and agreed with ABS.

3 Preparation for Welding *(1 July 2022)*

Unless otherwise agreed, the preparation for welding is to be in accordance with this 2-4-5/3.

3.1 Edge Preparation and Fitting for Butt Welds *(1 July 2022)*

The edge preparation is to be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved welding detail. Joint edges may be prepared by mechanical means, such as saws, millers and routers. Thermal cutting methods such as plasma arc cutting or laser cutting may be employed, provided it can be demonstrated to the satisfaction of the Surveyor that their use does not have deleterious effects on the base material or completed weld (e.g., the thermal cut edge of the material by laser should be removed up to 3 mm ($^1/_8$ in.) by mechanical means).

All means for correcting improper fitting are to be in accordance with the approved joint design, the approved WPS and to the satisfaction of the Surveyor. Where sections to be joined differ in thickness and have an offset on either side of more than 3 mm ($^1/_8$ in.), a transition having a length not less than three times the offset is to be provided. The transition may be formed by tapering the thicker member or by specifying a weld joint design which will provide the required transition.

i) *Buttering and Buildup*. Buttering or buildup by welding on the weld joint surface to correct oversized root opening or errors in joint preparation may be approved by the Surveyor on a case-by-case basis on one side of the joint only, provided such buildup of one joint edge does not exceed 0.25t or 12 mm (0.5 in.), whichever is less, where t is the thickness of the thinner member being welded. Temporary backing may be used to assist in the buttering or buildup. When root openings cannot be corrected within this limitation, plating is to be made using patches, make-up plates and so forth, repairs are to be in accordance with ii) and iii) as below.

Buttering or buildup may be employed for fairing or for other corrections over or adjacent to welds, provided the above restrictions are not exceeded. This buildup is to be considered as part of the involved weld.

ii) *Insert Plates*. Insert plates welded into primary structure are to have a minimum width of 300 mm (12 in.) and are to have full penetration, 100 percent efficient butt welds. All inserts are to be to the satisfaction of the attending Surveyor. Lap plates and spigot patches are not permitted for aluminum repair or rectification of construction defects.

iii) *Access and Closure Plates*. Boundaries of access and closure plates are to be located between principal vessel framing or bulkheads and are to be at least 75 mm (3 in.) from any of these members. When variance from this 75 mm (3 in.) minimum is required by special circumstances, such variances are subjected to approval by the Surveyor. The boundaries of access and closure plates are not to land on existing butts or seams, and wherever practical should extend beyond the heat affected zone of butts or seams. Refer to 2-4-5/3.3.1 FIGURE 1A. Corners of access or closure plates are to have a minimum radius of 100 mm (4 in.) or 5*t*, whichever is larger, except when it is unavoidable for a boundary to land on an existing hull longitudinal or transverse butt joint. For the latter instance, the corners are to intersect the weld at an angle of 90 ± 15 degrees (refer to 2-4-5/3.3.1 FIGURE 1A). Closure plate weld joints are to be full penetration 100 percent efficient butt welds.

- Access plates are sections of plating which are removed for access, installations, or removal of equipment, and are later reinstalled.
- Closure plates are those plates left off or removed for access, wherein at least one transverse frame is cut.

3.3 Alignment

Means are to be provided for maintaining the parts to be welded in correct position and alignment during the welding operation. In general, strong backs or other appliances used for this purpose are to be 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.

3.3.1 Plate Alignment Tolerances

3.3.1(a) Butt Welds (1 July 2022)

Where plates are tacked in preparation for butt welding, the deviation of alignment of surfaces at the weld joint shall meet the requirements specified below:

Thinner Plate Thickness	*Maximum Allowable Deviation*
t, Less than 30 mm (1.2 in.)	3 mm (0.125 in.)
t, Greater than 30 mm (1.2 in.)	0.1*t*

3.3.1(b) Fillet Welds (1 July 2022)

When the opening between elements of a fillet welded joint exceeds 1.5 mm ($^1/_{16}$ in.) but not more than 5 mm ($^3/_{16}$ in.) as a nominal condition along the joint, the fillet size shall be increased by an amount equal to the excess of the opening above 1.5 mm ($^1/_{16}$ inch). Where the gap between members exceeds 5 mm ($^3/_{16}$ in.) as a nominal condition along the joint fillet, methods outlined below shall be used. Fillet welds shall be extended around the ends of members to form closed loops, where possible.

i) *Insert Plates.* Insert plates welded into primary structure are to have a minimum width of 300 mm (12 in.) and are to have full penetration, 100 percent efficient butt welds except for fillet weld edge(s). Insert plate radius is not to be less than 100 mm (4 in.) or 5t, whichever is greater, refer to 2-4-5/3.3.1 FIGURE 1A.

ii) *Other Means of Correcting Fit-up.* It may be submitted for approval on a case-by-case basis.

FIGURE 1A
Inserts and Patches in Plating *(1 July 2022)*

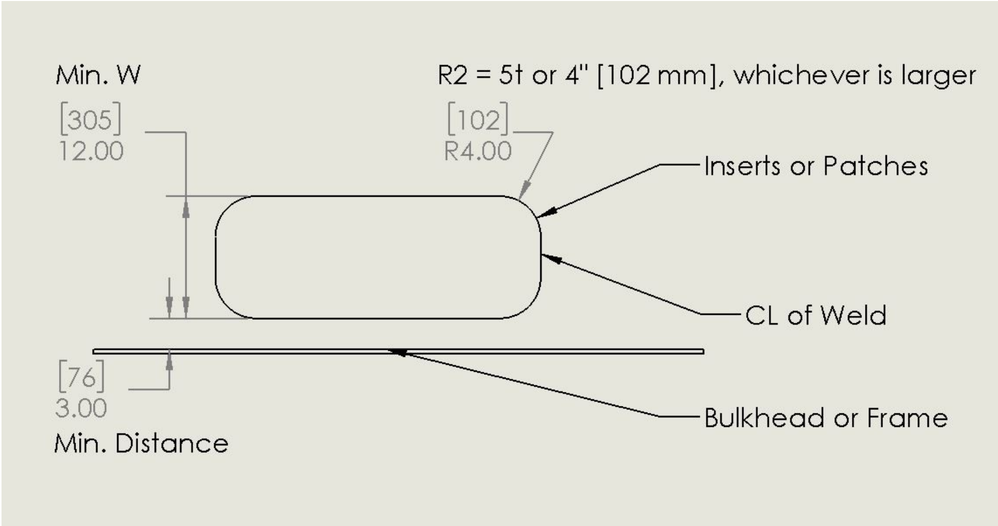
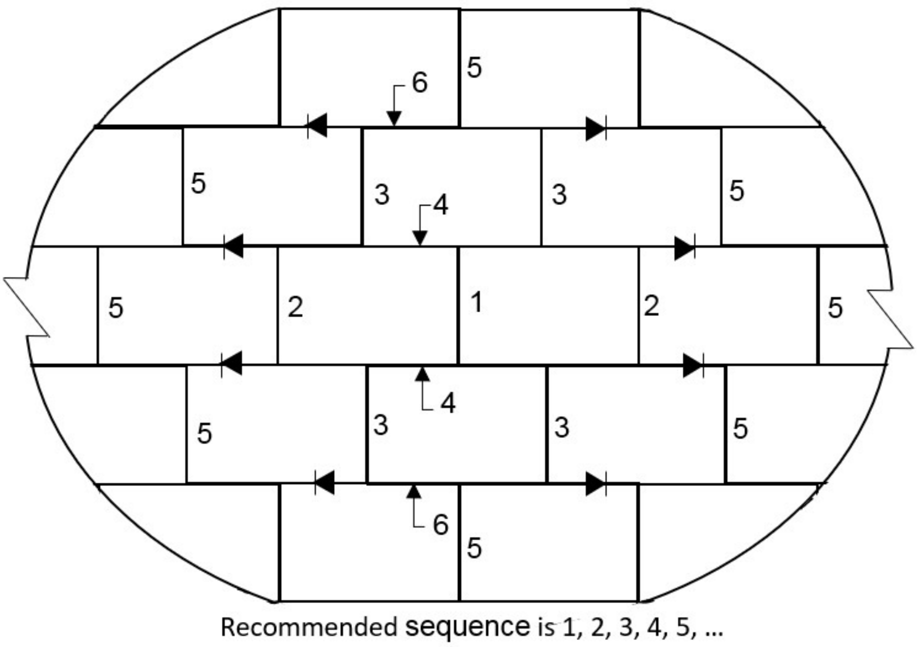


FIGURE 1B
Welding Sequence for Panels Consisting of Plates, Butts, and Seams
(1 July 2022)



3.5 Cleanliness *(2012)*

Suitable solvents or mechanical means are to be used to remove oil, grease, indelible markings, and all other contaminants from the vicinity of all joints prior to welding. -Oxide films that cannot be removed by the specific welding process, including any water stains (hydrated alumina oxide) are to be removed from the groove surfaces that are to be welded, including joint and faying surfaces as well as adjacent surfaces within one inch of the weld. Removal may be by mechanical means, such as a power driven, clean stainless steel wire brush, sanding with a 36-100 grit aluminum oxide sanding disk or by approved chemical means. Welding shall take place within eight hours of removal of oxide films except in way of faying surfaces of fillet welds. Interpass cleaning to remove slag, soot, overlap conditions, spatter, etc., is required. Degreasers are not to be used when the joint is such that the degreaser can collect in crevices such as faying surfaces between plate and backing bars or in way of lapped connections. Fusion welding is not to be performed on anodically-treated aluminum, except when the surface oxide is removed from the joint areas to be welded.

3.7 Tack Welds and Temporary Attachments *(2024)*

Tack welds are to be made with the same type of electrode as the final weld using a qualified WPS and should be deposited to facilitate incorporation into the final weld. Tack welds of poor quality or workmanship are to be removed.

Temporary attachments are to be made by qualified welders or tack welders using a qualified WPS. Removal of temporary attachments is to be made by either chipping or grinding so as to not damage the parent material. Upon completion, the parent material may be subject to surface NDT at the discretion of the attending Surveyor.

3.9 Stud Welding

The attachment of pins, hangers, studs and other related items by stud welding is to be approved at the discretion of the Surveyor. At the Surveyor's discretion, trial stud welds should be tested to demonstrate that stud welds and base material in way of stud welds are sufficiently sound for the intended application, prior to actual production work. The use of stud welding for structural attachments is subject to special approval and requires special procedure tests appropriate to each application.

3.11 Temporary Back-up Plates and Tapes *(2024)*

A temporary back-up plate may be applied using a qualified WPS to the opposite side of the joint during welding to assist in reducing distortion and to decrease heat concentration. Anodized "hard" aluminum back-up plates are recommended for this purpose, although clean stainless steel or rust-free mild steel plates may also be used. Back-up plates when used are to be free of contaminants and oxides which would interfere with welding. Welding is to be controlled to prevent arcing of the aluminum filler metal with the temporary back-up plate. Any accidental arcing to the back-up plate is to be corrected by removal of all contaminated weld or base metal. Approval of weld procedures involving the use of temporary back-up plates or backing tapes is to be in accordance with the approved WPS, provided it is demonstrated to the Surveyor's satisfaction that their use results in satisfactory welding and that plate distortion is not excessive.

3.13 Run-on and Run-off Tabs *(1 July 2022)*

When used, run-on and run-off tabs are to be designed to minimize the possibility of high-stress concentrations and cracking of the base metal and weld metal. Run-on and run-off tabs are to be removed by cutting means upon completion and cooling of weld. Ends of weld are to be made smooth and flush with the edges of the adjacent parts.

3.15 Forming

Cold forming of 5000 series aluminum alloys is to be conducted at temperatures below 52°C (125°F), except for the 5454 alloy, where the maximum temperature may be 149°C (300°F). See 2-4-5/3.15 TABLE 1 below for minimum cold-forming radii. When the extent of cold forming is such that base plate properties are changed beyond acceptable limits, appropriate reheat or stress relief treatments are to be used to reestablish acceptable properties. Hot forming of 5000 series aluminum alloys is generally conducted at temperatures between 260°C and 425°C (500°F and 800°F). Hot or cold forming is not to be performed in structures of any aluminum alloy unless supporting data is presented to the Surveyor's satisfaction indicating that significant material property changes will not result. Appropriate temperature control methods are to be used in all hot forming and stress relieving operations. In hot forming or stress relieving, exposure of the 5000 series alloys to the 65°C (150°F) to 200°C (400°F) temperature range is to be minimized by the use of appropriate cooling techniques. Typically, 6000 series aluminum is not to be formed. For 6000 series aluminum to be considered for forming, supporting technical data is to be submitted for review and approval prior to forming.

TABLE 1
Minimum Cold-forming Radii for Aluminum Alloys [1, 2, 3] *(1 July 2022)*

Alloy and temper	*3 mm (0.125 in.)*	*5 mm (0.1875 in.)*	*6 mm (0.25 in.)*	*9.5 mm (0.375 in.)*	*12 mm (0.50 in.)*
AB 5083-0	1t	1, 2t	1, 2t	2t	2t
H113	1, $1^1/_2t$	1, 2t	1, 2t	$1^1/_2$, 2t	2, 3t
H116	$1^1/_2t$	$1^1/_2t$	$1^1/_2t$	2t	$2^1/_2$
H321	$1^1/_2t$	$1^1/_2t$	$1^1/_2t$	2t	$2^1/_2$
H323	$1^1/_2$, 3t	$1^1/_2$, $3^1/_2t$	2, 4t	---------	---------
H343	$1^1/_2$, 3t	2, 4t	$2^1/_2$, $4^1/_2t$	---------	---------
AB 5052-0	1t	1t	1t	1, $1^1/_2t$	1, 2t
H32	1, $1^1/_2t$	1, $1^1/_2t$	1, $1^1/_2t$	1, 2t	$1^1/_2$, $2^1/_2t$
H34	$1^1/_2$, $2^1/_2t$	$1^1/_2$, $2^1/_2t$	2, 3t	2, 3t	$2^1/_2$, $3^1/_2t$
H36	$1^1/_2$, 3t	2, 4t	2, 4t	$2^1/_2$, 5t	$3^1/_2$, $5^1/_2t$
H38	2, 4t	3, 5t	4, 6t	4, 7t	5, 8t
AB 5086-0	1t	1t	1t	1, $1^1/_2t$	1, 2t
H32,H116,H117	1, 2t	1, 2t	$1^1/_2$, $2^1/_2t$	2, $2^1/_2t$	$2^1/_2$, 3t
H34	$1^1/_2$, $2^1/_2t$	2, 3t	2, 3t	$2^1/_2$, $3^1/_2t$	3, 4t
H36	2, $3^1/_2t$	$2^1/_2$, 4t	3, $4^1/_2t$	3, 5t	$3^1/_2$, $5^1/_2t$
H112			1, 2t	1, 2t	$1^1/_2$, $2^1/_2t$
AB 5456-0	1t	1, 2t	1, 2t	2t	2t
H116,H117	2, 3t	2, 3t	2, 3t	3, 4t	3, 4t
H323	$1^1/_2$, 3t	$1^1/_2$, $3^1/_2t$	2, 4t	------	------
H343	$1^1/_2$, 3t	2, 4t	$2^1/_2$, $4^1/_2t$	------	-----

Notes:

1. Where two radii are shown, the larger radius is applicable when the bend is parallel to the direction of rolling.
2. These bending radii are applicable to aluminum alloys which are free of visible oxide coating.
3. The radii shall be the mandrel radii or inside radii.

5 Production Welding

5.1 Environment

Proper precautions are to be taken to confirm that all welding is done under conditions where the welding site is protected against deleterious effects of moisture, wind and severe cold. Paint or oil mist and other contaminants which tend to cause weld porosity are to be excluded from the vicinity where welding is in progress.

5.3 Preheat *(1 July 2022)*

Preheating is not generally required for aluminum alloys. The use of preheat may be desirable when welding materials of thick cross section, materials subject to high restraint, and when welding is performed under high humidity conditions or when the temperature of the aluminum alloy is below 0°C (32°F). When preheating is used, appropriate production controls are to be used to maintain the specified temperatures, in accordance with accepted procedures and to the satisfaction of the Surveyor. Preheating temperatures which sensitize an alloy to corrosion are to be avoided. For the 5000 series alloys, it is generally recommended to avoid prolonged exposure to the 65°C to 100°C (150°F to 212°F) temperature range and less than 15 min. Preheat and interpass temperatures shall be verified by temperature sticks, small contact thermometer, pyrometer, etc., a minimum of 25 mm (1 in.) away from the weld area.

5.5 Postheating

Weldments of work hardenable 5000 series aluminum alloys are not to be postweld heat treated unless the procedures have been specially approved. Where use of a heat-treatable alloy has been approved, any postweld heat treatment proposed is to be as established in procedure qualification tests. Post weld heat treatment is not required on 5000 series aluminum materials, stainless steels, copper alloys or nickel alloys.

5.7 Accessibility

Assembly and welding is to be arranged to provide sufficient accessibility to the joint by the welder, the welding equipment and for inspection.

5.8 Avoiding Joint Corrosion *(2020)*

For guidance, refer to D3.7/6.11 of the AWS Guide for Aluminum Hull Welding.

5.9 Sequence *(1 July 2022)*

Welding is to be planned to progress symmetrically so that shrinkage on both sides of the structure will be equalized. Parts/joints with high shrinkage are to be welded first before the less shrinkage joint. The ends of frames and stiffeners are to be left unattached to the plating at the sub-assembly stage for a distance of about 300 mm (12 in.) until 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 especially approved.

In order to mitigate distortion and residual stresses in large panels consisting of multiple plates, the butt seams are to be welded before the panel seams. Welding is to progress from the center toward the outer edges. Refer to 2-4-5/3.3.1 FIGURE 1B. Starting at the center of a seam, weld outward with a backstep sequence.

5.10 Structural Design Details *(1 July 2022)*

The design of structural details is to avoid the harmful effects of stress concentration and notches such as noted below:

i) Details of the ends, the intersections of members and associated brackets

ii) Shape and location of air, drainage and lighting holes

iii) Shape and reinforcements of slots or cutouts for internals

iv) Elimination or closing of weld scallops in way of butt, "softening" of bracket toes, reducing abrupt changes of section or structural discontinuities

v) Details of welding sequence for local members to minimize heat input, residual stress and distortion, refer to 2-4-5/5.9 and 2-4-5/3.3.1 FIGURE 1B

vi) Details of hull fabrication sequence, refer to 2-4-5/5.9 and 2-4-5/3.3.1 FIGURE 1B

vii) Weld details are to minimize excessive weld reinforcement (excess weld metal introduces a stress concentration point). The maximum weld reinforcement is R_{max} - 2.5 mm (0.10 in.) for metal thickness less than 10 mm (0.40 in.)

5.11 Back Gouging

Chipping, routing, milling, grinding or other suitable methods are to be employed at the root or underside of the weld to obtain sound metal before applying subsequent beads for all full-penetration welds.

5.13 Fairing and Flame Shrinking

Shrink welds may be used, but fairing by heating or flame shrinking to correct distortion or defective workmanship in fabrication of main strength members within the midships portion of the craft and other plating which may be subject to high stresses is not generally recommended. If intended to be used, it is to be carried out only with the expressed approval of the Surveyor. For the 5000 series alloys, it is generally recommended that heating and cooling through the sensitizing range of 65°C-200°C (150°F-400°F) is to be as rapid as practicable.

5.15 Inspection of Welds *(2024)*

Welding inspection is to be in accordance with ABS *Guide for Nondestructive Inspection* or a recognized equivalent standard accepted by ABS. Additional requirements for aluminum alloys are included in this Subsection. Refer to 2-4-5/17 FIGURE 18 for examples of typical weld defects.

5.15.1 Visual Inspection *(1 July 2022)*

Visual inspection during construction is to consist of inspecting the surface appearance of welds for the existence of flaws or defects, as stated below. The surface of the welds is to be regular and uniform with proper contour, a minimum amount of reinforcement and reasonably free from undercut and overlap, slag, paint and weld splatter. Unless otherwise specified or required, the acceptance criteria for visual inspection is to be in accordance with AWS D1.2/Table 5.3.

5.15.1(a) Appearance *(1 July 2022)*

Welds shall be free of cracks, incomplete fusion and burn-through. Visible arc-strikes on welds and the adjacent base metal are not allowed and shall not exceed 1 mm ($^1/_{32}$ in.) in depth after removal. Weld spatter greater in diameter greater than 1 mm ($^1/_{32}$ in.) is not acceptable. Gouge marks, nicks and other fabrication scars in the weld inspection zone shall not exceed the requirements for undercut. Weld surfaces shall be free of slag to the extent that there is no interference with visual or other required nondestructive test. Crater pits are not acceptable and shall be filled to the full cross section of the weld.

5.15.1(b) Melt-through

Melt-through and repaired burn-through areas are acceptable, provided the areas do not contain cracks, crevices, excessive oxidation or globules, and provided that the root convexity and concavity limits are not exceeded.

5.15.1(c) Suckback

Suckback is unacceptable in a weld or base metal when it occurs as a sharp notch or where the depth reduces the weld thickness below the minimum base metal thickness.

5.15.1(d) Undercut *(1 July 2022)*

For strength members, the maximum undercut shall be 0.5 mm ($^1/_{64}$ in.) or 10% of the adjacent base metal thickness, whichever is less. For other members, the maximum undercut shall be 1 mm ($^1/_{32}$ in.). For base metal thickness 12 mm (0.5 in.) and greater, undercut from 1 mm ($^1/_{32}$ in.) to 1.5 mm ($^1/_{16}$ in) is allowed if the accumulated length of undercut does not exceed 15% of the joint length or 300 mm (12 in.), whichever is less.

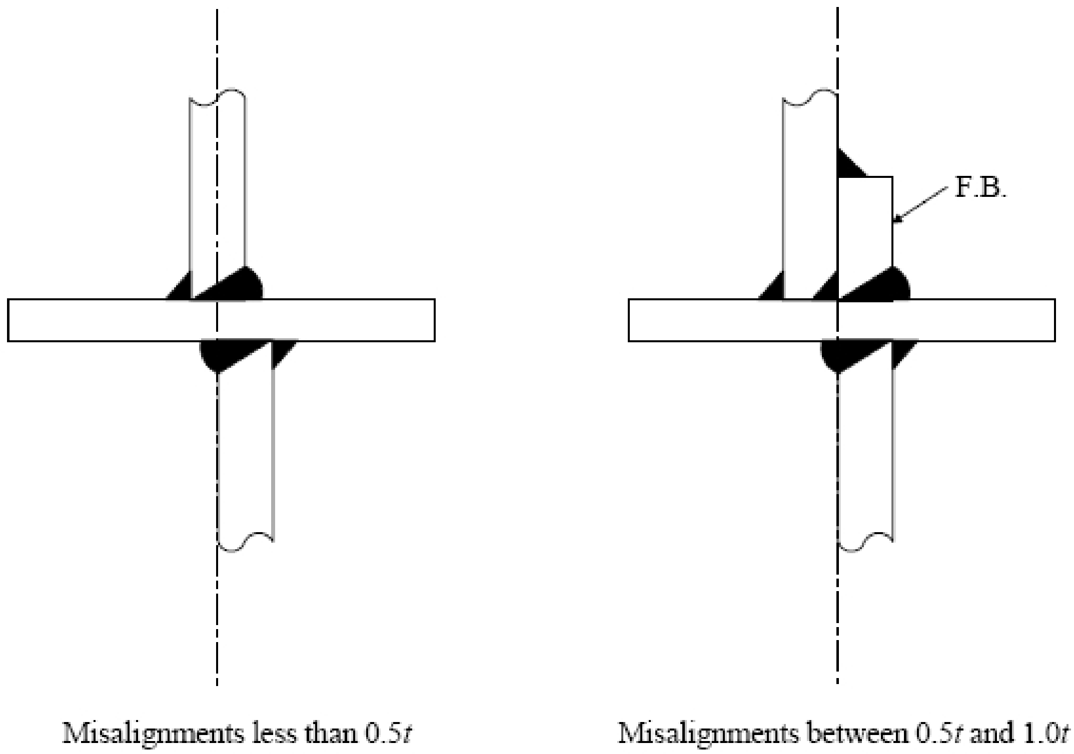
5.15.1(e) Welded Joint Offset

The maximum offset for all welded joints shall be as follows:

Base Metal Thickness	*Maximum Offset*
$^1/_4$ in. and less	25% of joint thickness
Over $^1/_4$ in. to $^3/_4$ in.	25% of joint thickness, but not to exceed $^1/_8$ in.
Over $^3/_4$ in. to $1^1/_2$ in.	$^3/_{16}$ in.
Over $1^1/_2$ in.	$12^1/_2$% of joint thickness, but not to exceed $^1/_4$ in.

For misalignments that exceed the table above and less than 0.50*t*, the structure may be fixed by using deep penetration welds. For misalignments that exceed 0.50t and are less than 1.0*t*, the structure may be fixed by aligning flat bar doubling strips. Misalignments greater than 1.0*t* are to be corrected by realignment of the structure. See 2-4-5/5.15.1(e) FIGURE 2.

FIGURE 2
Repairs of Misalignments



5.15.1(f) Quality Requirements for Critical Area or Fatigue Sensitive Area *(1 July 2022)*

Critical areas or fatigue sensitive areas are defined in 3-1-2/9 of ABS *Rules for Building and Classing for Light Warships, Patrol and High-Speed Naval Vessels*. Quality requirements of critical areas or fatigue sensitive areas are to be in accordance with 3-2-A4/1.3 of the ABS *Rules for Building and Classing for Light Warships, Patrol and High-Speed Naval Vessels*.

5.15.2 Dye Penetrant *(1 July 2022)*

Dye penetrant inspection is to be used when investigating the outer surface of welds or may be considered for use as a check of intermediate weld passes, such as root passes and also to check back-chipped, ground or gouged joints prior to depositing subsequent passes. Any dye penetrant used is to be thoroughly removed from the area before re-welding. Dye penetrant is not to be used where complete removal of the dye penetrant materials cannot be assured. The procedures and standards for Dye Penetrant inspection are to be in accordance with the ABS *Guide for Nondestructive Inspection*, or other recognized standards accepted by ABS. Surface cracks are not permitted when welds are subject to the Dye Penetrant inspection.

5.15.3 Radiographic or Ultrasonic Inspection *(1 July 2022)*

Radiographic or ultrasonic inspection or both may be used when the overall soundness of the weld cross section is to be evaluated. Finished welding is to be sound and thoroughly fused throughout its cross section and to the base material. Production welds are to be crack free. Other discontinuities, such as incomplete fusion or incomplete penetration, slag and porosity, are only to be present to the degree permitted by the pertinent inspection standard. The procedures and standards for radiographic and ultrasonic inspection is to be in accordance with ABS's separately issued publication, *Guide for Nondestructive Inspection*, or other approved acceptance standards. Unless otherwise specified or required, the acceptance criteria for Radiographic inspection is to be in accordance with ISO 10675-2 and the acceptance criteria for Ultrasonic inspection is to be in accordance with any recognized standard agreed by ABS and demonstrated to be acceptable.

5.15.4 Weld Plugs or Samples

The practice of taking weld plugs or samples by machining or cutting from the welded structure is not recommended and is to be considered only in the absence of other suitable inspection methods and is to be subject to the special approval of the Surveyor. When such weld plugs or samples are removed from the welded structure, the holes or cavities formed are to be properly prepared and welded, using a suitable welding procedure approved by the Surveyor and as established for the original joint

5.17 Workmanship Requirements *(1 July 2022)*

The workmanship requirements include the visual acceptance criteria stated in 2-4-5/5.15.2 above plus the following structural fairness requirements provided in 2-4-5/5.17.1 and 2-4-5/5.17.2 of these Rules and IACS Rec No. 47 Table 6.10 and Table 6.11, whichever is more stringent. In addition, welded attachments shall be removed to a minimum of 1.5 mm (0.0625 in.) away from the permanent member to which they are attached by chipping, sawing or cutting, followed by grinding or sanding to restore the plate surface.

5.17.1 Structural Fairness for Plating

Unfairness (deviation from the design molded line) of welded plating shall not exceed the tolerances shown on 2-4-5/17 FIGURE 3 and 2-4-5/17 FIGURE 4. Permissible unfairness should result in a generally fair curve across the panel, except that an additional deviation of 3 mm (1.8 in.) from the fair curve is permitted in way of welded butts and seams. Sharp knuckling or bend in way of stiffeners shall be avoided. A procedure for measuring fairness and taking corrective actions shall be developed and be available for review by the surveyor.

If aid is necessary in determining the acceptability of the fairness of welded structure, a measurement of the unfairness of plating may be made in the area of interest. In such cases, the measurement shall be made across the minor dimension of the panel. The tolerances specified on 2-4-5/17 FIGURE 3 and 2-4-5/17 FIGURE 4 are plus or minus the dimensions from a fair line.

For stiffener spacings greater or less than those shown on 2-4-5/17 FIGURE 3 and 2-4-5/17 FIGURE 4, the curves shall be extrapolated proportionately.

5.17.2 Structural Fairness for Framing and Stiffeners

Frame, beam and stiffener bows in primary strength structure or structure subject to dynamic loading shall be corrected when it varies plus or minus from the designated or molded line in excess of the following:

$$T = C\left(\frac{\ell}{dw}\right) \qquad \text{mm(in.)}$$

where

T = tolerance in mm (in.)

C = 530 (0.25)

ℓ = span of member between the fixed ends at the support structure in m (ft)

dw = depth of the stiffening member measured from the underside of the flange in mm (in.)

5.17.3 Underwater Exterior Surfaces

In general, weld surfaces shall not extend greater than 1.5 mm (0.0625 in.) above the plate surface.

5.17.4 Workmanship Requirements for Critical Area or Fatigue Sensitive Area *(1 July 2022)*

Critical area or fatigue sensitive area are defined in 3-1-2/9 of ABS *Rules for Building and Classing for Light Warships, Patrol and High-Speed Naval Vessels*. Workmanship requirements of critical area or fatigue sensitive area are to be in accordance with 3-2-A4/1.3 of the ABS *Rules for Building and Classing for Light Warships, Patrol and High-Speed Naval Vessels*.

5.19 Quality Control *(1 July 2022)*

To maintain quality control, sample welds may be required to be made by welders and operators during each three (3) month period, at the discretion of the Surveyor and at the location of production welding, using the same equipment, material and filler metal as intended for production. The sample welds are to be examined for acceptable workmanship and may be required to be sectioned, etched and examined for weld soundness. When necessary, measures are to be taken to correct unacceptable workmanship.

Production welds are to be marked with temporary means (marker, paint or similar) with the welder or welding operator's identification number for tracking purposes. Other equivalent means may be accepted to the satisfaction of the attending Surveyor.

5.21 Repair Welding

5.21.1 Weld Repairs *(1 July 2022)*

Unsatisfactory welding, as determined by visual inspection, nondestructive test methods, or leakage under hydrostatic tests, is to be corrected by the removal of the defective weld or adjacent material or both and corrected by rewelding, using a suitable repair welding procedure consistent with the material being welded. The repair procedures are to be available for the welder. Additionally, multiple heat cycles are considered on a case-by-case basis and are to be approved by ABS Engineering considering the potential reduced strength at the heat affected zone of the base metal. The number of heat cycles for 5000 series aluminum alloys is not to exceed three cycles, counted as the initial weld and two repairs, where the heat affected zone is overlapped with the initial weld. Unless otherwise agreed, only one repair is allowed on 6000 series aluminum, and welded properties are to meet design requirement. Before welding, repairs on 6000 series aluminum are to be submitted for review, and approval is subject to ABS technical assessment. Removal by mechanical means of minor surface defects such as arc strikes, scratches or shallow gouges may be permitted at the discretion of the attending Surveyor. Repaired welds must meet the inspection requirements for the original weld.

The following steps are to be taken in preparation for weld repairs

i) Remove the damaged sections of all components.

ii) Remove the original weld metal in new weld areas.

iii) Fabricate patches and reinforcements and form the proper fit-up. The minimum size of patches and reinforcement is given in 2-4-5/3.3.1 FIGURE 1A.

iv) Properly clean and brush the metal surface with an oxide and degreasing solvent.

v) All surfaces in the weld area are to be dried.

vi) Position and clamp the patch for tack welding.

vii) The patch is to be tack welded in place.

viii) Tack welds are to be chipped out or tapered at each end as required.

ix) Follow the chosen weld sequence to mitigate residual stress

5.21.2 Thermal Cycles *(1 July 2022)*

If applicable, tracking and controlling of heat cycles for aluminum are required in accordance with Construction Monitoring Plan (CMP), refer to 3-1-2/9.5 of the ABS *Rules for Building and Classing for Light Warships, Patrol and High-Speed Naval Vessels* and the applicable Section of the ABS *Rules for Survey after Construction (Part 7)*.

Locations which have exceeded the above welding thermal cycles are to be considered for inserting in lieu of gouging and rewelding to the satisfaction of the attending Surveyor. Any area with a high number of welding thermal cycles which has been inserted and is to be considered reset back to an initial weld.

5.21.3 Special Circumstance *(1 July 2022)*

Special repair procedures are to be qualified and submitted for approval. This includes the following items:

i) Arc welding repairs for Friction Stir welding

ii) Repair welding in the middle of a plate

iii) Repair of extruded materials

iv) Proper testing of weld repairs with particular regard to starts and stops.

Note: Each of the above repairs is to include proper testing of weld repairs with particular regard to starts and stops.

7 Butt Welds

7.1 Joint Design *(1 July 2022)*

Hull plating up to 5.0 mm ($^3/_{16}$ in.) in thickness may be square-butt welded without beveling the abutting plate edges. Plates exceeding 5.0 mm ($^3/_{16}$ in.) may be prepared for welding by similarly beveling the edges of both plates from one or both sides to form a single-Vee or double-Vee butt joint with an included angle from 60 degrees to 90 degrees. For single-Vee butt joints in material 5.0 mm ($^3/_{16}$ in.) and thicker, the root face or land may be up to 3.0 mm ($^1/_8$ in.) in depth. Root faces or lands below 1.5 mm ($^1/_{16}$ in.) are not generally recommended. For double-Vee butt joints in material 8.0 mm ($^5/_{16}$ in.) and thicker, the gap may vary from 0 to 5.0 mm ($^3/_{16}$ in.). Joints of other designs and root openings, such as the square butt joints in heavy thicknesses used with automated procedures will be subject to special consideration and in accordance with a nationally recognized welding code or standard. In general, use of double-Vee in lieu of single-Vee joints and the narrowest root gap practicable is recommended to minimize distortion.

Butt-type permanent backing strap joints welded from one side shall not be used. For both single-Vee and double-Vee joints, the weld metal at the root on the reverse side of a weld made without permanent backing is to be removed to sound metal by an approved method before applying subsequent weld passes. See 2-4-5/5.11. Welded butt joints made against removable backing and on which the root is inspected in accordance with these requirements shall be considered the equivalent of a joint welded from both sides.

9 Fillet Welds *(1 July 2021)*

See Section 3-2-13 of the ABS *Rules for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels*.

11 Filler Metals

11.1 General

Filler metals are to be of a type suitable to produce sound welds that have strength, ductility and corrosion-resistant properties comparable to the materials being welded. Appropriate precautions are to be used to prevent any critical property change of filler wire quality during storage and handling. A list of recommended filler metals for different alloys is given in 2-4-5/17 TABLE 4 and 2-4-5/17 TABLE 5.

11.3 Approval Basis *(2024)*

Filler metals will be approved and listed, subject to tests conducted at the manufacturer's plant in accordance with Appendix 2-A2-5. Upon satisfactory completion of tests, a certificate will be issued for general approval indicating the grade or classification to which the filler metal was tested and the relevant characteristics of the filler metal. Test assemblies are to be prepared in the presence of the Surveyor and all tests are to be attended by and carried out to the satisfaction of the Surveyor. Alternatively, procedure and testing may comply with either of the following standards.

i) Filler metals will be considered for approval based upon tests conducted to standards established by the American Welding Society or other recognized agency.

ii) Special approvals to manufacturer's specifications.

13 Approval of Welding Procedures

13.1 Approved Filler Metals

Approval of aluminum alloy filler metals used on ABS-classed weldments will depend on the specific application and alloys for which the filler metal is intended. Procedure tests may be required as a general condition of approval or at the discretion of the attending Surveyor to determine the shipyard's or fabricator's capability in the application of the proposed filler metal to the base material. The extent of such tests may vary depending upon the intended application, but generally would follow those tests outlined in 2-4-5/13.5, and are to be carried out under production conditions.

13.3 New Procedures and Methods

Weld tests, as outlined in 2-4-5/13.5 and 2-4-5/13.7 and 2-4-5/17 FIGURE 5 to 2-4-5/17 FIGURE 17, using procedures and materials similar to those intended for production welding and carried out under production conditions, may be required to be prepared by each shipyard or fabricator when new or unusual methods, base metals or filler metals are proposed.

All tests are to be made in the presence of the Surveyor and carried out to the Surveyor's satisfaction.

13.5 Tests *(1 July 2022)*

Tests Nos. 1 and 2 are to be carried out for procedures involving butt welds. Test No. 3 is to be carried out for procedures involving fillet welds. Unless otherwise specified, the number of specimens is to be as indicated. The minimum test results required are stated with the figures:

- *Test No. 1 – Reduced Section Tension Test* (with reinforcement removed) (2-4-5/17 FIGURE 7 or 2-4-5/17 FIGURE 8). Two specimens made in each position involved. The test specimens are to meet or exceed the ultimate tensile strength shown in 2-4-5/3.15 TABLE 1.
- *Test No. 2 – Guided Bend Test* (2-4-5/17 FIGURE 9 or 2-4-5/17 FIGURE 10). For material 9.5 mm (0.375 in.) thick and under, two face-bend and two root-bend specimens for each position; for material over 9.5 mm (0.375 in.) thick, four side-bend specimens for each position involved. The bending jig and test requirements are indicated in 2-4-5/17 FIGURE 11. Equivalent bending jigs, such as wrap around bend test fixtures, may also be used.
- *Test No. 3 – Fillet Weld Test* (2-4-5/17 FIGURE 13).

13.7 Special Tests

All-weld-metal tensile, macro-etch, radiographic inspection or other relevant tests may be required for certain applications, and the results submitted for consideration.

15 Welder Qualifications

15.1 General *(1 July 2022)*

The Surveyor is to be satisfied that the welders and operators are proficient in 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.

As an alternative, welders may be qualified in accordance with a recognized standard. The application of such recognized standard is to be submitted for agreement by the Surveyor.

15.3 Qualification Tests

The tests, if required for qualification for various welding processes, are given in 2-4-5/17 TABLE 6. Such tests are based on the material thicknesses and welding processes involved. Qualification of welders for a particular alloy may be acceptable for qualification of the welder for other aluminum alloys. Separate qualification tests are to be made for the gas metal arc and gas tungsten arc processes. The tests are referred to by Nos. Q1, Q2, Q4, and Q5, for which specimens are to be prepared and tested in accordance with 2-4-5/17 FIGURE 14 to 2-4-5/17 FIGURE 17,respectively. Specimens for qualification tests are to be bent in a bending jig having the profile shown in 2-4-5/17 FIGURE 11 or in a bending jig having an equivalent wrap around design. Alternatively, upon the request of the employer, the welder may be qualified by use of radiography, provided that the complete particulars of the equipment available and the procedures are demonstrated to be satisfactory. Test assemblies for either mechanical testing or radiographic examination are to be prepared according to material thickness and welding position, as indicated in 2-4-5/17 TABLE 6.

17 Alternatives

The foregoing are considered minimum requirements for aluminum welding in hull construction, but alternative methods, arrangements and details may be considered for approval.

TABLE 2
Minimum Mechanical Properties for Butt-Welded Aluminum Alloys *(1 July 2022)*

The adoption of test values higher than given in this table will be subject to special consideration. Filler wires are those recommended in 2-4-5/17 TABLE 3. Values shown are for welds in plate thicknesses up to 38 mm (1.5 in.) unless otherwise noted.

Alloy	*Ultimate Tensile Strength (U_{al})*	*Yield Strength (Y_{al}) (2)*	*Shear Strength (τ_a) (2)*
	N/mm ^{2} (psi)	*N/mm ^{2} (psi)*	*N/mm ^{2} (psi)*
AB 5083-H111	269 (39000)	145 (21000)	83 (12000)
AB 5083-H116, H321	276 (40000)	165 (24000)	96 (14000)
AB 5083-H323, H343	276 (40000)	165 (24000)	96 (14000)
AB 5086-H111	241 (35000)	124 (18000)	69 (10000)
AB 5086-H112 6 mm (0.25 in.) –12 mm (0.50 in.)	241 (35000)	117 (17000)	65 (9500)

Alloy	*Ultimate Tensile Strength (U_{al})*	*Yield Strength (Y_{al}) (2)*	*Shear Strength (τ_a) (2)*
	N/mm ^{2} (psi)	*N/mm ^{2} (psi)*	*N/mm ^{2} (psi)*
AB 5086-H112 12 mm (0.5 in.) –25 mm (1.0 in.)	241 (35000)	110 (16000)	62 (9000)
AB 5086-H112 Greater than 25 mm (1.0 in.)	241 (35000)	96.5 (14000)	55 (8000)
AB 5086-H32, H34, H116	241 (35000)	131 (19000)	76 (11000)
AB 5383-O, H111	290 (42000)	145 (21000)	83 (12000)
AB 5383-H116, H321	290 (42000)	165 (24000)(3)	83 (12000)
AB 5383-H34	290 (42000)	145 (21000)	83 (12000)
AB 5454-H111	214 (31000)	110 (16000)	65 (9500)
AB 5454-H112	214 (31000)	83 (12000)	48 (7000)
AB 5454-H32, H34	214 (31000)	110 (16000)	65 (9500)
AB 5456-H111	283 (41000)	165 (24000)	96 (14000)
AB 5456-H112	283 (41000)	131 (19000)	76 (11000)
AB 5456-H116, H321	290 (42000)	179 (26000)	103 (15000)
AB 5456-H323, H343	290 (42000)	179 (26000)	103 (15000)
AB 6061-T6(1) under 9.5 mm (0.375 in.)	165 (24000)	138 (20000)	83 (12000)
AB 6061-T6(1) over 9.5 mm (0.375 in.)	165 (24000)	103 (15000)	62 (9000)

Notes:

1 Values when welded with 4043, 5183, 5356 or 5556 filler wire.

2 Yield and shear strength is not required for weld procedure qualification.

3 Yield strength values as high as 185 N/mm^2 (27000 psi) have been satisfactorily demonstrated and statistically verified.

TABLE 3
Aluminum Alloy Filler Metal Composition *(2016)*

Composition in percent maximum unless shown as a range or specified. See also AWS A5.10

Alloy	*Silicon*	*Iron*	*Copper*	*Manganese*	*Magnesium*	*Chromium*	*Zinc*	*Titanium*	*Other**		*Aluminum*
									Each	*Total*	
4043	4.5-6.0	0.80	0.30	0.05	0.05		0.10	0.20	0.05	0.15	Remainder
4943	5.0-6.0	0.40	0.10	0.05	0.10-0.50		0.10	0.15	0.05	0.15	Remainder
5183	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.05–0.25	0.25	0.15	0.05	0.15	Remainder
5356	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.05–0.20	0.10	0.06–0.20	0.05	0.15	Remainder
5554	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	0.25	0.05–0.20	0.05	0.15	Remainder
5556	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	0.25	0.05–0.20	0.05	0.15	Remainder

* The maximum Beryllium content of all filler wires is to be 0.0003%.

TABLE 4
Filler Metals for Welding Aluminum Alloy – Sheet, Plate and Extrusions
(1 July 2022)

Recommendations in this table apply to gas shielded-arc welding processes.
Filler metal alloys 5183, 5356 and 5556 may be used interchangeably, provided that strength, ductility and corrosion resistance are suitable for the service conditions.

Base Metal Alloys	*AB 5083*	*AB 5086*	*AB 5383*	*AB 5454 (1)*	*AB 5456*	*AB 6061, 6082*
AB 5083	5183	5356	5183	5356 (1)	5183	5356 (1)
AB 5086	5356	5356	5356	5356 (1)	5356	5356 (1)
AB 5383	5183	5356	5183	5356 (1)	5183	5356 (1)
AB 5454 (1)	5356	5356	5356	5554 (1)	5356	5356 (1)
AB 5456	5183	5356	5183	5356 (1)	5556	5356 (1)
AB 6061, 6082	5356	5356	5356	5356 (2)	5356	4043, 4943 (2, 3)

Notes:

1 5454 aluminum alloy welded with 5554 filler metal is generally recommended for above 65°C (150°F), such as for smoke stacks and engine room enclosures

2 5183 or equivalents may be used.

3 In case 4943 is selected, tensile test results are to be submitted for ABS review.

TABLE 5
Filler Metals for Welding Aluminum Alloy Castings to Castings and Plate
(1 July 2022)

ASTM American Society for Testing and Materials

AA Aluminum Association

Castings		*SG70A SG70B, 357 (Note 1)*	*5154, 5454, 6061 (Note 2)*	*5456, 5083, 5086 (Note 3)*
ASTM	*AA*			
SG70A	AB 356.0	4043	4043	5356
SG70B	AB A356.0	4043	4043	5356
	AB 357.0	4043	4043	5356

Notes:

1 Filler metal with same analysis as base metal is sometimes used.

2 5183, 5356, 5554, 5556 and 5654 may be used. In some cases they may provide higher weld ductility and higher weld strength. 5554 is suitable for elevated temperature service.

3 5183, 5356 or 5556 may be used. 4043 may be used for some applications where filler metal properties are not of primary concern.

TABLE 6
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*
On material of limited thickness 19.1 mm ($^3/_4$ in.) or less. See Note 1.	Test No. Q1 in vertical and overhead positions	Test No. Q1 in vertical position	Test No. Q1 in flat position
On material of unlimited thickness (any thickness) See Notes 1 and 2.	Test No. Q2 in vertical and horizontal positions	Test No. Q2 in vertical position	Test No. Q2 in flat position
On piping or tubing. See Note 3.	Test No. Q3 in horizontal and vertical positions	Test No. Q3 in horizontal and vertical fixed positions	Test No. Q3 in horizontal rolled position
For tack welders	Test No. Q5 in vertical and overhead positions	Test No. Q5 in vertical position	

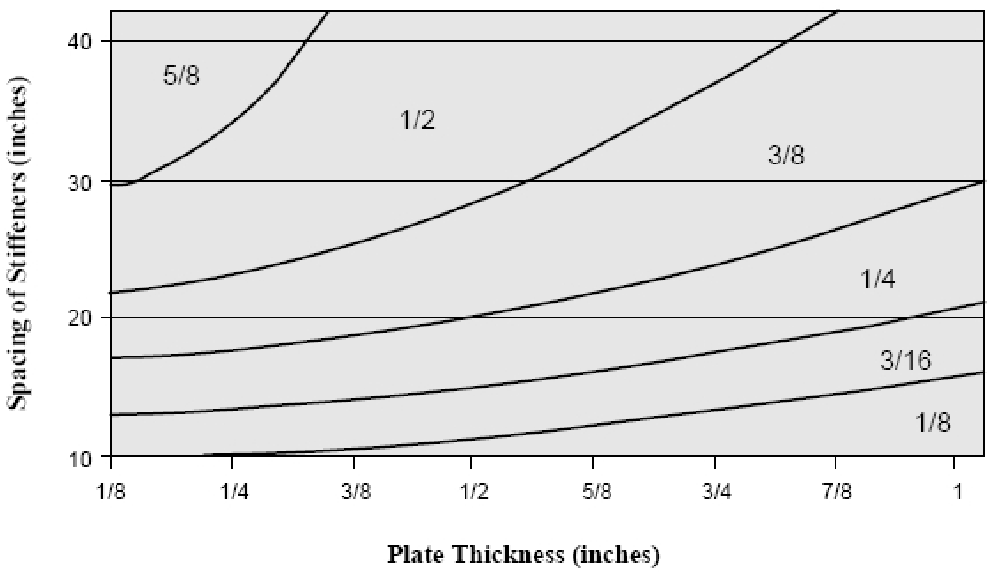
Notes:

1 Where the maximum thickness of material on which a welder may have occasion to work throughout the period governed by a test is indeterminate, the Surveyor may, if desired, require the welder to qualify under unlimited thickness requirements.

2 Where the maximum plate thickness to be welded is between 19.1 mm ($^3/_4$ in.) and 38.1 mm ($1^1/_2$ in.) qualification Test No. Q2 may, with the permission of the Surveyor, be conducted on plate of maximum thickness involved.

3 Welding operators qualified under the requirements of Test No. Q4 will be considered as qualified to make welds governed by Tests Nos. Q1 and Q2. Welding Operators qualified to weld on plate in the vertical position may be permitted to weld on pipe in the horizontal rolled position.

FIGURE 3
Permissible Unfairness in Aluminum Welded Structure



Applicability of tolerances:

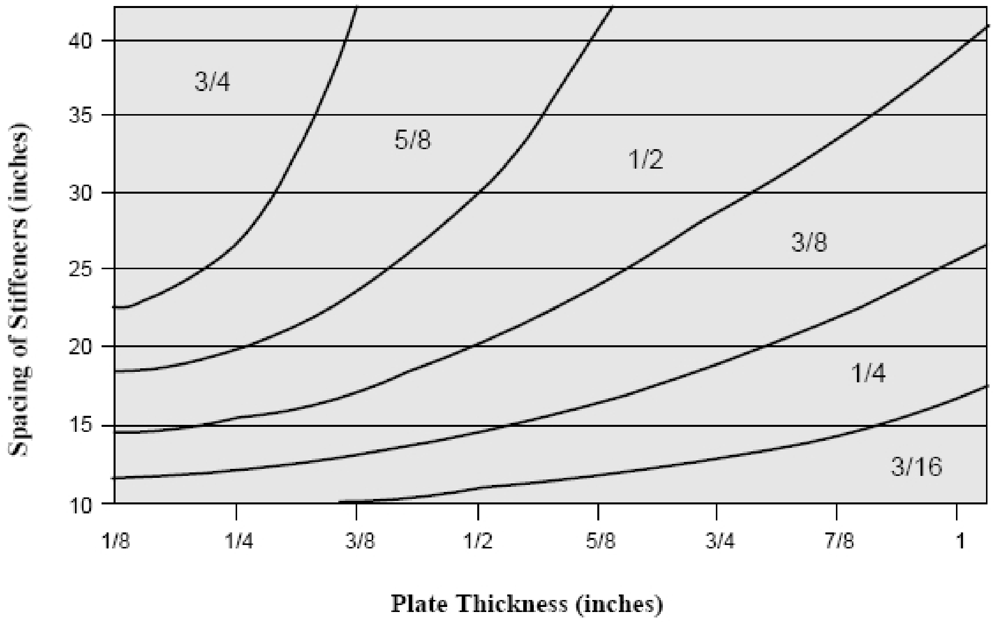
1 Entire shell plating

2 Uppermost strength deck

3 Longitudinal strength Deck structure which includes inner-bottom tank tops

4 Bulwarks and exterior superstructure bulkheads

FIGURE 4
Permissible Unfairness in Other Aluminum Welded Structure



Applicability of tolerance:

1 Structural bulkheads forming a boundary of living space (stateroom, office, berthing, messing or lounge area) and passageways contiguous to such spaces.

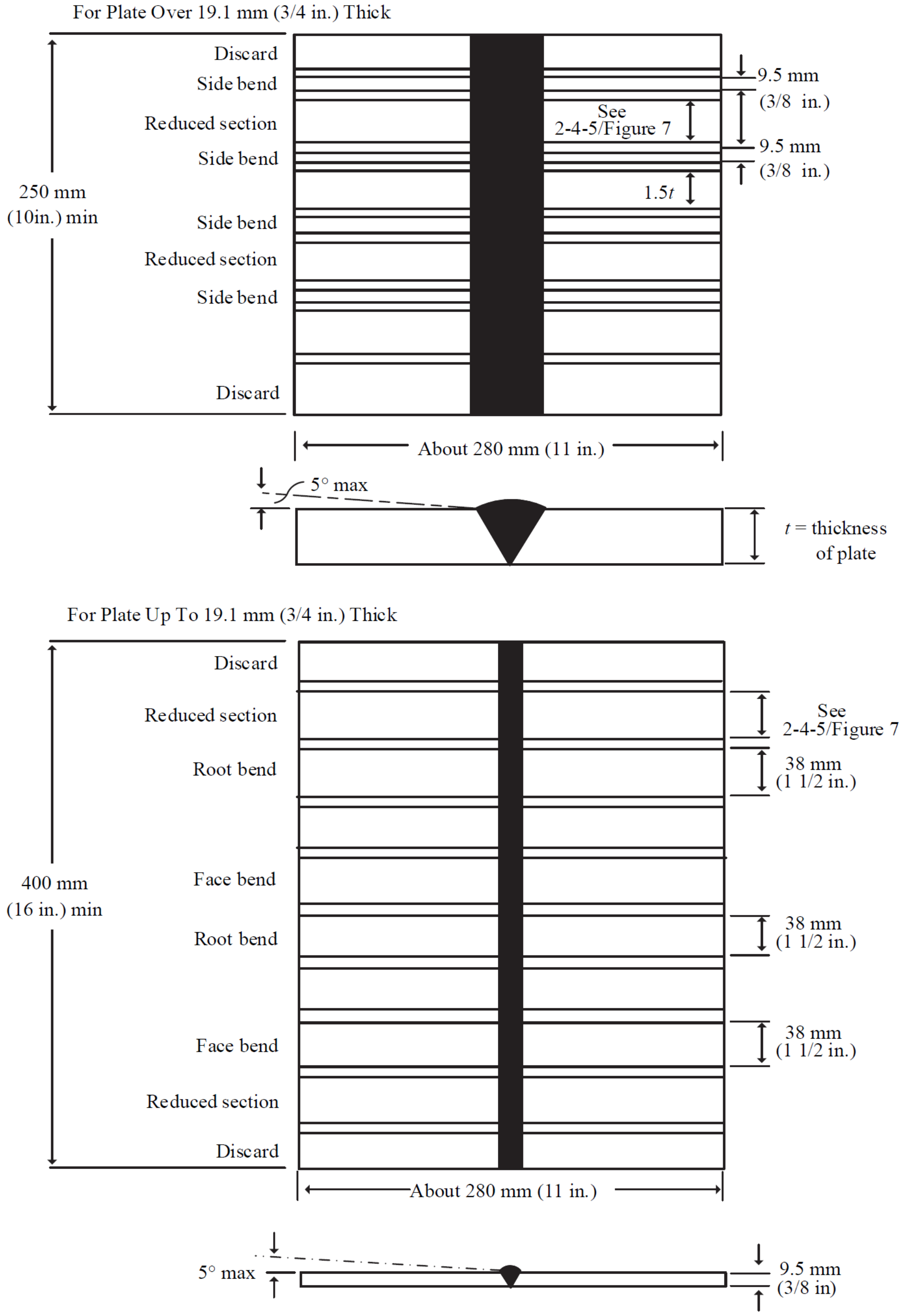
2 Decks within the hull and superstructure in way of the above living spaces.

3 Decks exposed to the weather.

4 Tank and main transverse bulkheads

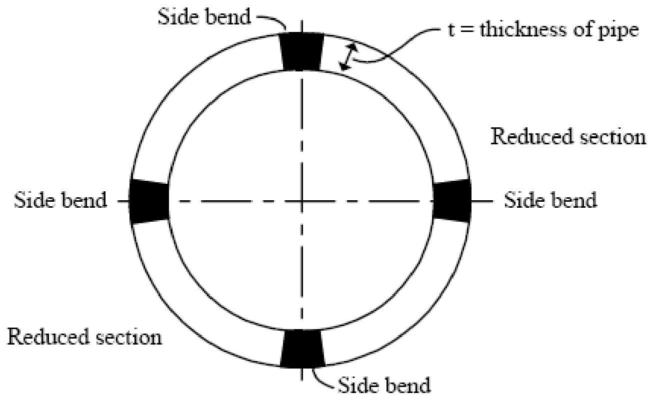
5 Inner-bottom plate and longitudinals and transverses.

FIGURE 5
Preparation of Test Plates and Pipes for Weld Tests Nos. 1 and 2

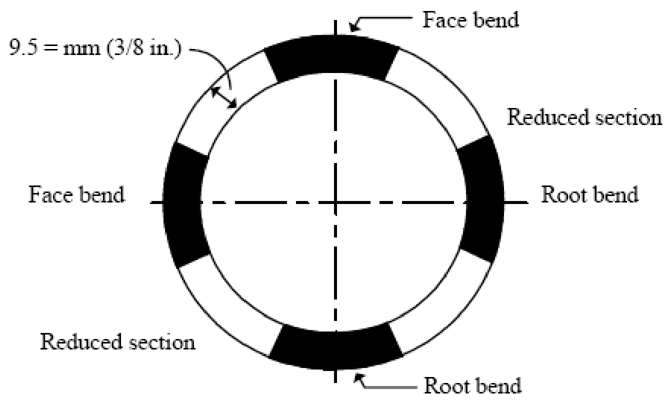


Note: Edge proparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

For Pipe Over 19.1 mm (3/4 in.) Thick

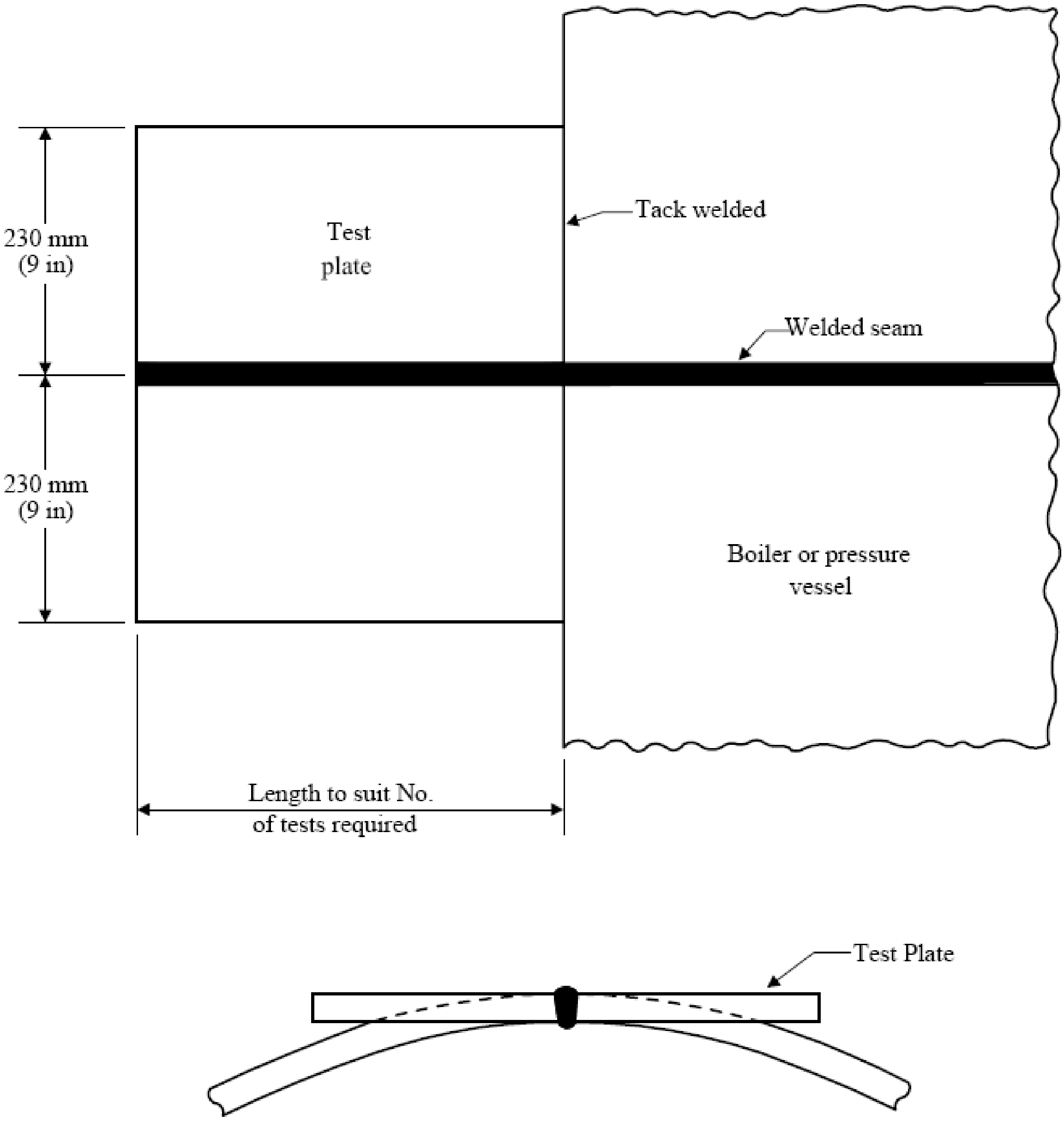


For Pipe Up To 19.1 mm (3/4 in.) Thick



Note: Edge preparation, welding procedure and postweld heat treatment, if any, are to be the same as those for the work represented.

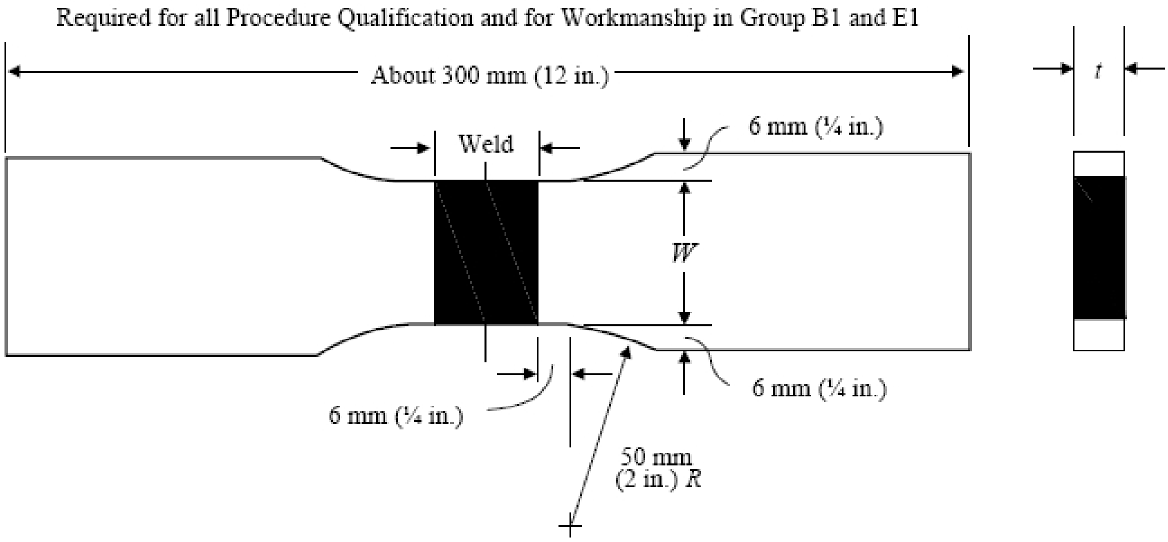
FIGURE 6
Typical Arrangement of Test Plates for Workmanship Tests in Group B1



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 postweld heat treatment.

FIGURE 7
Test No. 1 – Reduced-section Tension Test for Plate



Notes:

1 Both faces of weld are to be machined flush with base metal.

2 For procedure qualification, t is to be representative of thickness welded in production.

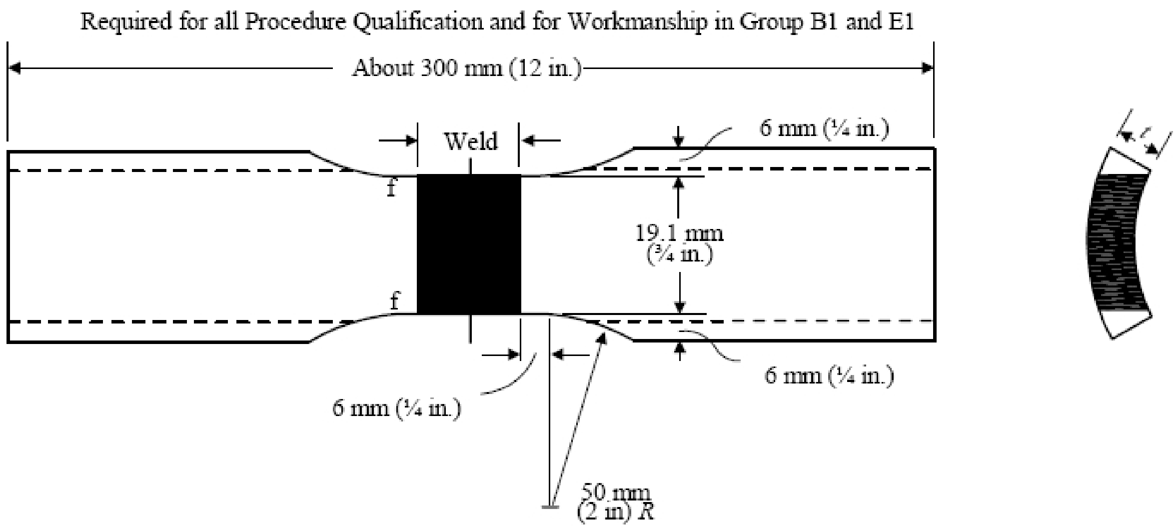
3 W = approximately 38 mm (1.5 in.) where t is 25.4 mm (1 in.) or less. w = 25.4 mm (1 in.) where t is more than 25.4 mm (1 in.)

4 When the capacity of the available testing machine does not permit testing 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.

Requirement

The tensile strength of each specimen, when it breaks in or adjacent to the weld, is not to be less than the minimum specified tensile strength, as indicated in 2-4-5/17 TABLE 2.

FIGURE 8
Test No. 1 – Reduced-section Tension Test for Pipe



Notes:

1 Both faces of weld are to be machined flush with base metal. The minimum amount needed to obtain plane parallel faces over 19.1 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 ($^3/_8$ in.) for construction materials up to 19.1 mm ($^3/_4$ in.). For construction material over 19.1 mm ($^3/_4$ in.), t = thickness of material.

3 For workmanship tests, t = thickness in material.

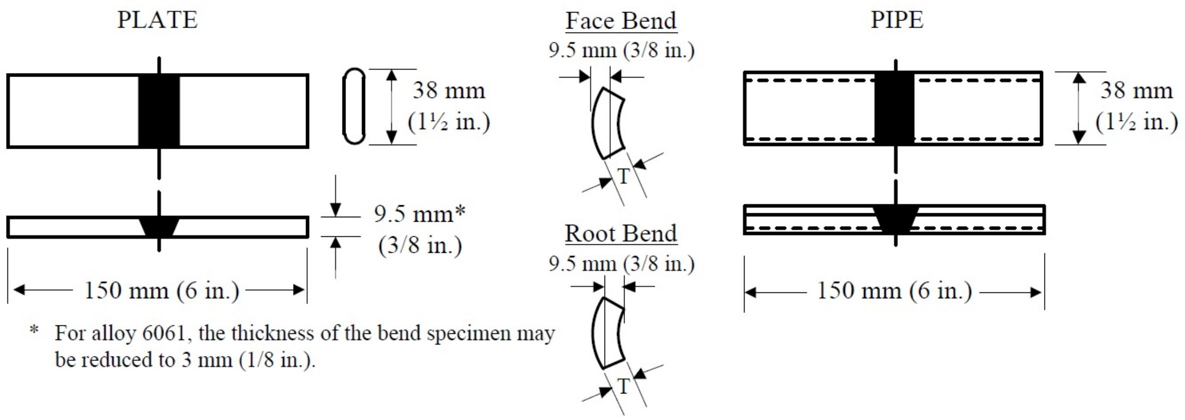
4 When the capacity of the available testing machine does not permit testing the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimen into sections, each of which is to meet the requirements.

Requirements:

1 The tensile strength of each specimen when it breaks in or adjacent to the weld is not to be less than the minimum specified tensile strength, as indicated in 2-4-5/17 TABLE 2.

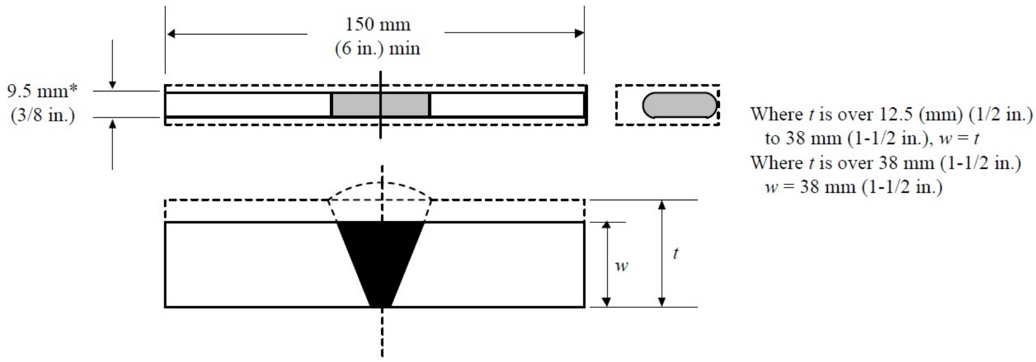
2 The tensile strength of each specimen when it breaks in the base metal and the weld shows no signs of failure is not to be less than 95% of the minimum specified tensile strength of the base material.

FIGURE 9
Test No. 2 – Guided Bend Test for Root Bend and Face Bend (Plate or Pipe) *(2007)*



Note: Both faces of weld to be machined flush with base metal.
On test assmeblies greater than 9.5 mm (3/8 in.) the opposite side of specimen may be machined as shown.

FIGURE 10
Test No. 2 – Guided Bend Test for Side Bend (Plate or Pipe)

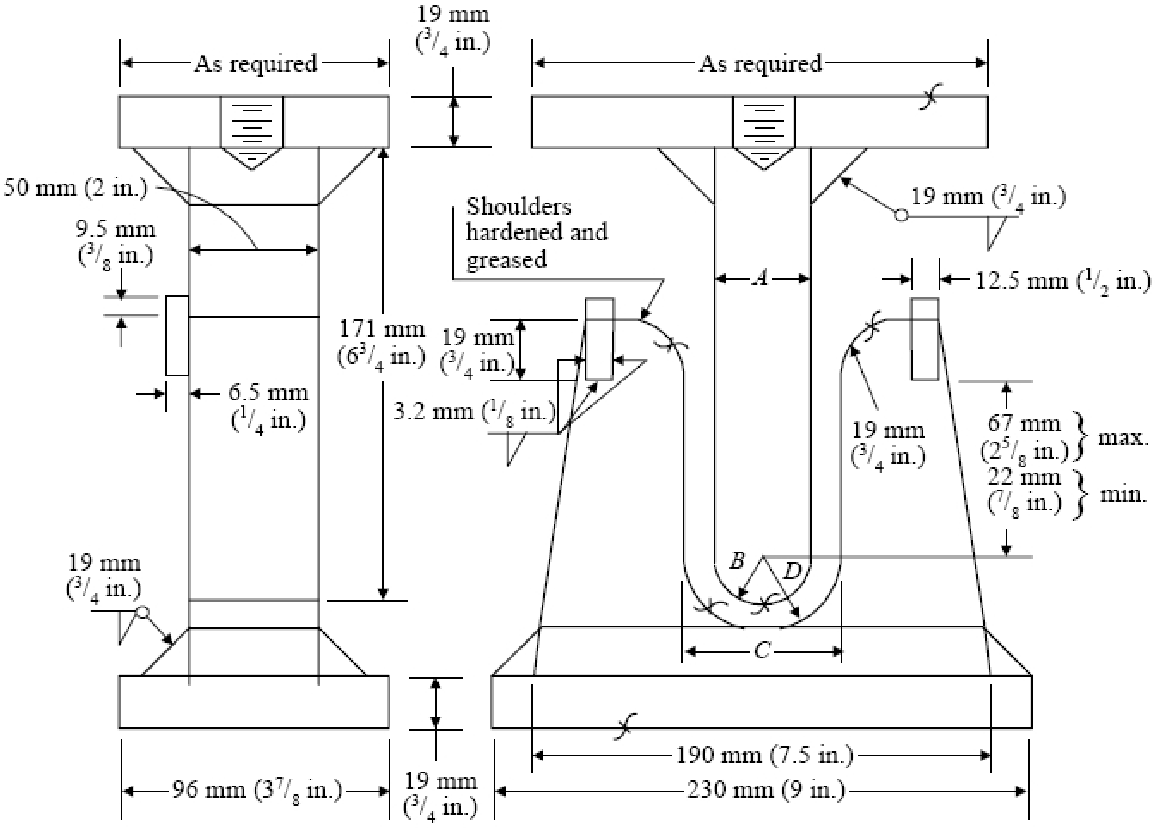


* For alloy 6061, the thickness of the bend specimen may be reduced to 3 mm ($^1/_8$ in.).

Note:
Both faces of weld to be machined flush with base metal.

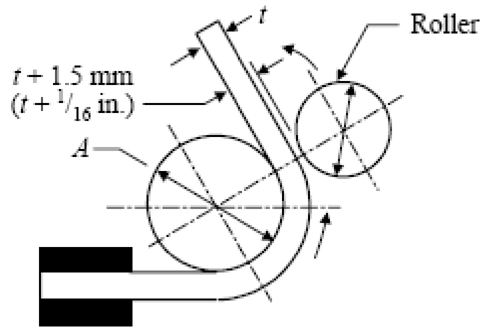
FIGURE 11
Guided Bend Test Jig *(1 July 2022)*

Test Requirement: After bending, the specimen is not to show any cracking or other open defects exceeding 3.2 mm ($^1/_8$ in.) on the convex side, except at the corners.



Applicable to material	*Thickness of specimens*	*A*	*B*	*C*	*D*
5083, 5086, 5383, 5456 and Annealed 6XXX	t, mm (in.)	$6^2/_3t$ ($6^2/_3t$)	$3^1/_3t$ ($3^1/_3t$)	$8^2/_3t + 3$ ($8^2/_3t + {}^1/_8$)	$4^1/_3t + 1.6$ ($4^1/_3t + {}^1/_{16}$)
	10 mm (0.375 in.)	64 ($2^1/_2$)	32 ($1^1/_4$)	86 ($3^3/_8$)	43 ($1^{11}/_{16}$)
5454	t, mm (in.)	$4t$ ($4t$)	$2t$ ($2t$)	$6t + 3$ ($6t + {}^1/_8$)	$3t + 1.6$ ($3t + {}^1/_{16}$)
	10 mm (0.375 in.)	38 ($1^1/_2$)	19 ($^3/_4$)	60 ($2^3/_8$)	30 ($1^3/_{16}$)
Alloy 6XXX	t, mm (in.)	$16^1/_2t$ ($16^1/_2t$)	$8^1/_4t$ ($8^1/_4t$)	$18^1/_2t + 1.6$ ($18^1/_2t + {}^1/_{16}$)	$9^1/_4t + 1$ ($9^1/_4t + {}^1/_{32}$)
	3 mm (0.125 in.)	52 ($2^1/_{16}$)	26 ($1^1/_{32}$)	60 ($2^3/_8$)	30 ($1^3/_{16}$)

FIGURE 12
Alternative Guided Bend Test Jig



Notes:

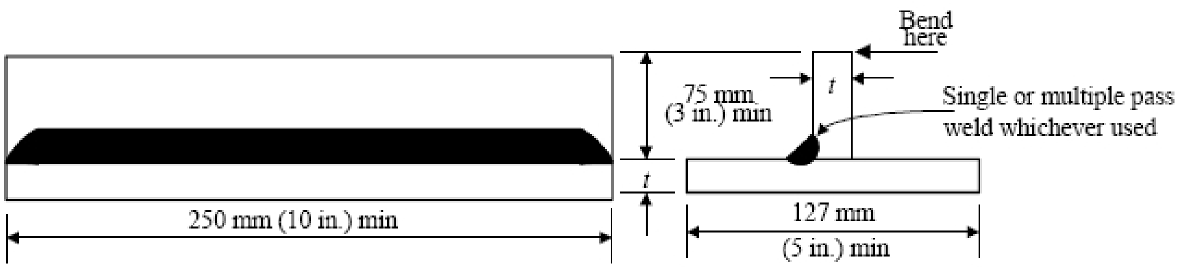
1 The dimension t is the thickness of the material.

2 The reduced section is to be parallel within 0.05 mm (0.002 in.) and may have a gradual taper in width from the ends toward the center with the ends not more than 0.13 mm (0.005 in.) wider than the center. The ends of the specimens are to be symmetrical with the centerline of the reduced section within 0.25 mm (0.01 in.).

3 Mandrel radius may be increased up to $8.25t$ maximum for alloy 6061.

4 For aluminum alloy bend requirements, see 2-4-5/17 FIGURE 10.

FIGURE 13
Test No. 3 – Fillet Weld Test *(2013)*



Notes:

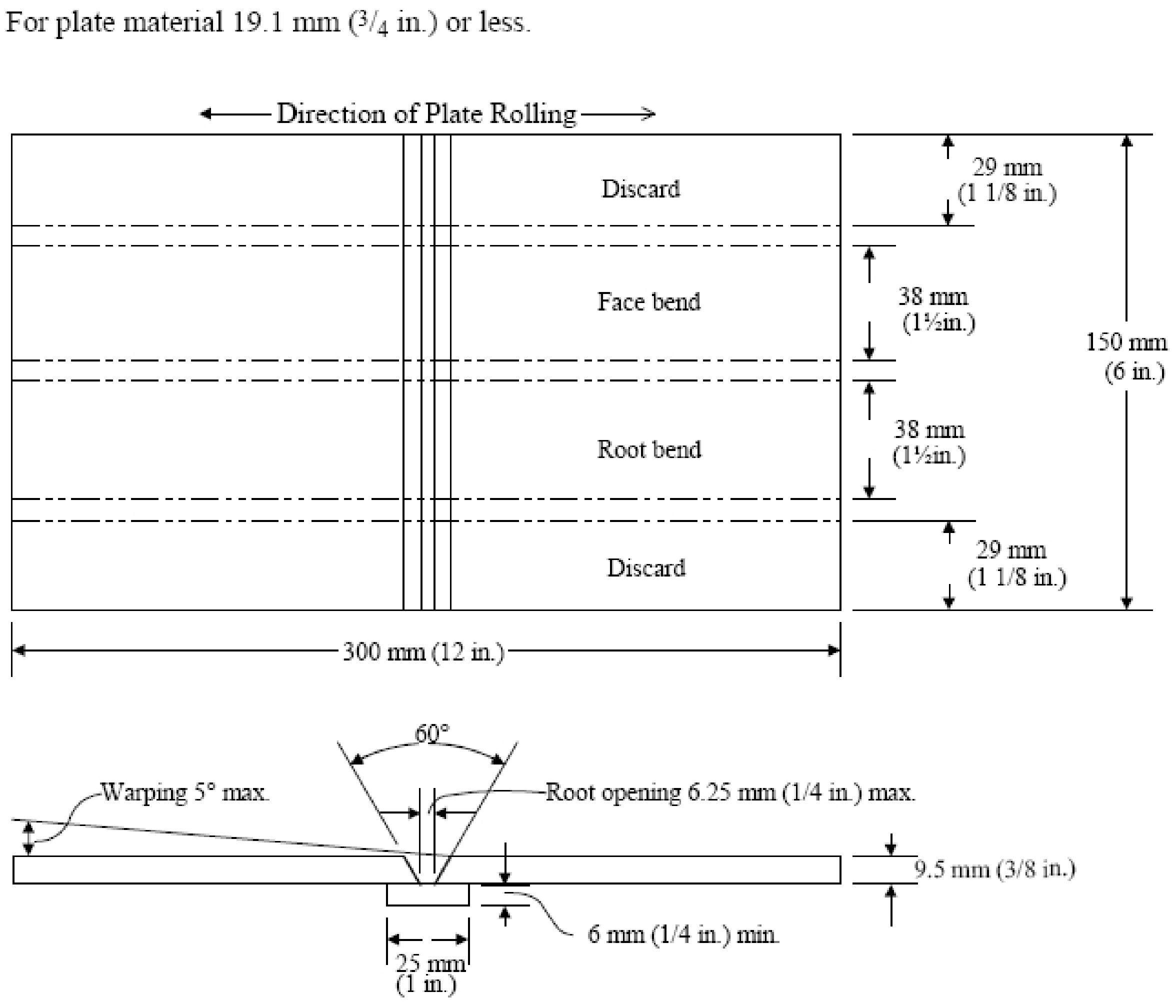
1 For procedure qualifications, t is to be representative of thicknesses welded in production. Base and standing web is to be straight and in intimate contact and securely tacked at ends before fillet-weld is made, to insure maximum restraint.

2 *(2013)* The test plate may be cut into short sections to facilitate breaking open.

Requirement:

The fillet is to be the required contour and size, free from undercutting and overlapping. When broken as indicated, the fractured surface is to be free from cracks, and reasonably free from visible porosity and lack of root infusion, except that porosity or incomplete fusion at the root corners of fillets may be acceptable, provided the total length of the incompletely fused areas is less than approximately 10% of the total length of the weld.

FIGURE 14
Welder Qualification Test No. Q1

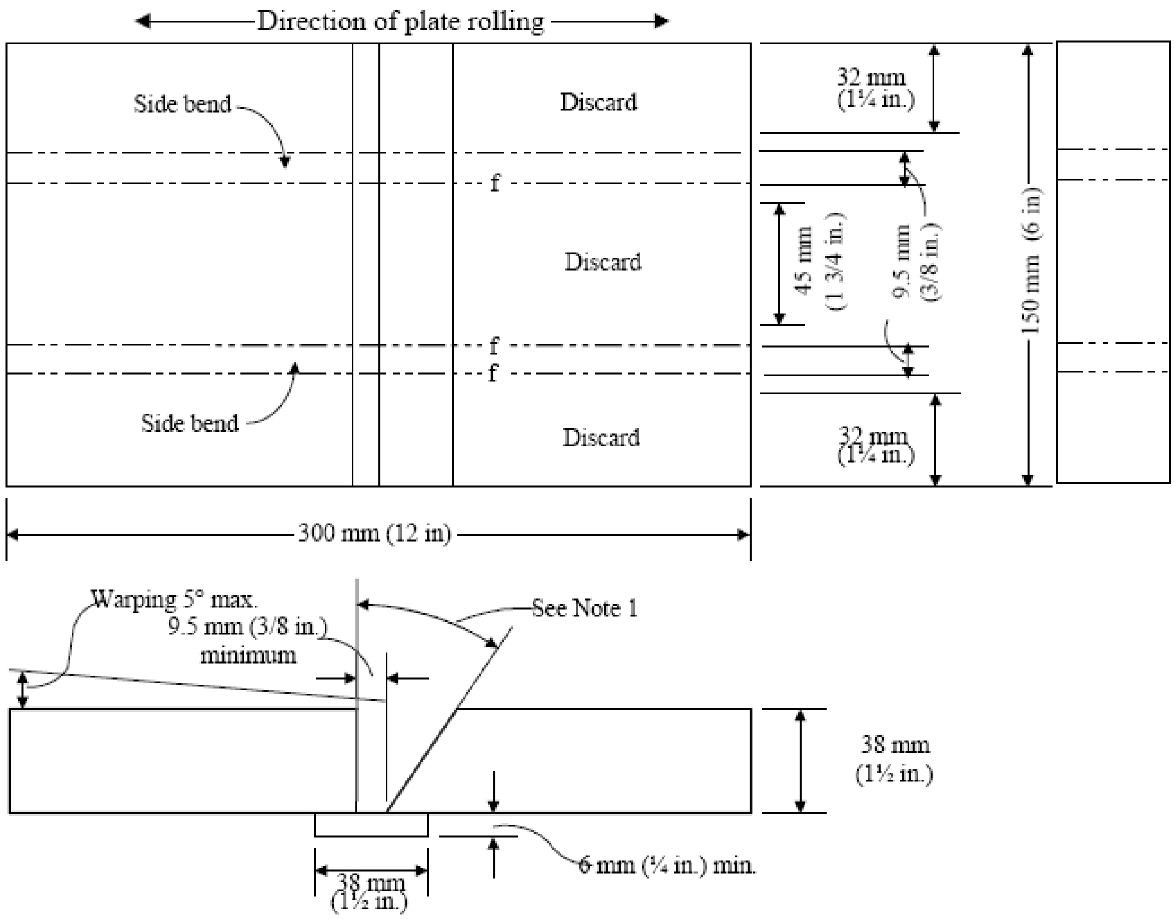


Notes:

1. Weld is to be made with the maximum size electrode that will be used in production and a maximum interpass temperature of 66°C (150°F).
2. Machine reinforcement and backing strap flush. Do not remove any undercutting.
3. Machining is to be done transverse to weld.
4. All specimens are to be machined or sawed from plate.
5. Backing strap is to be contiguous with plates.
6. Joints welded in the vertical position are to be welded upwards.
7. Welding is to be done from one side only.
8. Bend specimens in Guided Bend Test Jig (2-4-5/17 FIGURE 10 or 2-4-5/17 FIGURE 11.
9. 1 Face Bend and 1 Root Bend required.

FIGURE 15
Welder Qualification Test No. Q2

For material of unlimited 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 electrode that will be used in production and a maximum interpass temperature of 66°C (150°F).

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.

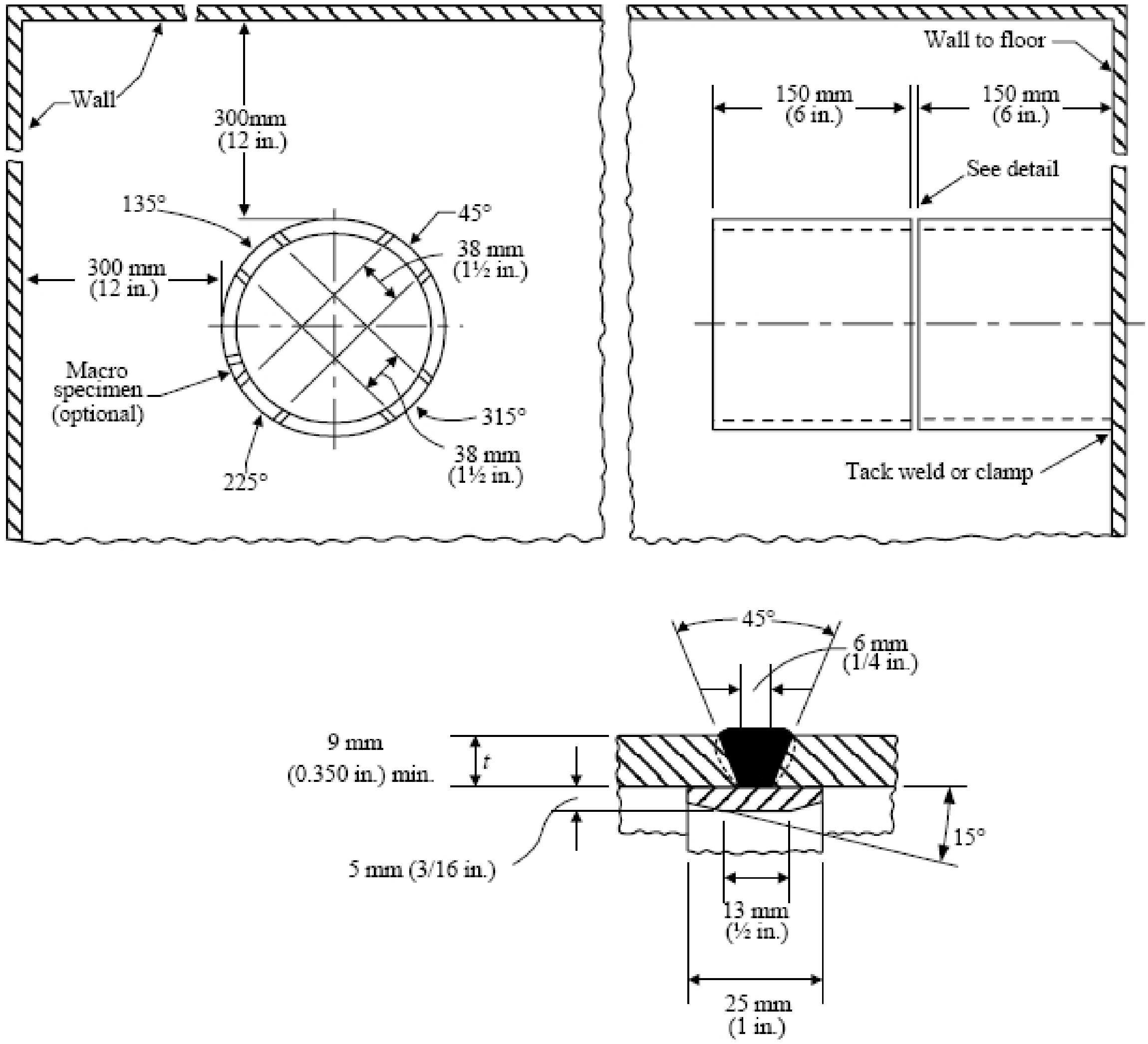
9 Break edges of specimens to a radius of $t/6$ maximum.

10 Bend Specimen in Guided Bend Test Jig (2-4-5/17 FIGURE 10 or 2-4-5/17 FIGURE 11).

11 2 Side Bends required for plate. 4 Side Bends required for pipe.

FIGURE 16
Welder Qualification Test No. Q4

For pipe 19.1 mm (3/4 in.) thick or less.



Use 150 mm (6 in.) piping (min.)

Notes:

1 Each pass of the weld is to be made with the same size electrode that will be used in production and a maximum interpass temperature of 66°C (150°F).

2 Machine reinforcement and backing strap flush. Do not remove any undercutting.

3 Machining is to be done transverse to weld.

4 All specimens are to be machined or sawed from piping.

5 Break edges of specimens to a radius of $t/6$ maximum.

6 Mark top and front of piping to insure proper location of specimens.

7 Remove face-bend specimens from 45 degree and 225 degree points, and root-bend specimens from 135 degree and 315 degree points, as indicated.

8 Welding is to be done from one side only.

9 Bend Specimen in Guided Bend Test Jig (2-4-5/17 FIGURE 10 or 2-4-5/17 FIGURE 11.

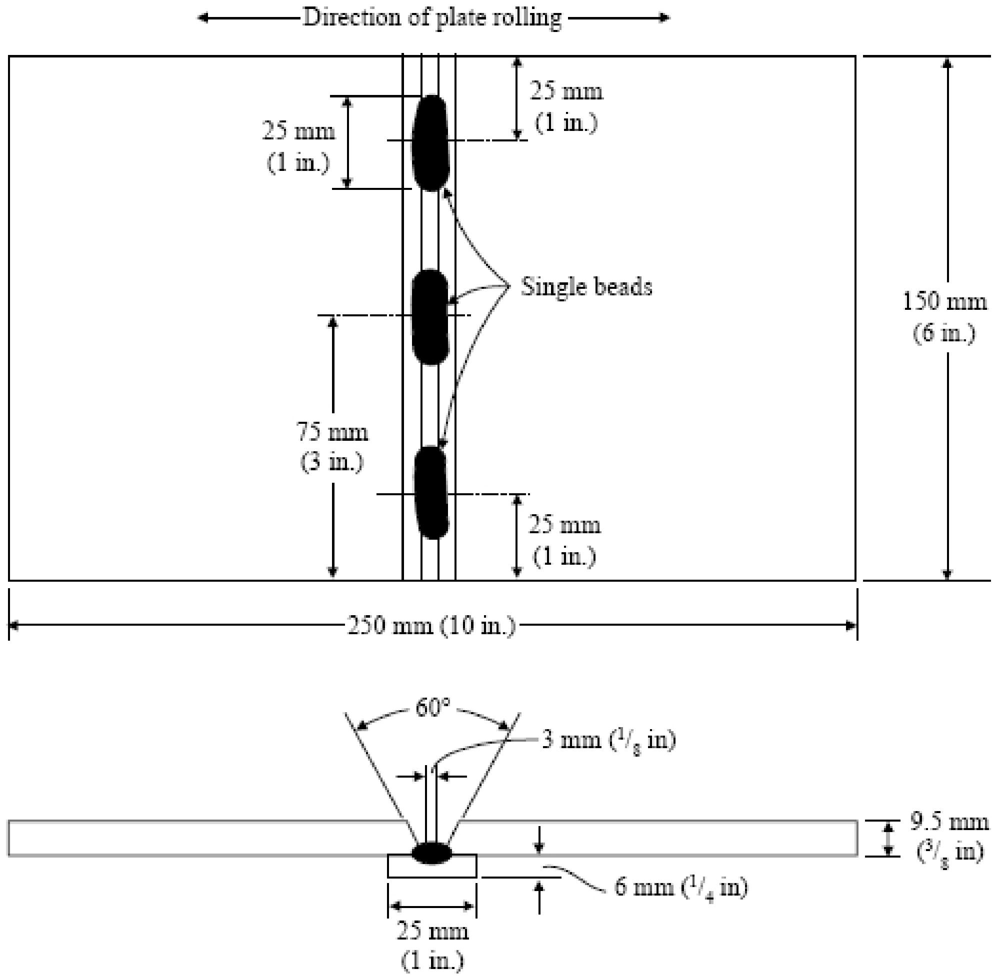
10 Two Root Bends and two Face Bends required.

11 For thicknesses over 19.1 mm (3/4 in.), t is to be a minimum of 1/2 of the thickness to be welded in production.

12 For GTA welding, no backing bar need be employed and root opening may be reduced to zero.

FIGURE 17
Welder Qualification Test No. Q5

For Tack Welders.



Notes:

1 Electrode diameter used is to be representative of that used for tack welding in production.

2 Backing strap is to be contiguous with plates.

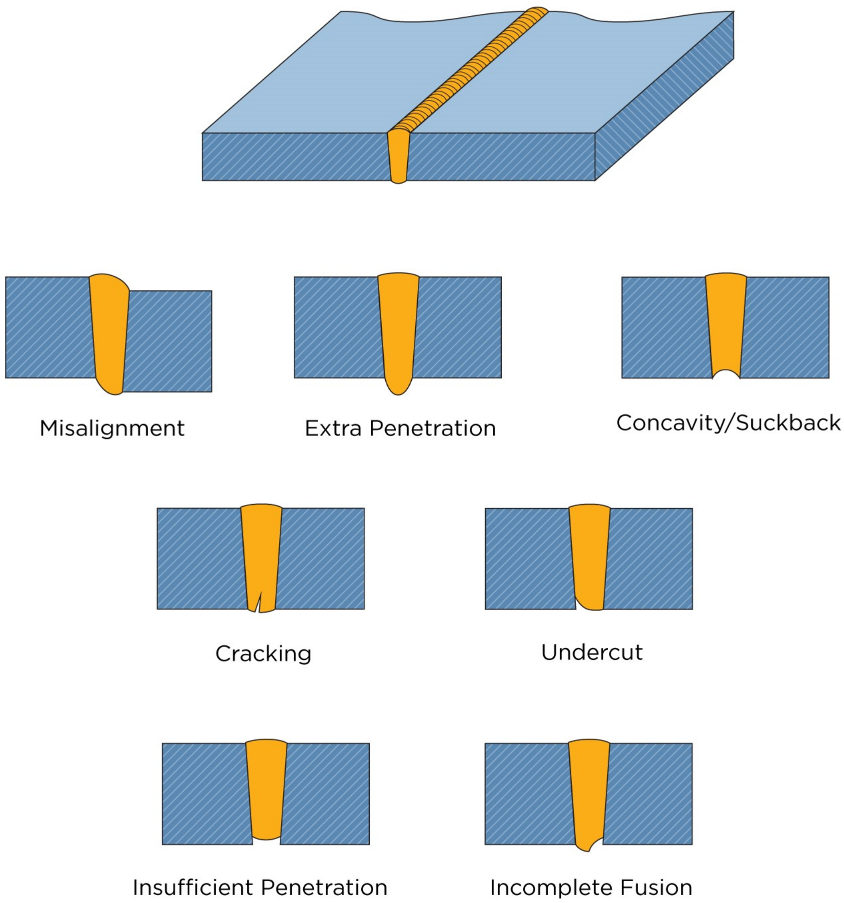
3 Joints welded in the vertical position are to be welded upwards.

4 Specimen is to be bent in one piece with backing strap in place and face of weld in tension.

5 Weld fractures are to exhibit no unfused areas on backing strap or sides of groove throughout length of each tack.

6 For GTA welding, no backing bar need be employed and root opening may be reduced to zero.

FIGURE 18
Typical Weld Defects *(2024)*



PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

CONTENTS

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

SECTION 1

General

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.
MAT-FR4	Products are to undergo sufficient plastic deformation to meet specified material properties.
MAT-FR5	Heat treatment, when applicable, is to be capable of producing the specified material properties and an appropriate microstructure.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control. Adhering to specification and quality requirements mitigates the risk of premature failure during testing, commissioning and in service.

End of commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Testing and Inspection *(2024)*

i) All materials subject to test and inspection, intended for use in the construction of the hulls of craft classed or proposed for classification, are to be tested by the material producer and inspected by the ABS Surveyor in accordance with the following requirements or their equivalent.

ii) These requirements are not applicable to aluminum alloys at low temperature for cryogenic applications.

iii) Materials, test specimens and mechanical testing procedures having characteristics differing from those prescribed herein may be approved for application, with consideration given to established practices in the country in which the material is produced and the purpose for which the material is intended, such as the parts for which it is to be used, the type of craft and intended service, and the nature of the construction of the craft.

iv) Consideration may be given to aluminium alloys not specified in these requirements, and to alternative temper conditions, subject to prior agreement with ABS further to a detailed study of their properties, including corrosion resistance, and of their conditions of use (in particular welding procedures).

v) All materials, including semi-finished products are to be manufactured at works which are approved by ABS for the grades and maximum thickness of aluminum alloy supplied.

Commentary:

i The requirements are based on both metric and U.S. customary units. Each system of units is to be treated as separate and independent from the other. Mixing and matching of units from one system to another is not permitted.

ii The numerical designation (grade) of aluminum alloys and the temper designation are based on those of the Aluminum Association or recognized Standards.

End of Commentary

1.3 Manufacturer Approval *(1 July 2022)*

All products for hull construction are to be manufactured at a works approved by ABS for the product type, grade and temper condition of aluminum contemplated. The suitability of the products for welding and assumed forming is to be demonstrated during the initial approval tests at the aluminum works. Approval of the aluminum works for rolled and extruded products is to be in accordance with Appendix 2-A10.

It is the manufacturer's responsibility to verify that effective procedures and production controls are implemented during the production, and that the manufacturing specifications are adhered to. If there is any deviation from the procedures and controls that could produce an inferior product, the manufacturer is to carry out a thorough investigation to determine the cause of the mishap and establish countermeasures to prevent its recurrence. The complete investigation report is to be submitted to the Surveyor. ABS reserves the right to request additional examinations until the cause is resolved to the satisfaction of the Surveyor. Each affected piece is to be tested to the satisfaction of the attending Surveyor prior to distribution from the aluminum works. In addition, the frequency of testing for subsequent products may be increased to gain confidence in the quality.

1.4 Witnessed Tests and Test Data *(1 July 2022)*

All tests are to be carried out by competent personnel and conducted in the presence of the Surveyors at the place of manufacture prior to shipping. Consideration will be given to the acceptance of rolled and extruded products without witnessing of mechanical tests by the Surveyor, on the basis of compliance with ABS's Quality Assurance Program. Testing procedures are to follow established practices in international or national Standards. Test samples are to be taken from material which has undergone the same treatment as the material to be certified. Preparation of specimens is not to involve significant straining or heating. Thermally cut samples are to have excess material to allow a specimen to be machined from material that is unaffected by the cutting process.

1.4.1 Witnessed Tests *(1 July 2022)*

The designation (W) indicates that a Surveyor is to witness the testing unless the plant is enrolled, and the product is manufactured, under ABS's Quality Assurance Program.

1.4.2 Manufacturer's Data *(1 July 2022)*

The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

1.4.3 Other Tests *(1 July 2022)*

The designation (A) indicates 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 Rule requirements.

Refer to Appendix 2-5-A3 for complete listing of indicated designations for the various tests called out by the applicable Section of Part 2, Chapter 5.

1.4.4 Certification on the Basis of the ABS Quality Assurance Program *(1 July 2022)*

Refer to 2-1-1/1.5 for certification on the basis of the ABS Quality Assurance (QA) program.

1.5 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

1.7 Calibrated Testing Machines

All testing machines are to be maintained in good condition by the manufacturer and to the satisfaction of the attending Surveyor. The measuring equipment and machinery used are to be periodically calibrated by the manufacturer in accordance with ISO standards or any other recognized national/international standards requirements. The validity of calibration certificates is to be verified by the Surveyor before witnessing tests.

1.9 Referenced Documents *(1 July 2022)*

The following documents form a part of the overall specification to the extent they are referenced in this ABS Rules document:

ANSI H35.1	Alloy and Temper Designation Systems for Aluminum
ASTM B928/928M	Standard Specification for High Magnesium Aluminum-Alloy sheet and plate for marine Service.
ASTM B221/221M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B247/247M	Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
ASTM B316/316M	Standard Specification for Aluminum and Aluminum – Alloy Rivet and Cold-Heading Wire and Rods
ASTM B209/209M	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B26/26M	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B108	Standard Specification for Aluminum-Alloy Permanent Castings
ASTM B918	Standard Practice for Heat Treatment of Wrought Aluminum Alloys
ASTM E34	Test methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys
ASTM E1251	Test Method for optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by Argon Atmosphere, point-to-plane, unipolar self-initiating Capacitor Discharge.
ASTM E8/8M	Standard Test methods for Tension Testing of Metallic Materials
ASTM B548	Standard Test Method for Ultrasonic Inspection of Aluminum-Alloy Plate for Pressure Vessels
ASTM B557/557M	Standard Test Methods of Tension Testing Wrought and Cast Aluminum – and Magnesium-Alloy Products
ASTM B565	Method for Shear Testing of Aluminum and Aluminum – Alloy Rivet and Cold-Heading Wire and Rods
AWS D1.2/D1.2M	Structural Welding Code – Aluminum
AWS D3.7	Guide for Aluminum Hull Welding
IACS UR W25	Materials and Welding – Aluminum Alloys for Hull Construction and Marine Structure
IACS UR W26	Materials and Welding – Requirements for Welding Consumables for Aluminum Alloys

3 Inspection *(2024)*

All materials and weldments are to be generally free from linear, planar and volumetric physical defects such as embedded and through thickness flaws, laminations and injurious surface flaws or similar forms of defects that would be detrimental to the use of the materials and weldments in the intended applications. Welding or dressing for the purpose of remedying defects is not permitted unless and until sanctioned by the Surveyor. Discoloration characteristic of proper heat treatment schedules is not cause for rejection.

5 Manufacturer's Certificates

5.1 Form of Certificate *(1 July 2022)*

Four copies of the mill certificates or the shipping statements of all accepted plate and shape materials, including the required inspection and testing results in 2-5-1/7.4, are to be furnished to the Surveyor for his approval; one is to be forwarded to the purchaser, three are to be retained for the use of ABS.

Before the mill certificates or shipping statements are distributed by the local ABS office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been sampled, tested and inspected in accordance with these Rules and that it has met the requirements. The following form of certificate will be accepted if printed on each mill sheet or shipping statement 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 specifications of alloy __________; temper __________, and the required samples tested in accordance with the requirements of __________ (The American Bureau of Shipping Rules or state other specification) in the presence of a Surveyor from the American Bureau of Shipping with satisfactory results."

At the request of manufacturers, consideration may be given to modifications to the form of certificate, provided it correspondingly indicates compliance with the requirements of these Rules to no less degree than indicated in the foregoing statement.

5.3 Other Certificates

Where an aluminum alloy ingot is not produced in the plant where it is rolled, extruded or forged, a certified report is to be supplied to the Surveyor stating the name of the manufacturer, the alloy, ingot or manufacturing and inspection lot identification numbers and certification that the alloy meets the required chemical composition limits.

5.5 Dual Certification

Dual certification of aluminum alloys is permitted only when alloy designations involved meet the specified chemical composition and specified minimum mechanical property requirements; provided they have the same ANSI temper designations in order to avoid any differences that may arise in welding and marine corrosion characteristics of the alloys with differing temper designations.

5.7 Electronic Certification System *(2011)*

An electronic certification system may be used to issue certified mill test reports, which may be electronically signed and stamped by an attending Surveyor, subject to the following conditions.

- All relevant information regarding the customer order, including the electronic certification request, is to be provided to the attending Surveyor by the manufacturer.
- Procedures are to be established to control handling and distribution of certified mill test reports among the manufacturer, ABS, and the purchaser.
- In order to implement the electronic certification system, the manufacturer is to be under mandatory ABS-QA program.

7 Identification Markings

7.1 Marine Grades

Aluminum alloys with ability to resist intergranular and exfoliation forms of corrosion when in direct contact with seawater or when used in marine environment conditions are to be treated as marine grades. Aluminum alloys with magnesium content greater than or equal to 3% are prone to these forms of corrosion and are to be tested, inspected and certified in accordance with ASTM B928 specification by the manufacturer. The acceptance criteria for corrosion tests (ASTM G66 and G67) are to follow ABS Rule requirements. The test results are to be reported on the mill certificates and are to be verified by the Surveyor. The alloy grade is to be suffixed with the letters "MG" while marking as indicated in 2-5-1/7.3.

7.3 Material Identification *(2011)*

All materials which have been sampled, tested and have successfully passed the requirements and have been approved by the Surveyor are to be clearly ink marked or stamped with the manufacturer's name or trademark and material identification on each finished sheet, plate, shape, bar, rod casing or forging to signify that the material has satisfactorily complied with the tests prescribed. The material identification is to include:

i) The initials **AB**.

ii) The aluminum alloy designation according to the Aluminum Association.

iii) The temper designation according to the Aluminum Association.

iv) The manufacturers batch number.

v) The letter "MG" is to be added after the grade and temper designation only if the material has been corrosion tested as per requirements of Section 2-5-6 of these Rules and ASTM B928. Example: AB/5083 H321 MG.

7.4 Certification *(1 July 2022)*

The manufacturer is to provide the required inspection and testing certificate, giving the following for each product which has been accepted:

i) Purchaser's name and order number

ii) Description of products, aluminum quality, quantity, dimension, and weight

iii) Identification of the grade and temper condition of aluminum alloy

iv) The construction project number (if available)

v) Specification

vi) Aluminum alloy making process

vii) Identification of the cast/heat, batch and plate/extrusion number

viii) Chemical analysis of ladle and/or product sample

ix) Details of heat treatment, including temperature, holding times and cooling media

x) Results of mechanical tests

xi) Results of drift expansion tests, macro section tests or bend tests, where applicable

xii) Results of corrosion tests, where applicable

xiii) Results of nondestructive tests, where applicable

xiv) Results of dimension and tolerance requirements, where applicable

7.5 Stenciled Material

In special cases, when approved, strapped or secured lifts or bundles of light sheet, plates, shapes, bars, rods or tubes of comparatively small size may be marked or stenciled on only the top piece or the marking may be shown on the tag attached to each lift or bundle.

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

SECTION 2

Standard Test Methods

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for testing and inspection to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

The latest issue of the following test methods or specifications or their equivalents are considered acceptable:

1.1 Chemical Analysis *(1 July 2022)*

The chemical analyses are to be carried out in accordance with ASTM E3061 or ASTM E716 or ASTM E1251 or equivalent, as may be appropriate to a specific alloy under testing and consideration for certification. The sampling practice for chemical analyses is to be carried out as indicated in 2-5-3/3 and may follow a recognized standard to the extent as may be modified or stated in this document.

1.3 Tension Testing

Refer to Section 2-5-5 for requirements for test specimens.

Alternative Standards ASTM E 8/8M or ASTM B557/557M or equivalent may be used.

1.5 Shear Testing *(1 July 2022)*

Shear tests are to be carried out in accordance with ASTM B769 for shear testing of aluminum alloys or ASTM B565 for rivets and cold-heading wire and rods or equivalent.

1.7 Hardness Testing*

Hardness tests, if applicable, are to be carried out in accordance with ASTM E18 or equivalent.

1.9 Electrical Conductivity Testing*

Electrical Conductivity tests, if applicable, are to be carried out in accordance with ASTM E1004 or equivalent.

Note:

* Hardness and Electrical Conductivity testing are reference only for evaluation of alloys and tempers of heat treatable aluminum products.

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

SECTION 3

Chemical Composition

1 General *(2024)*

1.1 Objective

This section includes requirements for chemical composition to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(2024)*

The chemical composition of each cast is to be determined by the aluminum manufacturer and is to conform to the applicable requirements of the alloys listed in 2-5-3/5 TABLE 1 or 2-5-3/5 TABLE 2 or such other requirements subject to ABS technical assessment and approval.

3 Sampling *(2024)*

A control sample for chemical analysis is to be taken before starting to pour and one additional sample is to be taken during the pouring of each group of ingots poured simultaneously from the same source of molten metal. If not analyzed during pouring samples, it may be taken from semi-finished or finished products. When samples are taken from finished or semi-finished products, one sample is to represent each 1800 kg (4000 lb), or fraction thereof, of each alloy in an inspection lot. The manufacturer's declared analysis will be subject to occasional checks by the Surveyor.

Product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

When the aluminum alloys are not cast in the same works in which they are manufactured into semi-finished products, a certificate issued by the works is to be provided to the Surveyor which indicates the reference numbers and chemical composition of the heats.

5 Definition of an Inspection Lot

An inspection lot is defined as:

For non-heat treated tempers, an identifiable quantity of material of the same mill form, alloy, temper, section and size submitted for an inspection at one time before shipment. And for heat treated temper an identifiable quantity of material of the same mill form, alloy, temper, section and size traceable to a heat treated lot or lots and submitted for inspection at one time before shipment. Mill forms: sheet and plate, all material of the same thickness is considered to be of the same size.

TABLE 1
Chemical Composition Limits of Wrought Aluminum Alloys *(2013)*

Limits are in weight percent. Single value represents maximum limit, unless shown as a range or indicated as a minimum.

Alloy	*Silicon*	*Iron*	*Copper*	*Manganese*	*Magnesium*	*Chromium*	*Zinc*	*Titanium*	*Others (1)*		*Aluminum*
									Each	*Total*	
5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10	–	0.05	0.15	Remainder
5059	0.45	0.50	0.25	0.60-1.2	5.0-6.0	0.25	0.40-0.90	0.20	0.05 (5)	0.15 (5)	Remainder
5083	0.40	0.40	0.10	0.40-1.0	4.0-4.9	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5086	0.40	0.50	0.10	0.20-0.7	3.5-4.5	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5383	0.25	0.25	0.20	0.70-1.0	4.0-5.2	0.25	0.4	0.15	0.05 (4)	0.15 (4)	Remainder
5454	0.25	0.40	0.10	0.50-1.0	2.4-3.0	0.05-0.20	0.25	0.20	0.05	0.15	Remainder
5456	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15	Remainder
5754	0.40	0.40	0.10	0.50 (2)	2.6-3.6	0.30 (2)	0.20	0.15	0.05	0.15	Remainder
6005A	0.50-0.9	0.35	0.30	0.50 (3)	0.4-0.7	0.30 (3)	0.20	0.10	0.05	0.15	Remainder
6061	0.40-0.8	0.70	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	0.05	0.15	Remainder
6063	0.20-0.6	0.35	0.10	0.10	0.45-0.9	0.10	0.10	0.10	0.05	0.15	Remainder
6082	0.70-1.3	0.50	0.10	0.40-1.0	0.6-1.2	0.25	0.20	0.10	0.05	0.15	Remainder

Notes:

1 *(2011)* The term *'Others'* includes any other element(s) for which no specific limit is shown in the above table. Other element(s), if added intentionally or analyzed by the alloy producer or specified by the purchaser, are to be reported and not to exceed the limit as given in the *'Others'* column.

2 Mn + Cr : 0.10 – 0.60

3 Mn + Cr : 0.12 – 0.50

4 Zr: maximum 0.20. The total for other elements does not include Zirconium.

5 Zr: 0.05-0.25. The total for other elements does not include Zirconium.

TABLE 2
Chemical Composition Limits of Cast Aluminum Alloys

AA Aluminum Association

Limits are in weight percent. Single value represents maximum limit, unless shown as a range or indicated as a minimum.

AA	*Silicon*	*Iron*	*Copper*	*Manganese*	*Magnesium*	*Zinc*	*Titanium*	*Others*		*Aluminum*
								Each	*Total*	
356.0	6.5–7.5	0.6 (1)	0.25	0.35 (1)	0.20–0.45	0.35	0.25	0.05	0.15	Remainder
A356.0	6.5–7.5	0.20	0.20	0.10	0.20–0.45	0.10	0.20	0.05	0.15	Remainder
357.0	6.5–7.5	0.15	0.05	0.03	0.45–0.6	0.05	0.20	0.05	0.15	Remainder

Note:

1 If the iron content exceeds 0.45%, manganese content is not to be less than one half of the iron.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

SECTION 4
Heat Treatment

1 General *(2024)*

1.1 Objective

This section includes information about heat treatment to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

3 Scope *(2024)*

Alloys 6005A, 6061 and 6082 products are to be suitably heat treated to develop the mechanical properties specified in 2-5-5/7.3 TABLE 2, 2-5-5/7.3 TABLE 4, 2-5-5/7.3 TABLE 5 and 2-5-5/7.3 TABLE 6 for the various tempers. Alternative heat treatments will be subject to ABS technical assessment and approval.

- T4 Solution heat treated and then naturally aged.
- T451 For sheet and plate that are stress relieved by stretching after solution heat treatment.
- T4511 For extruded bars, rods or shapes that are stress relieved by stretching after solution heat treatment.
- T5 Cooled from an elevated temperature shaping process and then artificially aged. Usually associated with extruded products.
- T6 Solution heat treated and then artificially aged.
- T651 For sheet and plate that are stress relieved by stretching after solution heat treatment and then artificially aged.
- T6511 For extruded bars, rods or shapes that are stress relieved by stretching after solution heat treatment and then artificially aged.

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

SECTION 5

Tensile Properties

1 General *(2024)*

1.1 Objective

This section includes tensile properties of Aluminum alloys to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(2024)*

Tensile properties are to conform to the applicable requirements of the alloys and tempers listed in 2-5-5/7.3 TABLE 1A through 2-5-5/7.3 TABLE 7. Mechanical properties for welded joints are lower for strain hardened or heat treated alloys. For as welded properties refer to Section 2-4-5.

3 Yield Strength *(2024)*

The yield strength is defined as that determined at 0.2% non-proportional elongation (i.e., 0.2% offset ($R_{p0.2}$)).

5 Standard Test Specimens

5.1 General *(2024)*

Tension test specimens may be the full cross section of the material being tested or they may be machined as indicated for specific product forms. Test specimens in accordance with other recognized standards may be accepted subject to ABS technical assessment and approval.

5.3 Full-Section Specimens

Tension test specimens of the full cross section of the material may be used for wire, rod, bar, shapes and tubular products. It is permissible to reduce the section slightly throughout the section to confirm fracture within the gauge marks.

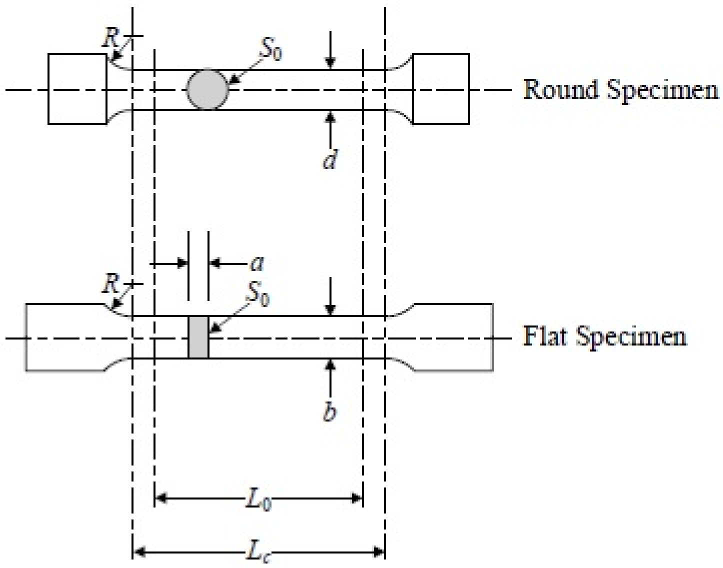
5.5 Machined Specimens

Standard tension test specimens' requirements are indicated in 2-5-5/5.5 FIGURE 1.

The following designations are used:

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

FIGURE 1
Standard Tension Test Specimen



5.7 Dimensions

Proportional test specimens with a gauge length:

$$L_0 = 5.65\sqrt{S_0}$$

can be used or preferably $5d$ can be used as the gauge length, L_0 is to be greater than 20 mm. The gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and L_0 is less than 10% of L_0.

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

5.7.1 Plates Strips and Sections

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

- *Proportional flat specimen*

a = t

b = 25 mm

L_0 = $5.65\sqrt{S_0}$

L_c = $L_0 + 2\sqrt{S_0}$

R = 25 mm

- *Non-proportional flat specimen*

a = t

b = 25 mm

L_0 = 200 mm

L_c > 212.5 mm

R = 25 mm

When the capacity of the available testing machine is insufficient to allow the use of test specimen of full thickness, this may be reduced by machining one of the rolled surfaces.

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

- *Round specimen*

d ≥ 10 mm to 20 mm, preferably 14 mm

L_0 = $5d$

L_c ≥ $L_0 + \frac{d}{2}$

R ≥ 10 mm (for materials with a specified elongation less than 10%, $R \geq 1.5d$)

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

5.7.2 Forgings and Castings

Proportional round test specimens with dimensions as specified above in 2-5-5/5.7.1 are usually to be used. are usually to be used. For small size bars and similar products the test specimens may consist of a suitable length of bar or other product tested in the full cross-section.

5.9 Test Specimens Orientation and Location *(2011)*

The practice for orientation and location of tension test specimens is to be followed as per ASTM B557/557M or equivalent standard and to the extent as may be modified or stated in this document. The orientation and location of tension test specimens are to be indicated in the test report.

7 Retests

7.1 Defective Test specimen

If the percentage elongation of a tension test specimen is less than that specified, and if any part of the fracture is outside of the middle half of the gauge length or in a punched or scribed mark within the reduced section, another test specimen may be selected.

7.3 Failure to Meet Requirements *(2024)*

If any tension test specimen selected in accordance with 2-5-7/5, 2-5-8/5 or 2-5-9/5 fails to conform to the requirements, two additional specimens, for each specimen that failed, may be selected from the area that is adjacent to the area represented by the failure or failures. In the case of separately cast test specimens, for each specimen that failed, two additional cast specimens from the same batch may be selected for retest. If both of these additional tests are satisfactory, the remaining piece and/or the remaining material from the same batch may be accepted.

If one or both of the additional tests referred to above are unsatisfactory, the piece is to be rejected. If the rejected piece is from a batch, the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch are tested and conform to the requirements. If tension test specimens from either of these two pieces fail to conform to the requirements, the whole batch of material is to be rejected.

If the failure to conform to the requirements is the result of an inadequate thermal treatment, additional aging treatment, as applicable to the material, may be permitted at the discretion of the attending ABS Surveyor. However, no re-solution heat treatment of the alloys and tempers listed in this section is allowed.

In the event of material failing to comply with the test requirements, the material is to be rejected.

TABLE 1A
Mechanical Property Limits of Non-Heat-Treatable Sheet and Plate Aluminum Alloys (2,3) *(1 July 2022)*

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	*Thickness (1)*		*Ultimate Tensile Strength N/mm^2 (ksi)*		*Yield Strength 0.2% Offset N/mm^2 (ksi)*		*Minimum Elongation Percent in*		
	millimeters over-through	*(inches)*	*minimum*	*maximum*	*minimum*	*maximum*	*50 mm*	*5d*	*2 in. /4d*
AB 5052-O	3.0–6.3	(0.118–0.249)	170 (25.0)	215 (31.0)	65 (9.5)		19	-	20
	6.3–80.0	(0.250–3.000)	170 (25.0)	215 (31.0)	65 (9.5)		18	16	18
AB 5052-H32(4)	3.0–6.3	(0.118–0.249)	215 (31.0)	265 (38.0)	160 (23.0)		7	-	9
	6.3–12.5	(0.250–0.499)	215 (31.0)	265 (38.0)	160 (23.0)		11	-	11
	12.5–50.0	(0.500–2.000)	215 (31.0)	265 (38.0)	160 (23.0)		11	10	12
AB 5052-H34(4)	3.0–6.3	(0.118–0.249)	235 (34.0)	285 (41.0)	180 (26.0)		6	-	7
	6.3–25.0	(0.250–1.000)	235 (34.0)	285 (41.0)	180 (26.0)		10	9	10
AB 5052-H112	6.3–12.5	(0.250–0.499)	190 (28.0)		110 (16.0)		7	-	7
	12.5–40.0	(0.500–2.000)	170 (25.0)		65 (9.5)		-	10	12
	40.0–80.0	(2.001–3.000)	170 (25.0)		65 (9.5)		-	14	16
AB 5059-O	3.0–20.0	(0.118–0.787)	330 (48.0)		160 (23.0)		24	24	24
	20.0-40.0	(0.788-1.575)	330 (48.0)		160 (23.0)		–	20	20
	40.0-50.0	(1.576-2.000)	300 (44.0)		145 (21.0)		–	17	17

Alloy and Temper	*Thickness* [1]		*Ultimate Tensile Strength N/mm² (ksi)*		*Yield Strength 0.2% Offset N/mm² (ksi)*		*Minimum Elongation Percent in*		
	millimeters over-through	*(inches)*	*minimum*	*maximum*	*minimum*	*maximum*	*50 mm*	*5d*	*2 in. /4d*
AB 5059-H111	3.0–20.0 20.0–40.0	(0.118–0.787) (0.788-1.575)	330 (48.0) 330 (48.0)		160 (23.0) 160 (23.0)		24 -	24 20	24 20
AB 5083-O	3.0–50.0	(0.118-2.000)	275 (40.0)	350 (51.0)	125 (18.0)		16	14	16
AB 5083-H111	3.0-50.0	(0.118-2.000)	275 (40.0)	350 (51.0)	125 (18.0)		16	14	16
AB 5083-H112	3.0-40.0 40.0-50.0	(0.250-1.500) (1.501-2.000)	275 (40.0) 270 (39.0)		125 (18.0) 115 (17.0)		12 –	10 10	12 12
AB 5086-O	3.0-6.3 6.3-50.0	(0.118–0.249) (0.250–2.000)	240 (35.0) 240 (35.0)	305(44.0) 305 (44.0)	95.0 (14.0) 95.0 (14.0)		18 16	- 14	18 16
AB 5086-H111	3.0-6.3 6.3-50.0	(0.118–0.249) (0.250–2.000)	240 (35.0) 240 (35.0)	305(44.0) 305 (44.0)	95.0 (14.0) 95.0 (14.0)		18 16	- 14	18 16
AB 5086-H112	3.0-12.5 12.5-40.0 40.0-80.0	(0.118–0.499) (0.500–1.000) (1.001-2.000)	250 (36.0) 240 (35.0) 235 (35.0)		125 (18.0) 105 (16.0) 95 (14.0)		8 - -	- 9 12	8 10 14
AB 5383-O	3.0–50	(0.118–2.000)	290 (42.0)		145 (21.0)		-	17	17
AB 5383-H111	3.0–50	(0.118–2.000)	290 (42.0)		145 (21.0)		-	17	17
AB 5454-O	3.0–6.3 6.3-80.0	(0.118–0.249) (0.250–3.000)	215 (31.0) 215 (31.0)	285 (41.0) 285 (41.0)	85 (12.0) 85 (12.0)		16 18	- 16	18 18
AB 5454-H32 [4,5]	3.0-6.3 6.3-50.0	(0.118–0.249) (0.250–2.000)	250 (36.0) 250 (36.0)	305 (44.0) 305 (44.0)	180 (26.0) 180 (26.0)		8 12	- 10	8 12
AB 5454-H34 [4,5]	3.0-4.0 4.0-6.3 6.3-25.0	(0.118–0.161) (0.162–0.249) (0.249–1.000)	270 (39.0) 270 (39.0) 270 (39.0)	325 (47.0) 325 (47.0) 325 (47.0)	200 (29.0) 200 (29.0) 200 (29.0)		6 6 10	- - 9	6 7 10
AB 5454-H112 [5]	6.3–12.5 12.5-40.0 40.0-80.0	(0.250–0.499) (0.500–2.000) (2.001–3.000)	220 (32.0) 215 (31.0) 215 (31.0)		125 (18.0) 85 (12.0) 85 (12.0)		8 - -	- 9 13	8 11 15
AB 5456-O	3.0-6.3 6.3-80.0	(0.118–1.500) (1.501–3.000)	290 (42.0) 285 (41.0)	365 (53.0) 360 (52.0)	130 (19.0) 125 (18.0)	205 (30.0) 205 (30.0)	16 16	- 14	16 16
AB 5456-H112	6.3-40.0 40.1-80.0	(0.250–1.500) (1.501–3.000)	290 (42.0) 285 (41.0)		130 (19.0) 125 (18.0)		12 -	10 10	12 12
AB 5754-O	3.0-12.5 12.6-50.0	(0.118–0.138) (0.139-2.000)	200 (29.0) 190 (27.5)	270 (39.0) 240 (34.8)	80 (12.0) 80 (12.0)		19 18	- 17	19 18
AB 5754-H111	3.0-12.5 12.6-50.0	(0.118–0.138) (0.139-2.000)	200 (29.0) 190 (27.5)	270 (39.0) 240 (34.8)	80 (12.0) 80 (12.0)		19 18	- 17	19 18

Notes:

1 Type of test specimen used depends on thickness of material: (See 2-5-5/5.)

2 *(2011)* Values applicable to longitudinal test specimens.

3 *(2011)* Use of the latest ASTM B209/209M specification may be approved upon application.

4 *(2011)* For the corresponding H2x temper, the maximum tensile strength and minimum yield strength do not apply.

5 *(2013)* 5454 is recommended for service applications where exposed to temperatures exceeding 65°C (150°F).

6 *(2014)* The mechanical properties for the O and H111 tempers are the same. However, they are separated to discourage dual certification as these tempers represent different processing.

TABLE 1B
Mechanical Property Limits of Non-Heat-Treatable Marine Grade Sheet and Plate Aluminum Alloys for Hull Construction (2, 3, 4) *(1 July 2022)*

Alloy and Temper	*Thickness (1)*		*Ultimate Tensile Strength N/mm² (ksi)*		*Yield Strength 0.2% Offset N/mm² (ksi)*		*Minimum Elongation Percent in*		
	millimeters over-through	*(inches)*	*minimum*	*maximum*	*minimum*	*maximum*	*50 mm*	*5d*	*2 in. /4d*
AB 5059-H116	3.0-20.0 20.0-40.0	(0.118–0.787) (0.788-1.575)	370 (54.0) 360 (52.0)	440 (64.0) 440 (64.0)	270 (39.0) 260 (38.0)		10 -	10 10	10 10
AB 5059-H321	3.0-20.0 20.0-40.0	(0.118–0.787) (0.788-1.575)	370 (54.0) 360 (52.0)	440 (64.0) 440 (64.0)	270 (39.0) 260 (38.0)		10 -	10 10	10 10
AB 5083-H116	3.0–12.5 12.5-40.0 40.0-80.0	(0.118–0.499) (0.500-1.500) (1.501–3.000)	305 (44.0) 305 (44.0) 285 (41.0)	385 (56.0) 385 (56.0) 385 (56.0)	215 (31.0) 215 (31.0) 200 (29.0)		10 - -	- 10 10	10 12 12
AB 5083-H321	3.2-5.0 5.0–12.5 12.5-40.0 40.0-80.0	(0.125–0.187) (0.188–0.499) (0.500-1.500) (1.501–3.000)	305 (44.0) 305 (44.0) 305 (44.0) 285 (41.0)	385 (56.0) 385 (56.0) 385 (56.0) 385 (56.0)	215 (31.0) 215 (31.0) 215 (31.0) 200 (29.0)	295 (43.0) 295 (43.0) 295 (43.0) 285 (41.0)	10 12 - -	- - 10 10	10 12 12 12
AB 5083-H323	3.2-6.4	(0.125-0.250)	310 (45.0)		230 (34.0)	-	10	-	-
AB 5083-H343	3.2-6.4	(0.125-0.250)	340 (50.0)		270 (39.0)	-	10	-	-
AB 5083-H128(5)	4.0–12.5 12.5-40.0 40.0-80.0	(0.157–0.499) (0.500-1.500) (1.501–3.000)	305 (44.0) 305 (44.0) 285 (41.0)	385 (56.0) 385 (56.0) 385 (56.0)	215 (31.0) 215 (31.0) 200 (29.0)		10 - -	- 10 10	10 12 12
AB 5086-H116	3.0-6.3 6.3-50.0	(0.118–0.249) (0.250–2.000)	275 (40.0) 275 (40.0)	360 (52.0) 360 (52.0)	195 (28.0) 195 (28.0)		8 10	- 9	8 10
AB 5086-H321	3.0-6.3 6.3-8.0	(0.118–0.249) (0.250–0.320)	275 (40.0) 275 (40.0)	360 (52.0) 360 (52.0)	195 (28.0) 195 (28.0)		8 9	- -	8 9
AB 5383-H116	3.0–50	(0.118–2.000)	330 (48.0)	400 (58.0)	230 (33.0)		10	10	10
AB 5383-H321	3.0–50	(0.118–2.000)	330 (48.0)	400 (58.0)	230 (33.0)		10	10	10

Alloy and Temper	*Thickness* (1)		*Ultimate Tensile Strength N/mm² (ksi)*		*Yield Strength 0.2% Offset N/mm² (ksi)*		*Minimum Elongation Percent in*		
	millimeters over-through	*(inches)*	*minimum*	*maximum*	*minimum*	*maximum*	*50 mm*	*5d*	*2 in. /4d*
AB 5456-H116	3.0–12.5 12.5-30.0 30.0-40.0 40.0-80.0	(0.118–0.499) (0.500–1.250) (1.251-1.500) (1.501–3.000)	315 (46.0) 315 (46.0) 305 (44.0) 285 (41.0)	405 (59.0) 385 (56.0) 385 (56.0) 370 (54.0)	230 (33.0) 230 (33.0) 215 (31.0) 200 (29.0)		10 - - -	- 10 10 10	10 12 12 12
AB 5456-H321	3.0-4.0 4.0-12.5 12.5-40.0 40.0-80.0	(0.118-0.187) (0.188-0.499) (0.500-1.500) (1.501-3.000)	330 (48.0) 315 (46.0) 305 (44.0) 285 (41.0)	405 (59.0) 405 (59.0) 385 (56.0) 370 (54.0)	235 (34.0) 230 (33.0) 215 (31.0) 200 (29.0)	315 (46.0) 315 (46.0) 305 (44.0) 290 (43.0)	10 12 - -	- - 10 10	10 12 12 12

Notes:

1 Type of test specimen used depends on thickness of material: (See 2-5-5/5.)

2 *(2011)* Values applicable to longitudinal test specimens.

3 *(2011)* Marine Grade sheet and plate as shown in 2-5-5/7.3 TABLE 1B are to be capable of passing an appropriate test for resistance to exfoliation and intergranular corrosion. Refer to Section 2-5-6 for full details of corrosion test requirements.

4 *(2013)* Use of the latest ASTM B 928/928M specification may be approved upon application.

5 The properties for Grade 5083 H128 are indicated as tentative in ASTM B 928/928M-15 and as such may be subject to revision.

TABLE 2
Long Transverse Mechanical Property Limits of Heat-Treatable Sheet and Plate Aluminum Alloys (2, 6) *(1 July 2022)*

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	*Type*	*Thickness* (1)		*Minimum Tensile Strength*	*Minimum Yield Strength 0.2% Offset*	*Minimum Elongation Percent in*		
		millimeters over - through	*(inches)*	*N/mm² (ksi)*	*N/mm² (ksi)*	*4d*	*5d*	*2 in. /4d*
AB 6061-T4	Sheet	3.0-6.3	(0118–0.249)	205 (30.0)	110 (16.0)	16	-	16
AB 6061-T451 (4,5)	Plate	6.3–25.0 25.0–80.0	(0.250–1.000) (1.001–3.000)	205 (30.0) 205 (30.0)	110 (16.0) 110 (16.0)	18 -	16 14	18 16
AB 6061-T6 and T62(3)	Sheet	3.0-6.3	(0.118–0.249)	290 (42.0)	240 (35.0)	10	-	10
AB 6061-T62 (3) and -T651 (4,5)	Plate	6.3–12.5 12.5–25.0 25.0–50.0 50.0–80.0	(0.250–0.499) (0.500–1.000) (1.001–2.000) (2.001–3.000)	290 (42.0) 290 (42.0) 290 (42.0) 290 (42.0)	240 (35.0) 240 (35.0) 240 (35.0) 240 (35.0)	10 - - -	- 8 7 5	10 9 8 6

Notes:

1 Type of test specimen used depends on thickness of material; (See 2-5-5/5).

2 *(2011)* Values applicable to long transverse test specimens.

3 *(2011)* These properties apply to samples of material, which are solution heat treated or solution and precipitation treated from O or F temper by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

4 For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

5 Upon artificial aging, T451 temper material is to be capable of developing the mechanical properties applicable to the T651 temper.

6 *(2011)* Use of the latest ASTM B209/209M specification may be approved upon application.

TABLE 3
Longitudinal Mechanical Property Limits of Non-Heat-Treatable Aluminum Alloys for Extruded Bars, Rods, Shapes, and Tubes (2, 3) *(1 July 2022)*

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	*Maximum Diameter or Thickness (1)*		*Maximum Area*		*Ultimate Tensile Strength N/mm² (ksi)*		*Minimum Yield Strength 0.2% Offset*	*Minimum Elongation Percent in*		
	mm	*(in.)*	*mm²*	*(in²)*	*minimum*	*maximum*	*N/mm² (kgf/mm², ksi)*	*4d*	*5d*	*2 in. /4d*
AB 5059-H112	50	(2.0)	---	---	330 (48.0)	---	200 (29.0)	-	10	10
AB 5083-O(4) AB 5083-H111(4) AB 5083-H112(4)	130.0 130.0 130.0	(5.0) (5.0) (5.0)	20000 20000 20000	(32) (32) (32)	270 (39.0) 275 (40.0) 270 (39.0)	350 (51.0)	110 (16.0) 165 (24.0) 110 (16.0)	14 12 12	12 10 10	14 12 12
AB 5086-O(4) AB 5086-H111(4) AB 5086-H112(4)	130.0 130.0 130.0	(5.0) (5.0) (5.0)	20000 20000 20000	(32) (32) (32)	240 (35.0) 250 (36.0) 240 (35.0)	315 (46.0)	95.0 (14.0) 145 (21.0) 95.0 (14.0)	14 12 12	12 10 10	14 12 12
AB 5383-O AB 5383-H111 AB 5383-H112	50 50 50	(2.0) (2.0) (2.0)	--- --- ---	--- --- ---	290 (42.0) 290 (42.0) 310 (45.0)	---	145 (21.0) 145 (21.0) 190 (27.5)	17 17 -	17 17 13	17 17 13
AB 5456-O(4) AB 5456-H111(4) AB 5456-H112(4)	130.0 130.0 130.0	(5.0) (5.0) (5.0)	20000 20000 20000	(32) (32) (32)	285 (41.0) 290 (42.0) 285 (41.0)	365 (53.0)	130 (19.0) 180 (26.0) 130 (19.0)	14 12 12	12 10 10	14 12 12

Notes:

1 Type of test specimen used depends on thickness of material; (see 2-5-5/5.)

2 *(2011)* Values applicable to longitudinal test specimens.

3 *(2011)* Use of the latest ASTM B221/221M specification may be approved upon application.

4 *(2011)* Properties not applicable to extruded tube over 70 mm (2.999 inch) wall thickness.

5 For closed profiles, the minimum mechanical properties are based upon the wall thickness.

TABLE 4
Mechanical Property Limits of Heat-Treatable Aluminum Alloys for Extruded Products (2,6) *(1 July 2022)*

Mechanical test specimens are taken as detailed in 2-5-5/5 as specified in ASTM B 557/557M.

Alloy and Temper	*Diameter or Thickness (1)*		*Area*	*Ultimate Tensile Strength N/mm^2 (ksi)*	*Yield Strength 0.2% Offset N/mm^2 (ksi)*	*Minimum Elongation Percent in*		
	millimeters over - through	*(inches)*	*mm^2/in^2*	*minimum*	*minimum*	*50 mm*	*5d*	*2 in. /4d*
AB 6005A-T5	3.0-6.3 6.3-50.0	(0.118-0.249) (0.250-2.000)	All	260 (38.0) 260 (38.0)	215 (31.0) 215 (31.0)	7 9	- 8	7 9
AB 6005A-T6	3.0-10.0 10.0-50.0	(0.118-0.400) (0.401-2.000)	All	260 (38.0) 260 (38.0)	215 (31.0) 200 (29.0)	8 8	- 6	8 8
AB 6005A-T61	3.0-6.3 6.4-25.0	(0.118-0.249) (0.250-0.999)	All	260 (38.0) 260 (38.0)	240 (35.0) 240 (35.0)	8 10	- 9	8 10
AB 6061-T4/T4511(4, 5)	All	All	All	180 (26.0)	110 (16.0)	16	14	16
AB 6061-T6(4, 5), -T62(3) and -T6511(4, 5)	3.0-6.3 6.3 and over	(0.118-0.249) (0.250 and over	All	260 (38.0) 260 (38.0)	240 (35.0) 240 (35.0)	8 10	- 9	8 10
AB 6063-T6, -T62(3)	3.0-3.2 3.2-25.0	(0.118-0.124) (0.125-1.000)	All	205 (30.0) 205 (30.0)	170 (25.0) 170 (25.0)	8 10	- 9	8 10
AB 6082-T5	3.0-50.0	(0.118-2.000)	All	270 (39.0)	230 (33.0)	8	6	8
AB 6082-T6, -T6511	3.0-5.0 5.0-50.0 50.0-150.0	(0.118-0.199) (0.200-2.000) (2.001-6.000)	All	290 (42.0) 310 (45.0) 310 (45.0)	250 (36.0) 260 (38.0) 260 (38.0)	6 10 -	- 8 8	6 10 8

Notes:

1 Type of test specimen used depends on thickness of material; (see 2-5-5/5.)

2 *(2011)* Values applicable to longitudinal test specimens.

3 *(2011)* These properties apply to samples of material, which are solution heat treated or solution and precipitation treated from O or F temper by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

4 For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

5 Upon artificial aging, T4 and T4511 temper material are to be capable of developing the mechanical properties applicable to the T6 and T6511 tempers, respectively.

6 *(2011)* Use of the latest ASTM B221/221M specification may be approved upon application.

7 For closed profiles, the minimum mechanical properties are based upon the wall thickness.

TABLE 5
Mechanical Property Limits for Die Forgings[3] *(1 July 2022)*

Alloy and Temper	*Thickness*	*Specimen Axis Parallel to Direction of Grain Flow*					*Specimen Axis Not Parallel to Direction of Grain Flow*				
		Minimum Ultimate Tensile Strength	*Minimum Yield Strength 0.2% Offset*	*Minimum Elongation Percent in*[4]			*Minimum Ultimate Tensile Strength*	*Minimum Yield Strength 0.2% Offset*	*Minimum Elongation Percent in*[4]		
	mm (in.)	*N/mm^2 (ksi)*	*N/mm^2 (ksi)*	*50 mm*	*5d*	*2 in. /4d*	*N/mm^2 (ksi)*	*N/mm^2 (ksi)*	*50 mm*	*5d*	*2 in. /4d*
AB 5083-H111	to 100 (4)	290 (42.0)	150 (22.0)	14	12	14	270 (39.0)	140 (20.0)	12	10	12
AB 5083-H112	to 100 (4)	275 (40.0)	125 (18.0)	16	14	16	270 (39.0)	110 (16.0)	14	12	14
AB 5456-H112[1]	to 100 (4)	303 (44.0)	140 (20.0)	16	16	16	-	-	-	-	-
AB 6061-T6	to 100 (4)	260 (38.0)	240 (35.0)	7[2]	6[2]	7[2]	260 (38.0)	240 (35.0)	5	4	5

Notes:

1 *(2011)* Alloy 5456 is not covered in ASTM B247/247M, but use of such forgings meeting these requirements may be considered.

2 *(2010)* When sample is selected from a separately-forged test coupon, an elongation minimum of 10% applies.

3 *(2011)* Use of the latest ASTM B247/247M Specification may be approved upon application.

4 *(2011)* Elongation values apply to test specimens taken from an actual forging or its prolongation.

TABLE 6
Mechanical Property Limits for Hand Forgings[2, 3] *(1 July 2022)*

Alloy and Temper	*Thickness*	*Axis of Test Specimen*	*Minimum Ultimate Tensile Strength*	*Minimum Yield Strength 0.2% Offset*	*Minimum Elongation Percent in*	
	mm (in.)		*N/mm^2 (ksi)*	*N/mm^2 (ksi)*	*5d*	*4d*
AB 5083-H111	to 100 (4)	Longitudinal Long transverse	290 (42.0) 270 (39.0)	150 (22.0) 140 (20.0)	12 10	14 12
AB 5083-H112	to 100 (4)	Longitudinal Long transverse	275 (40.0) 270 (39.0)	125 (18.0) 110 (16.0)	14 12	16 14
AB 5456-H112 [1]	to 75 (3)	Longitudinal Long transverse	305 (44.0) 290 (42.0)	140 (20.0) 125 (18.0)	16 14	16 14
AB 6061-T6/-T652	to 100 (4)	Longitudinal Long transverse Short transverse [2]	260 (38.0) 260 (38.0) 255 (37.0)	240 (35.0) 240 (35.0) 230 (33.0)	9 7 4	10 8 5
AB 6061-T6/-T652	over 100 (4) to 200 (8)	Longitudinal Long transverse Short transverse	255 (37.0) 255 (37.0) 240 (35.0)	235 (34.0) 235 (34.0) 220 (32.0)	7 5 3	8 6 4

Notes:

1 *(2011)* Alloy 5456 is not covered in ASTM B247/247M, but use of such forgings meeting these requirements may be considered.

2 Requirement applicable to thicknesses of 50 mm (2 in.) and greater.

3 *(2011)* Use of the latest ASTM B247/247M Specification may be approved upon application.

TABLE 7
Mechanical Property Limits for Aluminum Alloy Castings *(1 July 2022)*

AA Aluminum Association

<table>
<tr><th>Alloy</th><th rowspan="2" colspan="2">Temper</th><th rowspan="2">Casting</th><th>Minimum Ultimate Tensile Strength</th><th>Minimum Yield Strength 0.20% Offset</th><th>Minimum Elongation in 50 mm (2 in.)</th></tr>
<tr><th>AA</th><th>N/mm² (ksi)</th><th>N/mm² (ksi)</th><th>percent</th></tr>
<tr><td>AB 356.0</td><td colspan="2">T6</td><td>Sand
Permanent mold</td><td>205 (30.0)
228 (33.3)</td><td>140 (20.0)
152 (22.0)</td><td>3
3</td></tr>
<tr><td>AB A356.0</td><td colspan="2">T6
T61</td><td>Sand</td><td>235 (34.0)
245 (35.0)</td><td>165 (24.0)
180 (26.0)</td><td>3.5
1.0</td></tr>
<tr><td>AB A356.0</td><td>T-61
T-61</td><td>Separately cast coupons
Integral coupons</td><td>Permanent mold</td><td>262 (38.0)
230 (33.3)</td><td>179 (26.0)
179 (26.0)</td><td>5
5</td></tr>
<tr><td>AB 357.0</td><td colspan="2">T6</td><td>Permanent mold</td><td>310 (45.0)</td><td>-</td><td>3</td></tr>
</table>

TABLE 8
Cross Reference of Active International Designations with Former Wrought Alloy Designations *(2016)*

AA Aluminum Association

ASTM American Society for Testing and Material

CSA Canadian Standards Association

NF Normes Francaises

GB Chinese National Standard

BS British Standard

UNI Unificazione Nazionale Italiana

JIS Japanese Industrial Standard

ISO International Organization for Standardization

The chemical composition of wrought aluminum and aluminum alloys is specified in the document International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Aluminum Alloys - Unified North American and International Registration Records, edited by the Aluminum Association (also known as the Teal Sheets). The equivalents shown are former designations and are approximate based on available information.

Active International Designations	*Canada CSA*	*France NF*	*U.K. BS*	*Italy UNI*	*Japan JIS*	*ISO*	*China GB/T*
5052	GR20		2L, 55, 2L, 56, L80, L81	PA1Mg2.5	A2-1	A1Mg2.5Mn	5A02, 5052
5083	GM41, E54S*		N8		A2-7	A1Mg4.5Mn	5083
5086		AG4MC				A1Mg4	5086

Active International Designations	*Canada CSA*	*France NF*	*U.K. BS*	*Italy UNI*	*Japan JIS*	*ISO*	*China GB/T*
5454	GM31N, 55330*					A1Mg3Mn	5454
5456			N61				
6061	GS11N		H20		A2-4	A1Mg1SiCu	6061

Note:
* Commercial designations.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

SECTION 6
Corrosion Testing

1 General *(2024)*

1.1 Objective

This section includes corrosion testing of aluminum alloys to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(2024)*

Rolled 5xxx-alloys delivered in the H116, H128 and H321 tempers (as listed in 2-5-5/7.3 TABLE 1B) intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance as per requirements of this Section and ASTM B 928/928M. These alloys are not be used for service which provides prolonged exposure (continuous or discontinuous) to temperatures exceeding 65°C (150°F) because of the risk of sensitization and the resulting susceptibility to intergranular corrosion and stress corrosion cracking.

The alloy grades of the 6000 series are not be used in direct contact with seawater unless protected by anodes and/or paint system.

3 Reference Photomicrograph *(2016)*

For 5xxx-alloys delivered in H116 and H321 tempers, the manufacturers are to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500× [using 40% phosphoric acid etch for 3 minutes at 35°C (50°F)], under the conditions specified in ASTM B928, Section 9.4.1, is to be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples are to also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by ABS. Production practices are not to be changed after approval of the reference micrographs.

Other recognized test methods may also be accepted at ABS's discretion.

5 Batch Microstructural Analysis and Acceptance *(2016)*

For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate may be carried out, provided that surveillance testing as stated in 2-5-6/7 is performed. The microstructure of the sample is to be compared to the reference photomicrograph [taken at 500 × after 3 minutes etch in phosphoric acid at 35°C (50°F)] of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination, under the conditions specified in ASTM B928, Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminum-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation-corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample is to exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 ASSET test, and the sample is to exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2 (0.0002 lbs/in^2) when subjected to ASTM G67 NAMLT test. If the results from testing satisfy the acceptance criteria stated in 2-5-6/3 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B928, or equivalent standards and accepted if the results satisfy the acceptance criteria stated in 2-5-6/3.

7 Surveillance of Corrosion Testing *(2011)*

The manufacturer is to perform, each quarter or after any process change, at least one test for exfoliation corrosion resistance and one test for intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards for each approved alloy grade. The manufacturer is to maintain records of all surveillance test results and make them available to the Surveyor for product certification.

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

SECTION 7

Sheet, Plate and Rolled Products

1 General *(2024)*

1.1 Objective

This section includes testing and inspection of aluminum alloys to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(1 July 2022)*

The following requirements cover non-heat-treatable and heat-treatable aluminum alloys for sheet plate, and rolled products intended to be used in hull construction. These requirements are applicable to wrought aluminum products within the thickness range of 3 mm (0.12 in.) to 50 mm (2 in.). Plates and sections with thickness less than 3 mm (0.12 in.) or more than 50 mm (2 in.) may be manufactured and tested in accordance with the requirements of a recognized standard or specification. Certification of the thickness range is referred to the corresponding 2-5-5/7.3 TABLE 1A, 2-5-5/7.3 TABLE 1B or 2-5-5/7.3 TABLE 2.

The requirements in this Section are intended for the following products:

- Flat sheet
- Coiled sheet
- Plates
- Other rolled products

3 Selection of Tension Test Specimen *(2011)*

For rolled products, test samples are taken at one-third of the width from the longitudinal edge. Tension test specimens for non-heat-treatable rolled products are to be taken in the longitudinal direction. For heat-treatable rolled products, generally tests in the long transverse direction are required. If the width is insufficient to obtain long transverse test specimens, and when specified, tests in the longitudinal direction may be permitted. Short transverse testing, when specified, is only applicable to plate having a specified thickness of 40 mm (1.500 in.) or greater. The standard rectangular tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used for sheet and plate less than 12.5 mm (0.5 in.) in thickness. For plate 12.5 mm (0.5 in.) and greater in thickness, the round tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used. The tension test specimen is to be taken midway between the two plate surfaces for plate in thicknesses of 12.5 mm (0.5 in.) up to 40 mm (1.57 in.). For plate over 40 mm (1.57 in.) in thickness, the specimen is to be taken midway between the center and surface of the plate.

After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

5 Number of Tension Tests

Tension test specimens are to be selected as follows.

5.1 Sheet

For sheet under 6.3 mm (0.25 in.) in thickness, one tensile test specimen is be taken from one random sheet representative of 900 kg (2000 pounds) or fraction thereof in each batch.

5.3 Plate and Rolled Products

For plate and rolled products 6.3 mm (0.25 in.) and over in thicknesses, one tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg (4410 lb), or fraction thereof, one extra tensile test specimen is to be taken from every 2000 kg (4410 lb) or fraction thereof, in each batch.

For single plates or coils weighing more than 2000 kg (4410 lb) each, only one tensile test specimen per plate or coil is to be taken.

5.5 Definition of a Batch

The term batch applies to products if they are all:

- The same alloy grade from the same cast;
- The same product form and similar dimensions (for plates, the same thickness);
- Manufactured by the same process, and;
- Submitted simultaneously to the same temper condition.

7 Surface Finish *(2014)*

The material is to be free from injurious defects and have a workmanlike finish. Surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in 2-5-7/11. It is to be surface inspected at the mill by the surveyors only when specifically requested and so ordered by the purchaser.

9 Nondestructive Examination (NDE) *(1 July 2022)*

In general NDE of material is not required for acceptance purposes.

However, the manufacturer is expected to employ suitable methods of NDE for maintaining compliance with quality standards. All tests are to be carried out by personnel qualified in accordance with the ABS *Guide for Nondestructive Inspection* or a recognized equivalent standard acceptable by ABS, such as ASTM B548. When requested, the ABS Surveyor is to be given the opportunity to witness nondestructive tests.

11 Dimensions and Tolerance

It is the Manufacturer's responsibility to check dimensions and to comply with the following tolerance requirements.

Under-thickness for rolled products are given in 2-5-7/11 TABLE 1. Dimensional tolerances other than under-thickness tolerance are to comply with a recognized national or international standard.

TABLE 1
Under-thickness Tolerance for Rolled Products *(2018)*

Nominal Thickness (t), mm	*Thickness Tolerances for Nominal Width (w), mm*		
	$w \leq 1500$	*$1500 < w \leq 2000$*	*$2000 < w \leq 3500$*
$3.0 \leq t < 4.0$	0.10	0.15	0.15
$4.0 \leq t < 8.0$	0.20	0.20	0.25
$8.0 \leq t < 12.0$	0.25	0.25	0.25
$12.0 \leq t < 20.0$	0.35	0.40	0.50
$20.0 \leq t < 50.0$	0.45	0.50	0.65

Note:
For thicknesses greater than 50.0 mm, tolerances are to be agreed between the purchaser and manufacturer and accepted by ABS.

13 Repair *(1 July 2022)*

Surface imperfections may be removed by machining or grinding provided the final dimensions are within the tolerances. Repair by welding is not permitted.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

SECTION 8
Closed and Open Extrusions *(1 July 2022)*

1 General *(2024)*

1.1 Objective

This section includes testing and inspection of aluminum extrusions to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(1 July 2022)*

The following requirements cover extruded non-heat-treatable and heat-treatable aluminum alloy products intended to be used in hull construction. Open profiles are solid extrusions in the form of angle, flat bar, channel, beams, etc. Closed profiles are hollow extrusions in the form of square tube, round tube, pipe, complex multi-hollow shapes, etc. Certification of the thickness is to be in accordance with the corresponding 2-5-5/7.3 TABLE 3 or 2-5-5/7.3 TABLE 4.

3 Selection of Specimens

For extruded products tension test specimens are to be taken in the range $^1/_3$ to $^1/_2$ of the distance from the longitudinal edge to the center of the thickest part.

Tension test specimens are to be taken in the longitudinal direction and are to be of the full section of the material where practicable. Otherwise, the specimens shown in 2-5-5/5.5 FIGURE 1 are to be used. For material 40 mm (1.57 in.) and less in diameter or thickness, the specimen is to be taken from the center of the section. For material greater than 40 mm (1.57 in.) in thickness or diameter the specimen is to be located midway between the center and an edge.

After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation are maintained.

5 Number of Tests

5.1 Tension Tests

For the products with a nominal weight of less than 1 kg/m (0.7 lb/ft), one tensile test specimen is to be taken from each 1000 kg, (2205 lb) or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m (0.7 and 3.5 lb/ft), one tensile test specimen is to be taken from each 2000 kg (4410 lb) or fraction hereof, in each batch. If the nominal weight exceeds 5 kg/m (3.5 lb/ft), one tensile test specimen is to be taken for each 3000 kg (6615 lb) of the product or fraction thereof, in each batch.

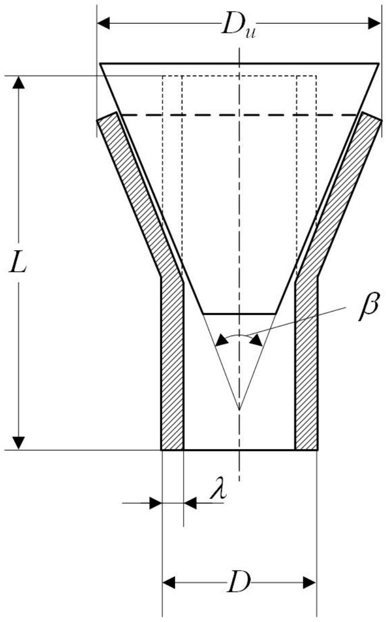
5.3 Drift Expansion Tests *(1 July 2022)*

The Manufacturer is to demonstrate by macrosection tests and drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

5.3.1 Drift Expansion Tests *(2024)*

- Every fifth profile is to be sampled after final heat treatment.
- Batches of five profiles or less are to be sampled one profile.
- Profiles with lengths exceeding 6 m (240 in.) are to be sampled every profile in the start of the production.
- The number of tests may be reduced to every fifth profile if the results from the first 3-5 profiles are found acceptable.
- Each profile sampled will have two samples cut from the front and back end of the production profile.
- The test specimens are to be cut with the ends perpendicular to the axis of the profile.
- The edges of the end may be rounded by filing.
- The length of the specimen is to be in accordance with 2-5-8/5.3.1 FIGURE 1 or recognized standard such as ISO 8493.
- Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having an included angle of at least 60°.
- The sample is considered to be unacceptable if the sample fails with a clean split along the weld line, which confirms lack of fusion.
- The entire batch of closed profiles (press welded) being tested is to be rejected if the sampled profile fails during drift expansion test. However, each profile in the rejected batch may be tested individually and accepted if it passes the test.
- The geometry of the mandrel is to be appropriate for the shape of the extruded pocket. Alternative test methods are subject to ABS technical assessment and approval.

FIGURE 1
Drift Expansion Test *(1 July 2022)*



Notes:

1 L equal to twice the external diameter D of the tube if the angle of the drift is 30°, and L equal to 1.5D if the angle of the drift is 45° or 60°.

2 The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5D.

3 The rate of penetration of the mandrel is not to exceed 50 mm/min.

4 No rupture or failure is permitted at the fusion zone when the penetration reaches Du, the maximum outside diameter after testing or the specified relative expansion as a percentage of the original diameter D.

5.4 Bend Tests *(1 July 2022)*

Bend tests across the fusion line may be additionally required if deemed necessary by ABS. The detailed procedures in accordance with 2-4-5/13.7 or equivalent standard and test results are to be submitted to ABS for review.

5.5 Definition of a Batch

The term batch applies to products if they are all:

- The same alloy grade from the same cast;
- The same product form and similar dimensions (for plates, the same thickness);
- Manufactured by the same process, and;
- Submitted simultaneously to the same temper condition.

7 Surface Finish *(2014)*

The material is to be free from injurious defects and have a workmanlike finish. Surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in 2-5-8/11. It is to be surface inspected at the mill only when specifically requested and so ordered by the purchaser.

9 Nondestructive Examination (NDE) *(1 July 2022)*

In general NDE of material is not required for acceptance purposes.

However, the manufacturer is expected to employ suitable methods of NDE for maintaining compliance with quality standards. All tests are to be carried out by personnel qualified in accordance with the ABS *Guide for Nondestructive Inspection* or a recognized equivalent standard acceptable by ABS such as ASTM B548. When requested, the ABS Surveyor is to be given the opportunity to witness nondestructive tests.

11 Dimensions and Tolerance *(1 July 2022)*

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

Under-thickness tolerances for extruded products are to be in accordance with recognized national or international standards (e.g., ISO 6362-5/6, EN755-3, ANSI H35.2).

Dimensional tolerances other than under-thickness tolerance are to comply with recognized national or international standards.

13 Repair *(1 July 2022)*

Surface imperfections may be removed by machining or grinding provided the final dimensions are within the tolerances. Repair by welding is not permitted.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

SECTION 9
Hull Forgings *(1 July 2022)*

1 General *(2024)*

1.1 Objective

This section includes testing and inspection of aluminum forgings for hull applications to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(2024)*

The following requirements cover non-heat-treatable and heat-treatable aluminum alloy die and hand forgings intended to be used in hull construction. The material covered is in substantial agreement with ASTM B247. Forgings differing in chemical composition, mechanical properties or heat treatment will be subject to ABS technical assessment and approval.

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

ABS 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 forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Raw materials for forgings, such as Aluminum ingots or semi-finished products, are to be manufactured at a facility approved by ABS and manufactured by a process approved by ABS.

3 Selection of Specimens

3.1 Location of Specimens

Tension test specimens are to be taken from prolongations having a sectional area not less than that of the body of the forging. Tension test specimens are normally taken parallel to the direction in which the metal is most drawn out (longitudinal) but may be taken transversely. Specimens taken in the longitudinal direction are to be taken from as near to the center of the cross-section of the forging as is practicable. The midpoint of the axes of transverse specimens are to be near to the center of the cross section of the forging.

3.3 Small Forgings

In the case of forgings weighing less than 114 kg (250 lb) each, where the foregoing procedures are impracticable, 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 testing. In such cases, the special forging is to be subjected to the same amount of working and reduction as the forging represented and, if applicable, be heat treated with those forgings. Alternatively, test specimens may be taken from one of the forgings in the lot.

3.5 Test Specimens

The tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used.

5 Number of Tests

5.1 Large Forgings

In the case of forgings weighing over 2700 kg (6000 lb) each, one tension test specimen is to be taken from each end of the forging.

5.3 Intermediate sized Forgings *(1 July 2019)*

In the case of forgings weighing less than 2700 kg (6000 lb) each, except as noted in 2-5-9/5.5 and 2-5-9/5.7, one tension test specimen is to be taken from each forging.

5.5 Small Forgings

In the case of forgings weighing less than 114 kg (250 lb) each, one tension test specimen may be taken from one forging as representative of 900 kg (2000 lb), provided the forgings are of similar size, of one alloy and temper, are made from the same lot of stock and, if applicable, heat treated in the same furnace charge.

5.7 Special Situations

In the case of a number of pieces cut from a single forging, individual tests need not necessarily be made for each piece, but forgings may be tested in accordance with whichever of the foregoing procedures is applicable to the primary forging involved.

5.9 Retests *(1 July 2019)*

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. 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.

7 Inspection *(1 July 2022)*

The forgings are to be inspected by the ABS Surveyor after final heat treatment, where applicable, to confirm that the forgings are free from injurious defects. In the event of any forging proving defective during subsequent machining or testing, it is to be rejected, notwithstanding any previous certification.

9 Nondestructive Examination (NDE) *(1 July 2022)*

The manufacturer is to carry out suitable methods of NDE for maintaining compliance with quality standards. All tests are to be carried out by personnel qualified in accordance with the ABS *Guide for Nondestructive Inspection* or a recognized equivalent standard acceptable by ABS such as ASTM B548. When requested, the ABS Surveyor is to be given the opportunity to witness nondestructive tests.

11 Dimensions and Tolerance *(1 July 2022)*

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

SECTION 10
Hull Castings *(1 July 2022)*

1 General *(2024)*

1.1 Objective

This section includes testing and inspection of aluminum castings for hull applications to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

2 Scope *(2024)*

The following requirements cover aluminum alloy castings for use in hull construction. The material covered is in substantial agreement with alloys in accordance with ASTM Designations B26 and B108 (Aluminum Association alloys 356.0, A356.0 and AA357.0)-. Except in cases specifically approved otherwise, all aluminum castings are to be furnished in the heat treated condition. Castings differing in chemical composition, mechanical properties or heat treatment from those covered herein will be subject to ABS technical assessment and approval.

Castings are to be made by a manufacturer approved by ABS.

ABS 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.

When two or more castings are joined by welding 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.

3 Selection of Specimens

3.1 Large Castings

Tensile specimens are to be taken from integral test bars. Integral test bars are not to be detached until the heat treatment of the castings has been completed nor until the coupons have been stamped by the Surveyor for identification.

3.3 Small Castings

In the case of castings weighing less than 450 kg (1000 lb) each, test coupons may be cast separately, provided they are poured from the same source of molten metal as the castings represented. When separate coupons are used, the Surveyor is to be furnished an affidavit by the manufacturer stating that the coupons were poured from the same source of molten metal as the castings represented and that they were heat treated with the castings.

3.5 Test Specimens

The tension test specimen shown in 2-5-5/5.5 FIGURE 1 is to be used.

5 Number of Tests

At least one tension test is to be made representative of the same source of molten metal and in each heat-treatment charge.

7 Inspection *(1 July 2022)*

The castings are to be inspected by the Surveyor after final heat treatment and thorough cleaning to confirm that the castings are free from injurious defects, such as cracks, laminations, or embedded porosity. The final machined casting is to be examined to avoid the presence of surface defects.

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

9 Welded Repair of Defects *(1 July 2022)*

Defects in noncritical areas may, with the Surveyor's approval, be repaired by welding using an approved procedure. The welding is to be done before the final heat-treatment.

After it has been agreed that a casting can be repaired by welding, full details of the extent and location of the repair, the proposed welding procedure, heat treatment as applicable, 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.

Before undertaking the repair welding of castings, the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are qualified for the work intended.

11 Nondestructive Examination (NDE) *(1 July 2022)*

The manufacturer is to carry out suitable methods of NDE for maintaining compliance with quality standards.

All tests are to be carried out by personnel qualified in accordance with the ABS *Guide for Nondestructive Inspection* or a recognized equivalent standard acceptable by ABS such as ASTM B548. When requested, the ABS Surveyor is to be given the opportunity to witness nondestructive tests.

13 Dimensions and Tolerance *(1 July 2022)*

The manufacturer is to verify that all dimensions meet the specified requirements. The Surveyor is to spot check key dimensions to confirm the manufacturer's recorded dimensions.

15 Marking and Retests *(1 July 2022)*

15.1 Marking

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

The manufacturer's name or identification mark/pattern number is to be cast on all castings, except those of such small size as to make this type of marking impracticable. The ABS markings, indicating satisfactory compliance with the Rule requirements, and as furnished by the Surveyor, are to be stamped on all castings accepted in such location as to be discernible after machining and installation. In addition, identification numbers of the heats used for pouring the castings are to be stamped on all castings individually weighing 2.2 kg (5 lb) or more.

15.3 Retests

If the results of the physical tests for any casting or any lot of castings do not conform to the requirements specified, the manufacturer may reheat-treat castings or a lot of castings that have failed to meet test requirements. Two additional test samples representative of the casting or casting batch may be taken. If satisfactory results are obtained from both of the additional tests, the casting or batch of castings is acceptable. If one or both retests fail, the casting or batch of castings is to be rejected.

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

SECTION 11

Rivets

1 General *(2024)*

1.1 Objective

This section is for manufacture of aluminum rivets to verify conformance to the goals and functional requirements outlined in Section 2-5-1.

3 Scope *(2024)*

Non-heat-treatable and heat-treatable aluminum alloy cold heading rod and wire for use in manufacturing rivets is to be in agreement with a specification equivalent to ASTM Designation B316. Material differing from ASTM B316 in chemical composition, mechanical properties or heat-treatment may be subject to ABS technical assessment and approval.

PART 2

CHAPTER 5

Materials for Hull Construction – Aluminum

APPENDIX 1

Aluminum/Steel Bi-material Transition Joints *(2015)*

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR3	Chemical composition is to be appropriate to achieve the specified material properties and be suitable for welding, when applicable.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D Chapter 2.

1.3 Scope

The following specification covers metallurgically bonded bimetallic transition joints intended for structural connections between aluminum and steel in an atmospheric or dry environment.

3 Requirements *(2024)*

Aluminum/steel bimetallic transition joints are to be produced, tested, inspected and certified in accordance the following supplementary requirements.

3.1 Reference Documents *(2024)*

The following documents of the issue in effect on the date of the material purchase form a part of this specification to the extent referenced herein.

- MIL-STD-1689 — Fabrication, Welding, and Inspection of Ship Structures
- NAVSEA — Technical Publication T9074-AS-GIB-010/271, Nondestructive Testing Requirements for Metals
- MIL-J-24445 — Joint, Bimetallic Bonded, Aluminum to Steel
- ASTM E466 — Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Test of Metallic Materials

3.3 Process of Manufacture *(2024)*

The bimetallic bond may be produced by explosion-bonding or by roll-bonding. In both cases, the material is to be produced in the form of plate, which will subsequently be cut into bar-like transition joints. Aluminum alloys in accordance with Part 2, Chapter 5 and the steels in accordance with Part 2, Chapter 1, are considered suitable for use as transition joint material.

The use of an intermediate aluminum material at the bond interface is permitted.

This part does not cover joints made by welding or brazing.

3.4 Test Conditions *(2024)*

Tests are to be made in the as-clad condition and in the simulated welded condition.

3.4.1 As-Clad Test Condition *(2024)*

No preliminary treatment is to be given to the specimens which are to represent the as-clad product. The testing is to be carried out at room temperature.

3.4.2 Simulated Welded Test Condition *(2024)*

A preliminary heat treatment is to be given to the specimens which represent the product after welding. The test specimen is to be heat treated at 315°C ± 14°C (600°F ± 25°F) for 15 minutes. The testing is to be carried out at room temperature.

3.5 Tensile Strength Test *(2024)*

The ultimate tensile strength of the bond zone is to be determined by means of the ram tensile test described in 2-5-A1/3.27 FIGURE 1. Test specimens machined to the dimensions in 2-5-A1/3.27 FIGURE 2 are to be loaded in tension to failure. Tests are to be made in the as-clad condition, and in the simulated welded condition. The minimum tensile strength of 75 N/mm^2 (8 kgf/mm^2, 11 ksi) in both test conditions is required for acceptance.

3.7 Bend Test *(2024)*

The method of removing specimens from the plate or assembly is shown in 2-5-A1/3.27 FIGURE 3. Testing of bent specimens is shown in 2-5-A1/3.27 FIGURE 3 and 2-5-A1/3.27 FIGURE 4. The test is to be repeated if any cracking occurs in the aluminum or steel base metal.

3.9 Shear Test *(2024)*

The ultimate shear strength of the bond zone is to be determined by means of the methods in 2-5-A1/ Figure 5. Tests are to be made in the as-clad condition and in the simulated welded condition. The minimum shear strength of 55 N/mm^2 (6 kgf/mm^2, 8 ksi) in both test conditions is required for acceptance.

3.11 Axial Fatigue Strength Test *(2024)*

The axial fatigue strength of the welded transition joint is to be determined in accordance with ASTM E466 or a recognized equivalent national standard by means of specimens in 2-5-A1/3.27 FIGURE 6, and the ratio of the cross sectional area of the aluminum web to the bond area of the bi-material transition joint is to be 1:4 for the fatigue test specimens. Three different fatigue tests are to be carried out on separate specimens. The loadings and total numbers of cycles are indicated in the table below. Test is to meet the minimum specified loadings and endurance without decohesion at the bond line, and the testing is to be repeated if the base metal fails before the specified number of cycles.

TABLE 1
Fatigue Test Conditions and Requirements *(2015)*

Tension Stress, in N/mm^2 (kgf/mm^2, ksi)	*Compressive Stress, in N/mm^2 (kgf/mm^2, ksi)*	*Number of Cycles*
35 (4, 5)	100 (11, 15)	175,000
7 (0.7, 1)	100 (11, 15)	650,000
20 (2, 3)	70 (7, 10)	1,000,000

3.13 Welded Tensile Test

The axial tensile strength of the welded transition joint is to be determined by means of specimens in 2-5-A1/3.27 FIGURE 6. The results are considered satisfactory provided the failure load is above that calculated for one of the web members based on the specified minimum tensile strength of the web material.

3.15 Nondestructive Examination

The bond zone is to be examined by means of ultrasonic inspection in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 to detect areas that lack a bond. Each bimetallic bond is to be continuously scanned. Complete loss of back reflection resulting from a discontinuity at the bond interface is cause for rejection.

3.17 Dimensional Tolerances

The transition joint flatness, edge straightness and edge chamfer are to comply with the following.

3.17.1 Flatness

The joints are to be flat to within 1.6 mm (0.062 in.) over any 305 mm (12 in.). The overall flatness is to be within 25.4 mm (1.0 in.) for joints over 2.5 m (8 ft) in length, and 19.1 mm (0.75 in.) for shorter joints.

3.17.2 Edge Straightness *(2024)*

The joints are to be straight at the edge to within 3.2 mm (0.125 in.) over any 305 mm (12 in.). The overall straightness is to be within 12.5 mm (0.50 in.).

3.17.3 Edge Chamfer

The joint edges are to be chamfered to a minimum radius of 1.6 mm (0.062 in.). The edge squareness is to be within 0.8 mm (0.031 in.) for cut ends, and 1.6 mm (0.062 in.) for cut edges.

3.19 Sampling Lots

A test lot consists of not more than ten (10) bimetallic bonded plates produced at one time and with the same set of manufacturing parameters. Changes to the manufacturing parameters listed below constitute a different lot.

3.19.1 Common Parameters

Manufacturing parameters common to both explosion-bonding and to roll-bonding are: alloy heat, plate thicknesses, base metal pre-cleaning, bonding agents, and assembly width and length.

3.19.2 Explosion-Bonding Parameters

Manufacturing parameters for explosion-bonding are: charge size, standoff distance, charge type, and process sequencing.

3.19.3 Roll-Bonding Parameters

Manufacturing parameters for roll-bonding are: roll pressure, roll temperature, and number of passes.

3.21 Production Lot Testing *(2024)*

One bonded plate from each lot is to be sampled for mechanical testing. The selected plate is to be sampled at diagonally opposite corners. Each sample is to be used for tensile strength testing, and bend testing. All plates are to 100% ultrasonically inspected, see 2-5-A1/3.15. All transition joints are to be dimensionally inspected, see 2-5-A1/3.17.

TABLE 2
Production Lot Testing *(2015)*

Test	*Section*	*Number of Specimens*	*Test Specimen Condition*
Tensile Strength	2-5-A1/3.5	One	As clad
		One	Simulated welded
Bend	2-5-A1/3.7	Two	As clad

3.23 Retest Sampling

Rejected lots may be reconsidered on a plate-by-plate basis provided two tensile tests and two bend tests are carried out with satisfactory results. A plate with any mechanical test failure is not to be reconsidered for acceptance.

3.25 First Article Inspection

A first article inspection is to be carried out for each type of bimetallic joint to validate the bond zone properties and the manufacturing process. All bonding practices are to be recorded and to serve as a baseline for production. Where production practices are modified from the baseline, first article inspection may be required. First article testing is to include ultrasonic inspection, 2-5-A1/3.15, and the following production tests and special tests:

TABLE 3
First Article Testing *(2015)*

Test	*Section*	*Number of Specimens*	*Test Specimen Condition*
Tensile Strength	2-5-A1/3.5	One	As clad
		One	Simulated welded
Bend	2-5-A1/3.7	Two	As clad
Shear	2-5-A1/3.9	Three (1)	As clad
		Three (1)	Simulated welded
Axial Fatigue Strength	2-5-A1/3.11	Three	As welded
Welded Tensile	2-5-A1/3.13	Two	As welded

Note:

If the specimen contains three lugs for testing, then one specimen may be used. In this case, each lug is to be tested individually and the specimen suitably cleaned of testing damage so as to not influence testing and results of the subsequent lug.

3.27 Ordering Data

Procurement documents are to list the following items with appropriate requirements specified:

i) Title and number of ABS specification.

ii) ABS designation and UNS alloy number of bimetallic materials.

iii) ASTM specification, if applicable.

iv) Dimensions or reference a drawing number.

v) ABS certification, if required.

vi) Special product marking, if required.

vii) First article inspection, 2-5-A1/3.25, if required.

FIGURE 1
Ram Tensile Strength Test Setup *(2024)*

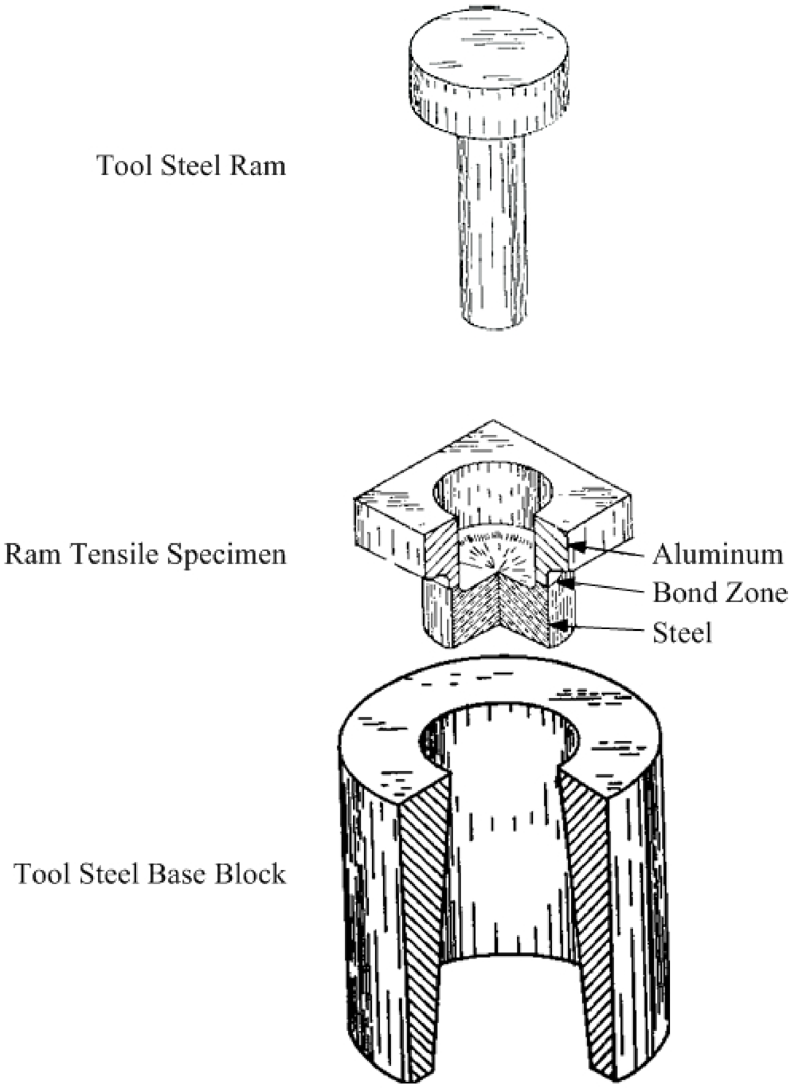
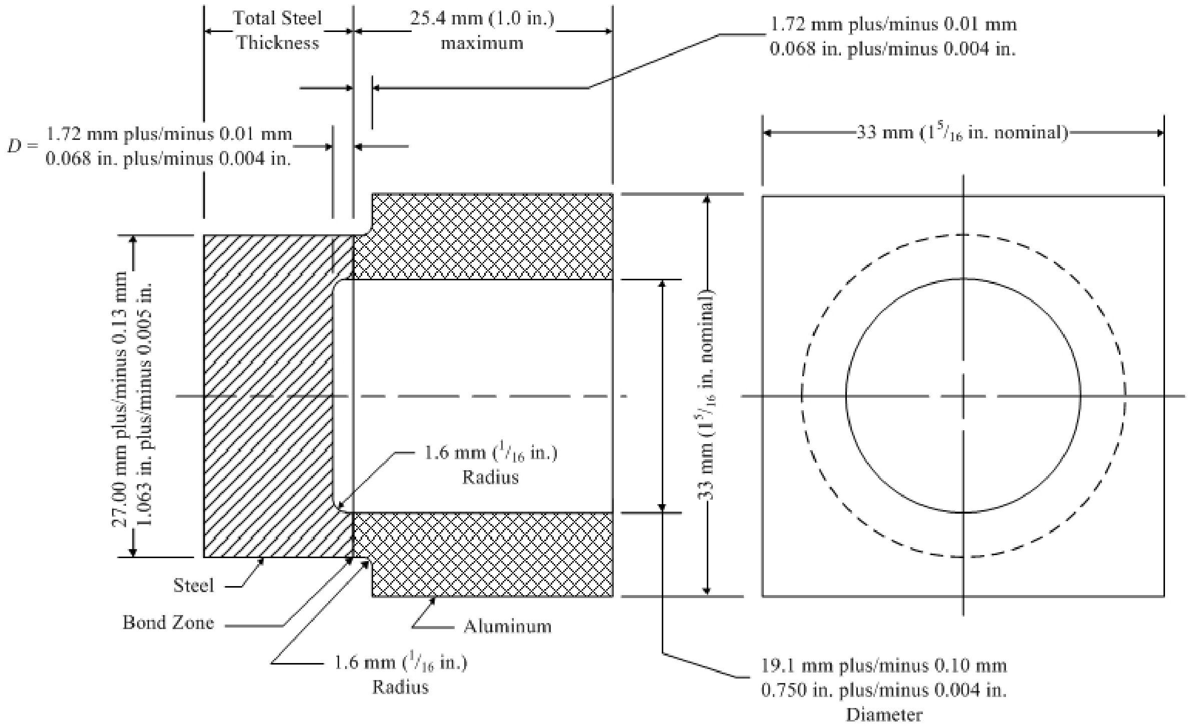


FIGURE 2
Ram Tensile Specimen *(2015)*

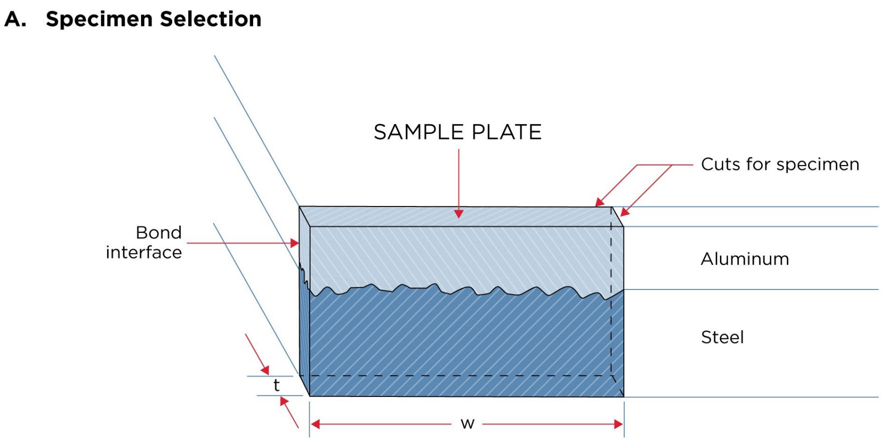


Notes:

1 Sketch dimensions may be appropriately scaled for testing product less than 33 mm ($^{15}/_{16}$ in.) in width.

2 The hole depth, *D*, below the bond line is to be 1.62 mm (0.064 in.) or greater in all cases.

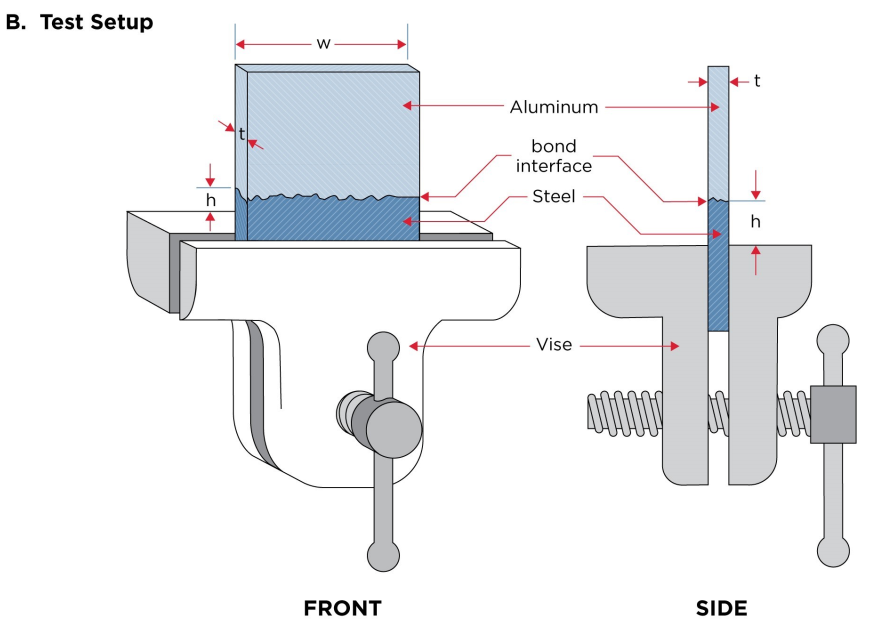
FIGURE 3
Selection and Setup of Bend Test Specimens *(2024)*



Notes:

1 Thickness *t* - 1/16 inch minimum.

2 Width *W* = 2 inch. Where width of product manufactured is less than 2 inch, or product geometry requries a curved bond interface of radius less then 12 inch, two (2) specimens of width *W* = 1 inch may be substituted for each 2 inch specimen.



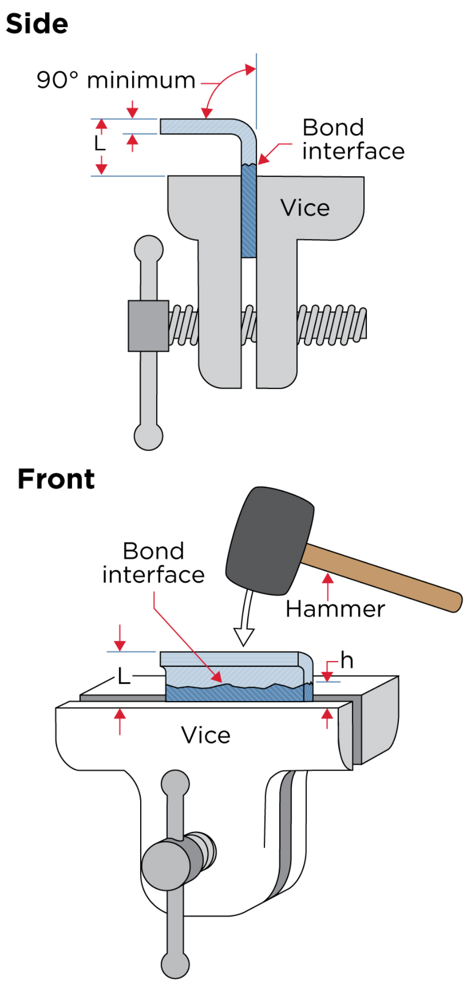
Notes:

1 Height *h* of top of bond interface above vise shall be at least 1/2 *t*, but not more than *t*.

2 Bond line is to be parallel to top of vise or edge of clamping jaws.

3 Test is to be commenced with specimen at ambient temperature.

FIGURE 4
Performance of Bend Test *(2024)*



Notes:

1 Specimen is to be tested by hammer bending or by bending in a press brake.

2 Bending is to result in the formation of an angle of at least 90 degrees between the aluminum portion and a line defined by continuation of the steel portion of the specimen held in the vise or clamping jaws.

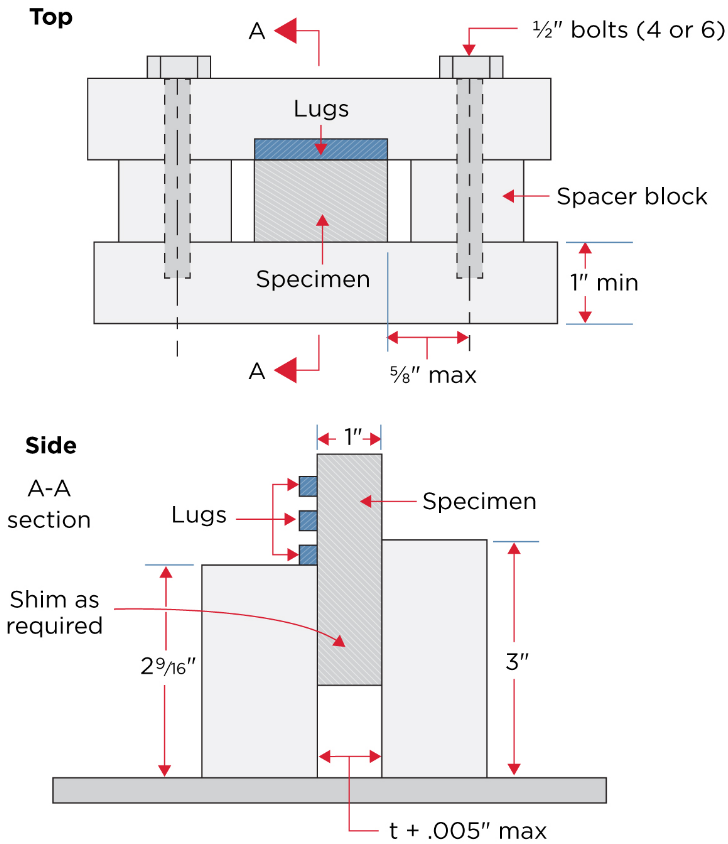
3 Bending is to be accomplished so that plastic deformation of the aluminum is initiated at the bond interface.

4 Distance *L* of highest portion of hammer bent specimens form the level of the top of the vise is not to exceed 3*t*. For specimens bent by press brake, bend radius measured to outer fiber of the aluminum is not to exceed 3*t*.

5 Bent specimen shall be examined with the unaided eye. For acceptance, there is to be no individual crack or other open defect greater than 1/8 inch. Total accumulated length of all visible defects is not to exceed 20 percent of the bond length *W*.

6 The test is to be repreated if any failure occurs in the aluminum or steel base metal before the specimen is bent 90 degrees.

FIGURE 5A
Triple Lug Shear Test - Fixture *(2024)*



Notes:

1 Fixture material: hardened tool steel.

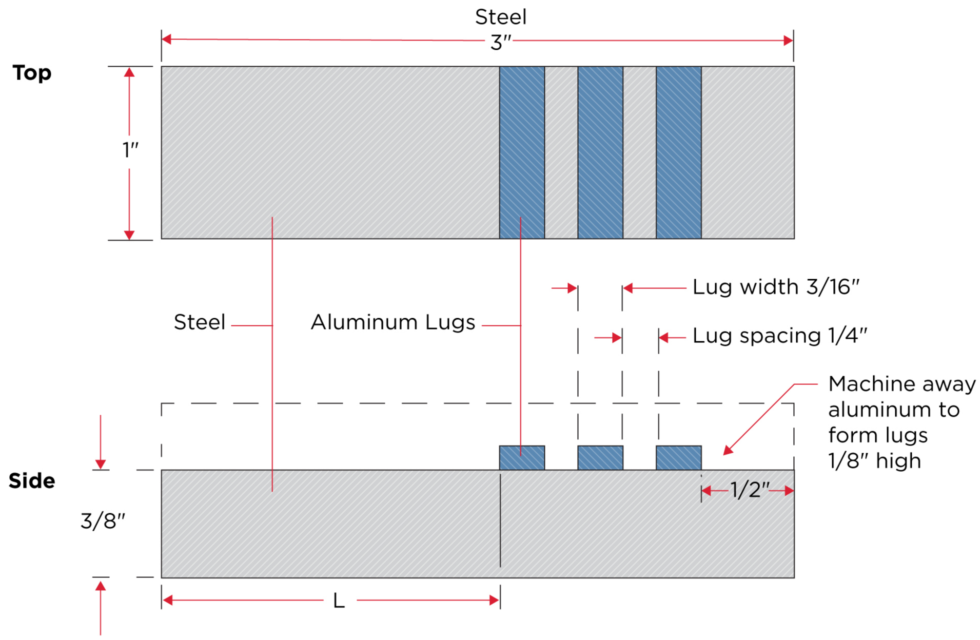
2 Spacer blocks sized to produce gap no more than 0.005 inch larger than specimen depth from bond interface to machined steel back face and no less than 0.002 inch.

3 Front steel face of specimen may be shimmed so that shorter shear block contacts lug at bond interface. On no accountis the shim to be so thick that the shear block contacts the aluminum lug outside bond interface.

4 Grease slinding surfaces lightly.

5 Apply load with calibrated testing machine.

FIGURE 5B
Triple Lug Shear Test - Specimen *(2024)*



Notes:

1 Meaure length and width of each lug for area determination prior to testing.

2 Shear each lug individually, recording load.

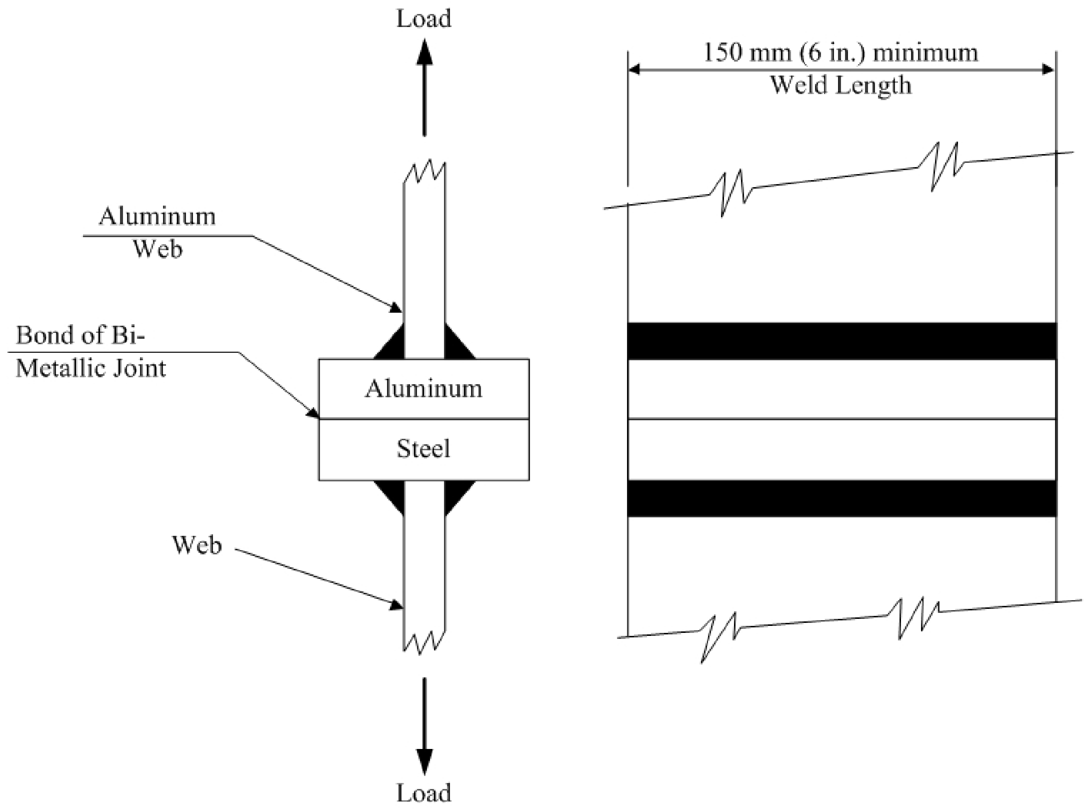
3 File burrs and smeared material smooth before shearing next lug.

4 All corners are 90° lug-steel root radius is to be no greater than .005 inch.

5 Machining of aluminum to form lugs is not to undercut the steel at the bond interface more than o.010 inch. Saturated aqueous $CuSO_4$ may be used to etch surface to determine that all aluminum is removed from the steel.

6 Back surface of the steelis to be machined flat and parallel.

FIGURE 6
Weld Tensile Test Assembly *(2015)*



Notes:

1 The web members are to be of the same composition and thickness as those used for the service application.

2 The width of the transition joint is to be the same as the product furnished to the purchaser.

3 The welding filler material is to be chosen in accordance with the requirements of MIL-STD-1689. The test assembly is to be cut from the approximate center of the welded assembly and is to be a minimum of 50 mm (2 in) in length. The welded assembly is to incorporate the necessary load tabs.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

APPENDIX 2
Dissimilar Materials *(2015)*

1 Objective *(2024)*

This section includes guidance about combination of dissimilar materials, with the intent to meet the goals and functional requirements outlined in Appendix 2-5-A1.

2 Material

2.1 Dissimilar Materials

Where dissimilar materials such as aluminum and steel, stainless steel and carbon steel, or copper/nickel and carbon steel, are used in combination and exposed to water or weather, measures are to be taken to avoid galvanic corrosion.

PART 2

CHAPTER 5
Materials for Hull Construction – Aluminum

APPENDIX 3
List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying

1 Objective *(2024)*

This Appendix includes requirements for verification testing, with the intent to meet goals and functional requirements outlined in the cross-referenced sections.

3 Test and Test Data

i) **Witnessed Tests**. The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under ABS's Quality Assurance Program.

ii) **Manufacturer's Data**. The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

iii) **Other Tests**. The designation (A) indicates 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 Rule requirements.

2-5-2 Standard Test Methods	
2-5-2/1.1	Chemical Analysis (M)
2-5-2/1.3	Tension Test (W)
2-5-2/1.5	Shear Test (W)
2-5-2/1.7	Hardness Test (W)
2-5-2/1.9	Electrical Conductivity Test (W)

2-5-6 Corrosion Testing	
2-5-6/5	Batch Microstructural Analysis (M)

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2-5-7 Sheet, Plate and Rolled Products	
2-5-2/1.1	Chemical Analysis (M)

2-5-7/3 and 5	Tension Test (W)
2-5-8/9	Nondestructive Examination (NDE) (A)

(1 July 2022)

2-5-8 Extrusions	
2-5-2/1.1	Chemical Analysis (M)
2-5-8/5.1	Tension Test (W)
2-5-8/3	Drift Expansion Test (W)
2-5-8/5.4	Bend Test (W)
2-5-8/9	Nondestructive Examination (NDE) (A)

(1 July 2022)

2-5-9 Forgings	
2-5-2/1.1	Chemical Analysis (M)
2-5-2/1.7	Hardness Test (W)
2-5-9/3 and 5	Tension Test (W)
2-5-9/9	Nondestructive Examination (NDE) (A)

(1 July 2022)

2-5-10 Castings	
2-5-2/1.1	Chemical Analysis (M)
2-5-2/1.7	Hardness Test (W)
2-5-10/3 and 5	Tension Test (W)
2-5-10/11	Nondestructive Examination (NDE) (A)

PART 2

CHAPTER 6

Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

CONTENTS

PART 2

CHAPTER 6

Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

SECTION 1

General

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirement

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR16	The constituent materials used in the construction are to be appropriate to achieve the specified material properties of the final composite structures.
MAT-FR17	Post curing treatment, when applicable, is to be capable of producing the specified material properties.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.2 Scope

The requirements in this section apply to raw materials for fiber-reinforced plastic (FRP) structures classed or intended for ABS classification.

Resins other than polyester, vinyl ester and epoxy, and coatings other than gelcoat and topcoat, fiber reinforcements other than glass fiber, carbon fiber, and aramid fiber, may be accepted based upon testing and approval in each individual case.

3 Raw Materials *(2024)*

3.1 Thermoset Resins *(2024)*

i) *Polyester Resins.* Unsaturated polyester resin is used for a wide variety of industrial applications. Isophthalic polyester (ISO) or orthophthalic polyester (ORTHO) may be used.

- ***a)*** Isophthalic and terephthalic resins generally are selected for use in more aggressive exposures, as these in general have a better chemical resistance.
- ***b)*** Orthophthalic resins typically are selected for parts exposed to normal weather and water resistance; these resins can also be formulated to have very good corrosion resistance in humid conditions.

ii) *Vinyl Ester Resins.* Vinyl ester resin is a common resin in the marine industry due to its high chemical resistance.

iii) *Epoxy Resins.* Epoxies offer high strength, low shrinkage, excellent adhesion to various substrates, effective electrical insulation, chemical and solvent resistance and low toxicity. They are easily cured without evolution of volatiles or by-products by a broad range of chemical specie. Epoxy resins are also chemically compatible with most substrates and adhere to wet surfaces easily, making them especially well-suited to composites applications.

iv) *Phenolic Resins*

a) Phenolic resins offer superior fire resistance, excellent high temperature performance, long term durability, and resistance to hydrocarbon and chlorinated solvents. However, it may not be suitable for structural applications.

b) Where fire retardant additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. The results of independently tested fire retardant and fire restricting materials are to be submitted. All fire-retardant systems are to be used strictly accordance with the resin manufacturer's recommendation.

3.3 Curing Systems

For polyester and vinylester resins, the level of catalyst and accelerator are to be as recommended by the manufacturer to provide full polymerization of the resin. In general, the rate of gelation is to be controlled by the amount of catalyst accelerator added to the resin. The amount of catalyst is not to be less than 1% of the base resin, by weight.

3.5 Gel Coats and Topcoats *(2024)*

Gel coats provide a high-quality finish on the visible surface of a fiber-reinforced composite. They have improved water-weather, UV resistance and long-term surface stability. All gel coats are to be used strictly in accordance with the manufacturers' recommendations.

3.7 Resin Properties *(2024)*

The properties of a resin are to be the final form of the resin used in production with all additives and fillers included. The amount of silicon dioxide or other material added to provide thixotropy additive or thickening is to be the minimum necessary to resist flowing or draining. The following liquid and cured condition properties of resins are to be provided for the gel coat resin and laminating resin, and if different, for the skin coat:

- Liquid Properties (at 25°C)

  i) Monomer Content %

  ii) Viscosity – Brookfield (Spindle No. & RPM) CPS

  iii) Thixotropic Index, Minimum

  iv) Specific Gravity

  v) Flash Point, Closed Cup

  vi) Fillers (type and amount)

- Cure Characteristics (at 25°C)

  i) Gel Time, Minutes (indicate initiator (catalyst) and activator (promoter) and %)

  ii) Gel to Peak, Minutes

  iii) Peak Exotherm

- Cured Properties for Resin Clear Casting

  i) Barcol Hardness

  ii) Heat Deflection Temperature

  iii) Tensile Strength and Tensile Modulus

  iv) Tensile Elongation at Break, %

  v) Flexural Strength & Modulus

  vi) Volume Shrinkage

vii) Water Absorption

- Chemical analysis and shelf life.

For polyester resins, the tensile elongation at break is generally not to be less than 1.0% for laminating resins and is to be generally not less than 2.0% for gel coat resins. Elongation of other resins will be specifically considered.

3.9 Additives

Additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. Where a resin contains an ingredient that can settle within the resin system, it is the builder's responsibility to confirm that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

3.11 Fillers

All fillers added by a builder are to be of the dispersed type. The amount of filler that may be added to a resin is to be recommended by the resin manufacturer and is not to significantly alter the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin manufacturer to adopt amounts of fillers in excess of 13% by weight of the base resin will be subject to individual approval and testing. Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content. Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to confirm that the entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed. Details of all fillers are to be submitted.

3.13 Reinforcing Materials - Fiber *(2024)*

Fiber reinforcement includes E glass fiber, S or R glass, carbon and aramid (Kevlar) fibers. The use of hybrid reinforcing materials is also acceptable. To be considered a reinforced plastic, the properties of the cured laminate of resin and fiber must exceed those of the cured clear resin without fiber. Where coupling agents are used, they are to be of the silane type, and are to be compatible with the laminating resins

5 Core Materials *(2024)*

Expected shear strengths of core materials are shown in 2-6-1/5.5 TABLE 1. Core materials other than those shown will be subject to ABS technical assessment and approval. Polyester fiber or vinylester mat is not considered a lightweight structural core, and use will be subject to ABS technical assessment and approval. Shear strength for use in the design is to be verified by test, as required in Section 2-6-5. Construction methods and procedures for core materials are to be in strict accordance with core manufacturer's recommendations.

5.1 PVC Foam Cores

Foam cores are to be of the closed cell types and impervious to water, fuel and oils. Foam cores are to be compatible with the resin system and have good aging ability. Foam cores are to have good strength retention at 60°C (140°F). If the foam core is manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble with the laminating resin. Where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature in excess of that which may be experienced in service may be necessary to confirm the release of entrapped residual gaseous blowing agents from the cells of the foam core.

5.3 Balsa Wood

Balsa wood is to be end-grained. Balsa wood is to be treated chemically against fungal and insect attack and kiln-dried shortly after felling, and is to be sterilized and homogenized. Balsa wood is to have an average moisture content of 12%. If the balsa wood is manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

5.5 Core Bonding Materials

Core bonding materials are to be used in accordance with the manufacturer's instructions. The proposed core bonding to be used with the core material is to be indicated on the Material Data Sheet and the construction plans.

TABLE 1
Properties of Core Materials

	Density		*Minimum Shear Strength*		
Material	*kg/m³*	*lb/ft³*	*N/mm²*	*kgf/mm²*	*psi*
Balsa, end-grain	104	6.5	1.6 (1)	0.16 (1)	225 (1)
Balsa, end-grain	144	9	2.5 (1)	0.25 (1)	360 (1)
PVC, crosslinked	80	5	0.9	0.09	122
PVC, crosslinked	100	6.25	1.4	0.14	200
PVC, linear (2)	80–96	5–6	1.2	0.12	170

Notes:

1 These values are for Ecuadorian balsa.

2 Caution is to be taken when linear PVC cores are used in areas that are susceptible to high temperatures because of their low heat distortion temperature.

7 Laminates

7.1 Basic Laminate

The basic laminate consists of an unsaturated general-purpose polyester resin and alternate plies of E-glass, fiberglass mat and fiberglass-woven roving fabricated by the contact or hand lay-up process. The minimum glass content of this laminate is 35% by weight.

7.3 Uni-directional Laminates

Lay-up details showing the thickness and weight of the plies are to be indicated on the drawings.

A sufficient balance of properties in the warp and fill directions is to be maintained to prevent laminate failure in any direction. The ratios of the verified minimum laminate strengths in the fill direction to those in the warp direction are to be not less than the following:

Member	*Fill Strength/Warp Strength*
Panel, aspect ratio = 1.0	0.80
Panel, aspect ratio > 2.0	0.61
Stiffening member	0.25

For panels with aspect ratios between 1.0 and 2.0, the ratios are to be obtained by interpolation.

The values of $E_F/F, E_T/T$ and E_C/C in the fill direction are not to exceed the same ratios in the warp direction.

7.5 Bi-Directional Laminates

Lay-up details showing the thickness and weight of the plies are to be indicated on the drawings.

7.7 Sandwich Laminates

All core materials are to be effectively bonded to their laminated skins.

7.9 Mechanical Properties

The mechanical properties used in design for all laminates are to be verified by approved material tests. See Section 2-6-5.

2-6-1/7.15 TABLE 2 gives the average mechanical properties for various laminating materials. Thickness, strength and stiffness vary from the type of construction (hand lay-up, vacuum bagging, RTM or resin infusion) and the quality of the builder. These values are minimum for hand lay-up construction and are to be used for guidance only. For sandwich construction, the core to skin bond line is to be tested in tension (flatwise tension test, see 2-6-1/5.5 TABLE 1) to determine its integrity. The bondline is considered acceptable if failure occurs in the cored region of the sample or within the laminate skins. The properties to be used for a particular laminate are subject to verification by approved material tests, as required in Section 2-6-5.

7.11 Nonstructural Plies

Gel coats and skin coats of either fiber mat or fiber cloth weighing less than 30 grams per square meter (0.1 ounce per square foot) are considered to be nonstructural. They are not to be included when assessing laminate strength and stiffness.

7.13 Laminate Thickness

The average thicknesses given below are provided only as guidance to the designer for mat and woven plies laid-up separately. Thickness indicated on the submitted plans for use with the guide are to be verified by the Surveyor and approved material tests.

The cured resin-and-mat plies may be taken to have average thickness equal to 0.25 millimeters per 100 grams of mat in each square meter (0.03 inches per ounce of mat in each square foot) of the basic laminate. The cured resin-and-woven roving plies may be taken to have an average thickness equal to 0.12 millimeters per 100 grams of woven roving in each square meter (0.0016 inches per ounce of woven roving in each square yard) of the basic laminate.

For mat and woven roving laminates differing in glass content from the basic laminate, the average cured laminate thickness, t, (excluding nonstructural plies) can be obtained from the following equation:

$$t = \frac{Wk}{c}\left(\frac{305}{f_g} - 2.69\right) \quad \text{mm(in)}$$

where

k = 0.35 mm (0.0138 inches)

f_g = glass content, percentage by weight, of one ply of the mat and one ply of the woven-roving of the laminate to be used

c = glass content per pair of composite fiberglass reinforcement of basic laminate,

= 1272 g/m^2 (4.17 oz/ft^2)

W = total weight of fiberglass reinforcement of the laminate in g/m^2 (oz/ft^2), of the laminate thickness, t

7.15 Plywood and Timber Members

Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.

TABLE 2
FRP Laminate Properties *(2024)*

SI Units:

	Basic Laminate kgf/mm²	*"S" Glass kgf/mm²*	*Aramid Kevlar kgf/mm²*	*Carbon kgf/mm²*
Flexural Strength, F	17.5	45.9	23.5	51
Flexural Modulus, E_f	773	1835	2236	4500
Tensile Strength, T	12.6	36.4	39.4	43.4
Tensile Modulus, E_t	703	1920	2314	4500
Compressive Strength, C	11.9	30.5	14.4	30
Compressive Modulus, E_c	703	1828	2285	4430

MKS Units:

	Basic Laminate N/mm²	*"S" Glass N/mm²*	*Aramid Kevlar N/mm²*	*Carbon N/mm²*
Flexural Strength, F	172	450	230	500
Flexural Modulus, E_f	7580	18000	22000	43800
Tensile Strength, T	124	357	386	425
Tensile Modulus, E_t	6890	18800	22700	43800
Compressive Strength, C	117	299	142	284
Compressive Modulus, E_c	6890	18000	22500	43700

U.S. Customary Units:

	Basic Laminate psi	*"S" Glass psi*	*Aramid Kevlar psi*	*Carbon psi*
Flexural Strength, F	25000	65300	33400	72500
Flexural Modulus, E_f	1100000	2610000	3180000	6400000
Tensile Strength, T	18000	51800	56000	61700
Tensile Modulus, E_t	1000000	2730000	3290000	6400000
Compressive Strength, C	17000	43400	20500	41100
Compressive Modulus, E_c	1000000	2600000	3250000	6300000

9 Adhesives

9.1 General

Adhesives for structural applications are to be used in accordance with the manufacturer's recommendations. The details of all structural adhesives are to be specified on the Material Data Sheet and on the construction plans submitted. Details concerning the handling, mixing and application of adhesives are to form part of the Builders Process Instruction. Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded. Where excessive unevenness of the faying surfaces exists, a suitable gap-filling adhesive is to be used or local undulations removed by the application of additional reinforcements. The Builder Process Description is to identify the level of training required for personnel involved in the application of structural adhesives.

9.3 Requirements for Structural Application

For adhesive materials to be acceptable for use in structural applications, they are to comply with the following requirements:

i) The minimum shear strength of the adhesive is to be between 6.9 N/mm^2 (1000 psi) and 10 N/mm^2 (1500 psi). This shear strength is to be achieved in temperatures ranging from ambient to 49°C (120°F). The testing is to be performed to ASTM D1002 or ASTM D3165 using FRP substrates. All failures of test samples are to be either cohesive or fiber tear.

ii) The adhesive is to be tested in fatigue using ASTM D3166 (note: the test substrates may be metallic). The test is to be conducted at 50% of the ultimate tensile strength and is to last for a minimum of one million cycles at 30 Hz.

iii) The process for the application of the adhesive is to be submitted for review and is to include the maximum bondline thickness, nondestructive testing methods and maximum creep.

iv) The elastic modulus of the adhesive is to be considerably less than that of the FRP skin to which it is being adhered

v) The strain of failure ratio of the adhesive is to be much larger than the surrounding structure.

vi) The mechanical properties of the adhesive are achieved rapidly, such that the use of screws or bolts will not be necessary to hold the substrates together while the adhesive cures.

vii) The adhesive is to be compatible with the lamination resin.

PART 2

CHAPTER 6

Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

SECTION 2

Fabrication

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR16	The constituent materials used in the construction are to be appropriate to achieve the specified material properties of the final composite structures.
MAT-FR17	Post curing treatment, when applicable, is to be capable of producing the specified material properties.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Scope *(2024)*

This section covers requirements for fabrication of FRP Laminates. Use of fabricating procedures differing from those given below are to be submitted to ABS for technical assessment and approval.

3 Fabrication Procedures

3.1 General

The laminate is to be laid-up by one of the following methods:

- Hand layup or contact process
- Vacuum Bagging
- Resin Impregnation
- Resin Transfer Molding (RTM)
- Resin Infusion
- Pre-preg

3.3 Laminate Layup *(2024)*

A composite laminate consists of several plies or layers of reinforcing material. Adjacent reinforcing plies are to overlap each other to promote structural continuity and the overlap is to be no less than 50 mm. The distance between two overlaps in adjacent plies are not to be less than 100 mm, unless otherwise specifically approved by ABS.

Transitions in laminate thickness are to be tapered over a minimum distance not less than three times the thickness of the thicker laminate.

3.5 Sandwich Panel Layup *(2024)*

Sandwich panels may be laminated with different core materials depending on the application. In load bearing structures, the core material contributes to the overall design by increasing the bending and flexural strength as well as the overall stiffness by increasing the moment of area. In non-primary structures, the core material is used mainly for increased the ratio of strength to weight as well as for its acoustic and insulating properties (e.g.. polystyrene foam).

Core material that contributes to overall structural integrity by resisting bending, tension/compression and shear is considered effective core. Core material that is not capable resisting all these resultant stresses but contributes via shear load transferring is considered ineffective core.

All cores are to be effectively bonded to the skins in accordance with the manufacturer's recommendation (e.g., vacuum bag techniques with an approved bedding putty). Joints in core materials are to be scarphed and bonded or connected by similar effective means.

The ply of skin laminate in contact with each face of a core material is to be thoroughly impregnated with resin and the core is to be coated with resin before lay-up. For foam cores, the resin is to be applied and sufficiently rolled so that all voids are filled, and the coat of resin for wood cores are to be substantial enough to seal the grain of the wood.

3.7 Secondary Bonds *(2024)*

Secondary bonds are only to be used when a primary bond cannot be achieved. Wherever possible, peel-ply may be applied to the outer layer of the surface requiring the secondary bond. When preparing for a secondary bond, the following criteria along with the manufacturer's recommendations are to be adhered to:

i) The area is to be clean and free from all foreign particles such as wax, grease, dirt and dust.

ii) When grinding is required, the grinding is not to damage any of the structural glass fibers, thus weakening the laminate, especially in highly stressed areas.

The first ply of the secondary lay-up is to be chopped-strand mat or other reinforcement as per approved plans. The final ply of laminate along the bond line of the cured laminate is preferably to be chopped-strand mat.

Where methods other than conventional secondary bonding are proposed, the shipyard is to demonstrate that the proposed method is equivalent in strength to a conventional secondary bond.

Commentary:

The grinding of Fiber Reinforced Plastic, FRP, should be carried out manually by hand. The machine grinding of plastic composite materials generates heat which can cause the composite materials to deform. In addition, with machine grinding there is less control over the rate of material removal, which can damage the fiber reinforcement and result in weakened areas, and local stress risers.

End of Commentary

PART 2

CHAPTER 6

Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

SECTION 3

Building Process Description

1 General

1.1 Objective *(2024)*

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements..
MAT-FR16	The constituent materials used in the construction are to be appropriate to achieve the specified material properties of the final composite structures.
MAT-FR17	Post curing treatment, when applicable, is to be capable of producing the specified material properties.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Building Process and Facilities *(2024)*

A description of the building process is to be submitted for review by the builder before commencing construction. Information on the following is to be included:

i) Description of construction facilities, including environmental control and material storage and handling.

ii) Specifications for resins, reinforcing products and core materials including the manufacturer's recommendations.

iii) Lay-up procedures, including type, orientation of reinforcements, sequence, resin mixing methods and resin pot-life limits.

iv) Secondary bonding procedures.

v) Inspection and quality control systems.

vi) Laminate properties derived from destructive qualification testing including sample check sheets, forms and guides.

3.1 Material Storage Premises

The premises are to be equipped and arranged so that the material manufacturer's recommendations for storage and handling can be followed:

3.1.1

Premises are to be sheltered, protected from the sun, clean, dry, ventilated as necessary and sufficiently free of dust so that materials are not contaminated or degraded. Materials are to remain sealed in storage as recommended by the manufacturer.

3.1.2

Before use, fiber reinforcements are to be stored for at least 48 hours at a temperature and humidity similar to that of the laminating premises.

3.1.3

Resins, catalysts, hardeners and accelerators are to be stored in a well-ventilated space at temperatures recommended by the manufacturer. The storage period is not to exceed the shelf lives. Fillers and additives are to be stored in closed containers impervious to humidity and dust. Resin tanks are to be arranged so that they can be stirred at the frequency and time recommended by the manufacturer.

3.1.4

Core materials are to be stored in a dry space and protected against damage; they are to be contained in their protective packaging until immediately prior to use.

3.1.5

Materials that may be considered hazardous to each other are to be stored separately. Catalyst is to be stored in a cool, dry location away from manufacturing facility in accordance with fire and insurance codes.

3.3 Mold Construction

Molds are to be constructed to the following criteria:

3.3.1

Molds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

3.3.2

The materials used in the construction of molds are not to affect the resin curing process.

3.3.3

The finish on a mold is to be such that the moldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the molding is not part of ABS Survey and approval.

3.3.4

Where multiple section molds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to molding. Mismatch between mold sections is to be avoided.

3.3.5

The release agent (e.g., mold wax, etc.) is to be of a type recommended by the resin manufacturer and is not to affect the curing of the resin.

3.3.6

Prior to use, all molds are to be conditioned to the workshop temperature.

3.3.7

Lifting arrangements are to be designed such that moldings are subjected to minimal distortion and unnecessary stressing. Moldings are to be adequately supported to avoid distortion during the final curing stage.

3.5 Laminating Premises

Premises are to be arranged and equipped so that the material manufacturer's recommendations and builder's standards for handling, laminating and curing are followed:

3.5.1

Premises are to be fully sheltered, dry, clean, shaded from the sun and adequately ventilated to remove fumes, overspray and dust from the molds and laminating area and properly and adequately lighted. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

3.5.2

Temperature is to be maintained adequately constant between 16°C and 32°C (60°F and 90°F). The humidity is to be kept adequately constant to prevent condensation and is not to exceed 80%. Where spray molding is taking place, the humidity is not to be less than 40%. The temperature and humidity are to be within limits recommended by the manufacturer of the materials. Deviation from these values may be considered, provided the temperatures and humidity are within the limits recommended by the manufacturer and are reviewed by ABS prior to laminating.

3.5.3

The temperature in the laminating premises is to be attained at least 24 hours before commencement of lamination, and is to be maintainable, regardless of the outdoor temperature.

3.5.4

Sufficient temperature and humidity monitoring equipment is to be provided, and detailed records are to be kept in accordance with the Quality Assurance system.

3.5.5

Laminating areas are to be remote from operations creating dust.

3.5.6

Scaffolding is to be provided, where necessary, to avoid standing on cores or on laminated surfaces. Such arrangements are to conform to the National Authority requirements and are not to be connected to the molding or impinge on the mold surface.

3.5.7

It is the responsibility of the builder to maintain the ventilation and working conditions, together with discharges into the atmosphere, are such that the levels of substances are within the limits specified in any pertinent National or International legislation.

3.7 Equipment

All equipment is to be well maintained and operated to the specifications underlined by the equipment manufacturer's recommendations and the following guidelines:

3.7.1

Production equipment, hose connections, gauge faces, spray guns, meters and pumps are to be kept clean and properly serviced.

3.7.2

Floors and work tables are to be regularly cleaned and reasonably free of accumulation of resin and reinforcing materials.

3.7.3 *(2024)*

Compressed air for air operated equipment is to be clean, dry and free from contaminates such as oil, moisture or dirt. The system is to include filter and water traps that are cleaned and serviced frequently.

3.7.4 *(2024)*

The catalyst is to be introduced into the resin or gel coat by the injection accelerator of the spray gun in a precise ratio and to result in a thoroughly homogeneous mixture. This accelerator is to be checked and calibrated frequently.

3.7.5 *(2024)*

Chopper guns are to be maintained and properly adjusted so the desired fiber to resin ratio, fiber length and fiber distribution are maintained.

3.7.6

Resin delivery systems, both portable and fixed, are to be readily accessible for service and maintenance, including the cleaning of lines to prevent contamination.

3.7.7 *(2024)*

For spray laminating, the weight of resin and reinforcement used is to be continuously monitored to check the fiber/resin ratio. Laminate samples are also to be taken for testing on a regular basis to validate the calibration equipment.

3.7.8

All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

5 Specifications and Data Sheets for Materials *(2024)*

Material specifications and data sheets are to be provided to the builders by the material manufacturers. These data sheets are to include the mechanical properties of sample laminates in cured state, as guidance to the designer. The material specification and data sheets are to also include information indicating the safe use and handing of the materials as well as the first aid and medical treatment of operators in the case of contamination.

5.1 Resins, Gel Coats, Catalysts, Accelerators, Hardeners and Other Additives *(2024)*

The specifications are to indicate the contents of the resin and gel coats, type and amount of catalyst, accelerators, hardeners and other additives, as well as recommendations for storage, handling and use.

Data sheets are to denote the physical and mechanical properties of the materials in both liquid and cured form. The curing characteristics at a specified temperature are also to be provided, indicating the gel time variation with air temperature and amount of catalyst and accelerator, or amount of hardener. The mechanical properties of the resin in cured state without fiber reinforcement (i.e., matrix) are to be given. Batch data sheets are to be supplied with each delivery, indicating the physical and mechanical properties of the particular delivered batch. All resins are to be used within 90 days the shelf-life indicated for each batch subject to the storage conditions being in accordance with the manufacturer guidelines. Batch data sheets are to be retained.

5.3 Reinforcing Materials

For reinforcing material, the specification is to indicate the fiber type and form, weave, fiber orientation, weight, physical and mechanical properties.

Detailed storage records are to be maintained as part of the quality control documentation.

5.5 Core Materials

Core material specifications are to indicate the material specification number, material type, density and recommendations for storage, handling and use.

7 Receiving Materials

7.1 Resins, Gel Coats, Catalysts, Accelerators, Hardeners and Other Additives *(2024)*

The builder is to have an acceptance criteria for properties of the incoming material. The builder is to sample and test each batch to verify properties. Cured samples are to be retained for future reference in the event of subsequent problems such as rapid yellowing, sun blistering and print through. All incoming raw materials are to be tested and inspected on receipt. Following testing, the drums or containers are to be labeled "Approved" or "Rejected." "Rejected" material is to be immediately returned to the manufacturer. See Section 2-6-5.

7.3 Reinforcing Materials

Testing on incoming materials is to include a weight check and a visual inspection of a sample of the material for its physical condition. Batch data sheets are to be retained.

7.5 Core Materials

Check tests on density and moisture content for core materials are required. Batch data sheets are to be retained.

9 Laminating Procedure *(2024)*

This laminating procedure is for a standard hand lay-up technique. Different laminating techniques are subject to ABS technical assessment and approval.

9.1 Start-up

Before laminating, the following items are to be checked and complied with:

9.1.1

Clean, dry, contaminant free air is delivered to equipment.

9.1.2

All materials are at laminating premise temperature.

9.1.3 *(2024)*

Resins and gel coats are to be agitated to maintain a uniform mix. Manufacturer's recommendations are to be adhered to, do not over agitate. Curing agents, fillers and pigments are to be added in strict ratios in accordance with the resin manufacturer's recommendations.

9.1.4

The condition of the resin, gel coat and catalyst delivery system is to be checked to confirm proper pump operations, tips are clean and in good condition, seals and lines are free of leaks and that the filters are clean.

9.1.5

The equipment is to be calibrated in accordance with the equipment manufacturer's instructions. Set delivery rates, ratios and mix to the material manufacturer's instructions. Check the gel and cure times to verify calibration.

9.1.6 *(2024)*

The temperature, flow rates and catalyst ratios are to be recorded and the data are to be maintained.

9.1.7

Catalyst amount is to be determined in accordance with the manufacturer's instructions.

9.1.8 *(2024)*

The mold is to be inspected to confirm that there is adequate mold release agent, that the surface is dry and clean and that the mold temperature is the same as the laminating premise temperature.

9.3 Application of Gel Coat

9.3.1 *(2024)*

The catalyzed gel coat is to be applied by typically using multiple uniform passes of six to eight mils to build up a uniform wet thickness of 25 to 30 mils. Recommended time between passes is 15 to 30 seconds; consult the manufacturer for optimum time and for optimum gel coat thickness.

9.3.2 *(2024)*

Lamination of the skin coat is to be commenced as soon as adequate film cure has occurred in accordance with gel coat manufacturer's specification.

9.5 Lamination of Skin Coat

9.5.1

The exposed surface of gel coat is to be kept clean, free of dust and contaminants.

9.5.2

Wet film of catalyzed resin is to be applied by pouring, brushing or spraying to the entire gel coat surface. Apply at least 300 g/m^2 (1 oz/ft^2) chopped strand or other skin coat, as indicated on the approved plans, into wet resin and apply sufficient additional resin to complete wet-out of glass (i.e., resin encirclement of each individual fiber or complete impregnation of the mat, roving or cloth).

9.5.3 *(2024)*

The skin coat is to be rolled out to maintain saturation of fibers and elimination of air and voids in the skin coat. The consolidation is to be done with gentle rolling and with care not to damage the gel coat.

9.7 Main Lamination – Single Skin

9.7.1

Laminating is to be carried out by skilled workers trained and qualified to the level required by the Quality Control Plan.

9.7.2

Carry out lay-up in accordance with the lay-up schedule on the approved plans giving particular attention to type of reinforcing ply and their orientation.

9.7.3

Wet film of catalyzed resin is to be applied by pouring, brushing or spraying to the entire skin-coated surface. Apply next reinforcing ply as required, and apply it to sufficient resin to completely saturate the glass fibers. Carefully roll-out the laminate to remove air pockets and void spaces.

9.7.4

Continue as indicated in the lay-up schedule. Time between plies is to be in accordance with the material manufacturer's recommendations.

9.7.5

The approved laminate schedule is to be carefully followed with respect to the particular ply type, weight and orientation. Ply overlaps along edges and at ends and ply staggering are to be in accordance with the approved plan.

9.7.6 *(2024)*

During lay-up, guidance on gel time is to be strictly followed with regard to laminating premise temperature and the amount of catalyst. The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the resin.

9.7.7 *(2024)*

The degree of laminate cure is established by the Barcol Hardness Test. The hardness meter is to be regularly checked for calibration during use. The measured hardness values are to be in accordance with the manufacturer's recommendations for the given resin system.

9.7.8

Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid, the builder is to demonstrate to the Surveyor's satisfaction that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any adverse effect on the mechanical properties of the cured laminate.

9.7.9

Laminating is to be carried out in a sequence documented in the quality control procedure for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within the limits recommended by the resin manufacturer. Where this is not practicable, the surface of the laminate is to be prepared to improve the bond in accordance with the resin manufacturer's instructions.

9.7.10 *(2024)*

Particular attention is to be given to localized thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition of plies is required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

9.7.11

The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water, the edges of such openings are to have rounded edges and are to be sealed by two plies of 450 g/m^2 (1.5 oz/ft^2) chopped strand mat (or equivalent) reinforcement.

9.9 Main Lamination – Sandwich Laminate

9.9.1

For sandwich laminates, where applicable, single skin requirements are to be adhered to.

9.9.2 *(2024)*

The ply before the core is to be chopped strand mat. The mat is to be thoroughly wet-out with a generous application of resin. Alternatively, the core manufacturer's putty or compound may be used. The core is to be laid-up in strict accordance with the core manufacturer's instructions and approved plans. A generous coat of resin or putty, etc. is to be applied to the core and subsequent ply/chopped strand mat, are to be applied and thoroughly wet-out and rolled out. The core is to be vacuum bagged to the skins. Where vacuum bagging is not practicable, alternative lamination will be subject to ABS technical assessment and approval.

Commentary:

Alternatives to chopped strand mat may be approved so long as adherence between the core and adjacent reinforced layers can be maintained.

End of Commentary

9.9.3

Where the core material is to be laid onto a pre-molded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

9.9.4

Where the core is applied to a laminated surface, particular care is to be taken to confirm that a uniform bond is obtained. Where a core is to be applied to an uneven surface, additional building up of the surface or contouring of the core is required.

9.9.5 *(2024)*

Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type or other reinforcement compatible with the resin system and in accordance with the manufacturer's recommendation. No additional flow coating is to be applied to the foam core prior to laminating.

9.9.6

Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bond process. The primer is to seal the panels, including all surfaces between the blocks of contoured material, without completely filling the surface cells.

9.9.7 *(2024)*

Where panels of rigid core materials are to be used, the vacuum bagging techniques are to be adopted. The core is to be prepared by providing "breather" holes such that efficient removal of air under the core is maintained. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such "breather" holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer.

9.9.8 *(2024)*

Thermoforming of core material is to be carried out in accordance with the core manufacturer's recommendations. Maximum temperature limits are to be observed.

9.9.9 *(2024)*

When shaped core material are to be used for the construction of grid-scored panels, it is necessary to confirm that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the molding. The builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure is sufficient to penetrate the full depths between the core blocks. Grid-scored panels using a carrier scrim cloth are to be adopted.

9.9.10 *(2024)*

In all application procedures, after curing, excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

9.9.11 *(2024)*

Inserts in sandwich laminates are to be of a material capable of resisting impact forces and crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict compliance with the approved plans.

9.9.12 *(2024)*

The level of vacuum applied for initial lamination and during the cure period is not to be higher than that recommended by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of resin.

9.9.13

Exposed edges of openings cut in sandwich panels are to be suitably sealed. The cut edges are to be sealed with a weight of reinforcement not less than that required for the outer skin of the sandwich. Where other than an epoxy resin system is used, the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m^2 (1.5 oz/ft^2).

9.9.14 *(2024)*

Core material that is scored is to be avoided whenever possible. However, when necessary, only single cut core material is to be used in all external panels. When core material is scored, the scores are to be properly filled with bedding putty. The layer of bedding putty between the core material and the FRP skins is to be between 0.5 mm and 2 mm (0.02 in. and 0.08 in.) thick.

9.11 Release and Curing

9.11.1 *(2024)*

After completion of the lay-up, the laminated material is to be left in the mold for a period to allow the resin to cure before being removed. This period is not to be less than 12 hours or that recommended by the resin manufacturer.

9.11.2 *(2024)*

Care is to be exercised during removal from the mold to confirm that the hull, deck and other large assemblies are adequately braced and supported to avoid damage and to maintain the form of the molded structure.

9.11.3

Where female molds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to the removal from the mold unless agreed otherwise.

9.11.4 *(2024)*

Molded assemblies are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for moldings to be protected against adverse weather conditions.

9.11.5 *(2024)*

Molded assemblies are to be stabilized in the molding environment for at least 24 hours, or that recommended by the resin manufacturer, before the application of any special post cure treatment, details of which are to be submitted for approval.

9.13 Secondary Bonding

9.13.1

Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made, it is to be carried out with the resin manufacturer's recommendation, details of which are to be incorporated into the builder's quality assurance plan.

9.13.2

Internal stiffening members, internal structural bulkheads, etc. are generally secondary bonded to the hull. Secondary bonding is the application of a resin wet ply to an already fully cured surface.

9.13.3 *(2024)*

The cured laminated surface is to be sanded and thoroughly cleaned and dry. A generous coat of resin is to be applied to the cured surface and the first ply laid-on and further resin applied. The first ply is to be chopped strand mat or other reinforcement suitable for the application and the resin system. An alternative method is to use a peel ply on the cured laminate, which is to be removed and the laminate is to be lightly abraded prior to the secondary bond.

9.13.4

The overlap of the resin wet plies to the cured laminate is to be in accordance with the approved plans.

11 Inspection

11.1 General *(2024)*

Inspection is to be carried out by the builders and Surveyors, as indicated and approved in the building process description and building quality control manual. A constant visual inspection of the laminating process is to be maintained by the builder. If improper curing or blistering of the laminate is observed, immediate remedial action is to be taken. Inspections of the following are to be carried out:

i) Confirmation that the mold is clean and the releasing agent is properly applied.

ii) Confirmation of the thickness of the gel coat, uniformity and application and cure before applying laminating resin and first layer of reinforcement.

iii) Check resin formulation and mixing. Check and record amounts of base resin, catalysts, hardeners, accelerators, additives and fillers.

iv) Check that reinforcements are uniformly impregnated and well wet-out. The lay-up is to be in accordance with approved drawings and the approved plan of overlaps is to be complied with. Any variation in materials is to be brought to the attention of the ABS Materials Department.

v) Check and record resin/fiber ratios.

vi) Check that curing is occurring as specified. Immediate remedial action is to be taken when improper curing or blistering is noted.

vii) Visual overall inspection of completed lay-up is to be carried out for defects that can be corrected before it is released from the mold. The laminated parts are to be free of open voids, pits, cracks or protruding fibers.

viii) Check and record hardness of cured hull prior to release from the mold.

ix) The ambient temperature, humidity and gel time is to be monitored and recorded.

11.3 Voids

Excessive void content can reduce the overall strength of the laminate, and therefore, the laminate is to be inspected for the following:

i) There are to be no voids extending through more than one ply of laminate.

ii) There are to be no voids larger than 12 mm (0.50 in.) in their greatest dimension.

iii) There are to be no voids larger than 3 mm (0.125 in.) on each ply in any 150 mm × 150 mm (6 in. × 6 in.) area, with a maximum of six (6) total voids in this area.

iv) There are to be no more than three (3) voids larger than 3 mm (0.125 in.) on each ply in any 300 mm × 300 mm (12 in. × 12 in.) area, with a maximum of twenty (20) total voids in this area.

Note:

Interconnected voids are to be considered as a single void, and spaces occupied by foreign matter in the laminate are to be considered as voids.

13 Faults

13.1 General

All faults are to be classified according to their severity and recorded, together with the remedial action taken, in accordance with the requirements of the Quality Assurance systems.

13.3 Production Faults

Production faults are to be brought to the attention of the attending Surveyor and a rectification plan is to be agreed upon.

PART 2

CHAPTER 6

Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

SECTION 4

Quality Control

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR2	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR16	The constituent materials used in the construction are to be appropriate to achieve the specified material properties of the final composite structures.
MAT-FR17	Post curing treatment, when applicable, is to be capable of producing the specified material properties.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many possible failure mechanisms that can occur in materials associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Scope *(2024)*

A quality assurance system is to be set up in association with the building process description. The objective of the system is to measure and record compliance with approved plans and the building process description. Quality control records are to be kept in a safe location and are to be available at all times for review and routine verification by the ABS Surveyor. Compliance with the quality assurance system is required for craft built under ABS classification.

3 Definitions

3.1 Hull Construction *(2024)*

Hull construction consists of construction of the hull, deck, deckhouse and all other structure that affects the weathertight and watertight integrity of the craft. Windows, doors, hatches, rudders, skegs and keels are also part of the hull construction.

3.3 Quality Assurance Standard

The quality assurance requirements of ABS for the hull construction of small craft.

3.5 Quality Assurance *(2024)*

All activities and procedures concerned with determining whether a product or service meets specified requirements, including records and documents to verify accomplishment.

3.7 Quality Assurance System *(2024)*

The established measures for the effective functioning of the quality management. It is indicating responsibilities, activities, resources, and procedures in order to verify the builder's capability to comply with specific quality requirements. It includes the building process description.

3.9 Building Process *(2024)*

A description of the construction process, covering building facilities, material receiving procedures, laminating process, inspection and testing. A quality control program is established for monitoring and recording of the building process description.

3.11 Quality Control *(2024)*

The operational means and functions used to measure and regulate the quality of construction to the required standards by testing and inspecting the products during the fabrication.

3.13 Inspection

The process of measuring, examining, testing and comparing an item with the approved plans, approved building process and approved builder's standards.

3.15 Assessment *(2024)*

The initial inspection of the quality system at the builder's facilities to verify that all requirements are met and that the facilities are operated in accordance with the approved building process description and quality control procedures.

3.17 Audit *(2024)*

Periodic verification that the building process and quality control process are maintained as they were at the initial assessment.

3.19 System Monitoring *(2024)*

The inspection by ABS Surveyors on a regular basis of the processes, activities and necessary documentation to verify that the builder's quality system continues to be effectively implemented and functioning in accordance with the ABS approved quality assurance standard.

5 Design

5.1 Plan Review

The plans showing scantlings and arrangements and details of materials, building process description and quality assurance manual, as listed below, are to be submitted for review prior to start of production. All review amendments are to be included on the working plans.

5.3 Revisions *(2024)*

Any revisions made after plan approval are to be submitted to the attending Surveyor, who, at his discretion, may agree to the revision or require the plans to be resubmitted for approval to ABS Engineering. Where the Surveyor agrees to the revision, he is to provide the ABS Office responsible for plan approval with the details.

7 Building Process Description – Quality Control *(2024)*

A building process description is to be submitted for review. It is to cover in detail the building facilities, receipt of materials process, manufacturing, inspection and testing equipment and pertinent procedures. The relevant stages in the building process description are to be monitored and recorded in accordance with the quality assurance manual. It is to be agreed upon at which stages the Surveyor will carry out quality control monitoring and direct inspection. Direct inspection will include, but will not be limited to, final inspection on completion of construction.

9 Certification of Quality Assurance *(2024)*

At the request of the builder, ABS will carry out plan approval of the craft to be constructed and review of the Building Process Description and Quality Assurance Manual. On satisfactory completion of the review and subsequent inspection by an ABS Surveyor to verify the building process and quality assurance system are in accordance with the reviewed documents, a Quality Assurance Certificate will be issued.

The certificate is valid for one year and will be reissued each year, subject to a satisfactory audit.

All information and data submitted by the builder for approval or review under the ABS Quality Assurance program will be treated with confidence and will not be shown to or discussed with any third party without the written consent of the builder.

Builders obtaining ABS Quality Assurance by ABS will have their Certificates published, together with information on whether the craft is acquiring ABS classification.

11 Documentation of Quality Assurance System

The builder is to establish, document and maintain an effective quality assurance system to verify that the material, processes and procedures employed comply with the applicable requirements.

This documentation is to be in the form of a quality assurance manual that provides the policies, and fully details the procedures adopted to comply with the applicable requirements.

13 Personnel *(2024)*

A representative of the builder will be named to have the necessary authority and responsibility to confirm the requirements of the QA system complied with. Unless specifically approved otherwise, the quality assurance representative is to have no other duties or functions. This representative is to have the authority to stop production in the event of a serious quality problem.

The builder is to have a quality control group, adequately staffed, whose duties are carried out free of production priorities. This group is to be supervised by the builder's quality assurance representative.

Other staff whose duties affect quality, including production management, are to have specified responsibility and authority to identify, control and assess quality. During production, inspections may be carried out by production staff, provided it is checked by the builder's quality control group.

15 Internal Audit *(2024)*

Internal audits of the quality assurance system in all production areas and other areas concerned with product quality, as given in the QA manual, are to be carried out under the supervision of the builder's quality assurance representative. The audits are to be at an agreed frequency and the results are to be evaluated at a management review meeting attended by the builder's quality assurance representative and the production and testing management.

17 Documentation *(2024)*

The approved quality assurance manual, building process description, approved plans, material specifications, material data sheets, completed quality control forms, material sample and test results are to be prepared and maintained readily available for inspection by the Surveyor.

19 Purchase

19.1 *(2024)*

Materials and components incorporated into the hull construction that affect quality are to be obtained from recognized manufacturers and suppliers. Recognition may be obtained by the following:

i) Documented records of previous satisfaction in supply.

ii) Approval by a recognized independent organization to a suitable quality assurance standard.

iii) Batch sample inspection and testing against batch data sheets and approval by ABS.

iv) Satisfactory assessment and evaluation of the manufacturer's/supplier's capability or quality assurance system at the manufacturer's/supplier's plant by the builder's quality assurance representative.

19.3 *(2024)*

Records of manufacturers and suppliers are to be maintained to monitor their performance. Those with a poor record are to be considered as non-compliant and alternatives sources are to be established.

19.5 *(2024)*

Purchase requisitions are to contain all the necessary technical specification and certification details.

21 Material Receipt, Inspection and Storage

21.1

The material is to be kept separate prior to receiving inspection.

21.3

All materials are to be confirmed as identifiable to a purchase order, and that they are in a satisfactory condition, having no damage or contamination. Data batch sheets are to be provided with each delivery, and where required, certificates of conformity. Batch sample test may be required.

21.5 *(2024)*

The temperature, humidity and cleanliness of the storage spaces for resin system materials, fiber reinforcing materials and core materials are to be monitored and recorded at a frequency depicted by the QA manual.

21.7

Materials with a limited shelf life are to be used before the expiration date and in full compliance with the manufacturer's recommendations.

21.9

Where the ambient temperature of the production area differs from that of the storage area, and the material performance is affected by this temperature difference, the material is to be placed in the production area in time to allow the necessary temperature change to occur before the material is used.

21.11 *(2024)*

All material is to be fully identifiable in storage and the traceability is to be maintained throughout the life cycle from purchase and storage to production.

21.13 *(2024)*

All material known or thought to be nonconforming is to be segregated from the rest of the stock.

23 Production

23.1 *(2024)*

The necessary plans and necessary instructions are to be available to the manufacturing staff in all work areas.

Instructions are to include control of equipment and specific work instructions.

23.3 *(2024)*

All material, parts, hulls and decks during construction are to be specifically identified and are to be traceable to the plans, work instructions, etc.

23.5 *(2024)*

The work carried out through the manufacturing steps is to be carried out in accordance with the applicable building process description and monitored and recorded on documents that are part of the building process description. The builder's staff member responsible for each step of manufacturing is to sign to accept responsibility as soon as each phase is satisfactorily completed.

23.7 *(2024)*

Production areas are to have the means of controlling the ambient temperature and humidity. The respective values are to be monitored and recorded at regular intervals in accordance with the work instructions. The working areas are also to be kept adequately clean and dust free.

23.9 *(2024)*

Materials are to be taken from the stores in sufficient quantities so that they can be processed without interruptions during production. Materials waiting to be used are to be kept in conditions that will not lead to contamination, such as moisture absorption or deterioration.

23.11 *(2024)*

The production staff is to always have access to instructions on mold preparation, resin mixing, laminating, curing and release processes.

23.13 *(2024)*

The time of application of gel coat, laminating and other time sensitive processes is to be monitored and recorded in the designated work sheets.

23.15 *(2024)*

All equipment and tools in the laminating process such as gel coat and resin application systems, catalyst mixing systems, spray lay-up equipment, compressed air systems, etc. are to be maintained, serviced and calibrated at predefined intervals to confirm that they are in good working order.

23.17 *(2024)*

The list of personnel trained in the laminating processes, and their certification, is to be readily available.

25 Production Inspections and Tests *(2024)*

Inspection and tests are to be carried out at certain manufacturing steps in accordance with the building process description. The acceptance/rejection criteria are also to be in accordance with the building process description. Inspections and tests are to be carried out and recorded by authorized personnel and each inspection and test is to be signed for when satisfactorily completed. Subject to prior agreement, certain inspections may be carried out by production personnel, provided there is a system for monitoring by the quality control staff.

27 Final Inspection *(2024)*

Final inspection of each completed hull is to be carried out by the designated quality department. The quality department is to verify that the construction processes and inspections have been completed satisfactorily, documented and that no outstanding nonconforming items are remain.

29 Nonconforming Materials and Components

29.1

All materials and components considered to be nonconforming are to be clearly labeled as such and kept separated from accepted materials.

29.3 *(2024)*

There is to be a system of recording a nonconformance, for documenting the authorized corrective measures and for confirmation that the nonconformance items have been resolved.

31 Corrective Action

31.1

Guarantee claims and other customer complaints are to be recorded, together with the agreed method of rectification.

31.3

Records of guarantee claims and customer complaints, cases of nonconformance and inspection test results are to be analyzed at suitable intervals to detect trends and introduce corrective measures to reduce the probability of any recurrence.

31.5

Corrective actions are to be kept under surveillance until their effectiveness and suitability are proven satisfactory by experience.

33 Calibration and Maintenance of Equipment

33.1 *(2024)*

Production and inspection equipment is to be calibrated and maintained to confirm the procedures and criteria for workmanship and inspection can be carried out with the necessary precision and quality. The calibration of the equipment is to be carried out by an accredited or recognized body.

33.3

A list of all such equipment is to be maintained with each item specifically identified and its required calibration/maintenance marked on the item.

33.5 *(2024)*

The calibration and maintenance interval as well as the method and accuracy of the procedure for each type of equipment are to be established and documented.

33.7

Records of the calibration/maintenance process are to be maintained and are to include details of any adjustment or repairs.

33.9

Calibration is to be carried out against master instruments of known accuracy based on national or international standards or in accordance with the manufacturer's instructions.

33.11

The interval, method and results of calibration/maintenance are to be reviewed at internal audits.

35 Training

The necessary basic training, qualifications or experience for, as a minimum, the quality assurance, inspection and test personnel, and those performing the laminating and forming processes, calibration, maintenance and internal or external auditing/assessing, are to be prescribed by the builder.

37 Records

37.1

The builder is to develop and maintain records that show achievement of the required quality and the effective operation of the quality system. The following categories of documents, as a minimum, are to be retained as records after their use:

37.1.1 *(2024)*

Superseded versions of the quality assurance manual, documented procedures, work instructions and workmanship standards, internally produced standards, accept/reject criteria and representative samples, procedure approval tests and lists of recognized suppliers.

37.1.2

Working drawings and their revision history, copies of purchase orders, records of incoming, in-process and final inspections and tests, certificates of conformity for the raw materials used, records of temperature and humidity, completed nonconformance reports, guarantee claims, customer complaints, training records, internal audit reports, corrective action analysis and minutes of management review meetings.

37.3 *(2024)*

All records are to be kept for a defined period of time. Product related records are to be kept for a period as agreed upon with the client with a minimum statutory period of five-year time.

37.5 *(2024)*

All records are to be efficiently collated, held in secure storage and archieved in an appropriate manner to enable retrieval when requested.

PART 2

CHAPTER 6
Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

SECTION 5
Testing

1 General *(2024)*

1.1 Objective

This section includes requirements for the approval of manufacturers with the intent to meet the goals and functional requirements outlined in the cross referenced sections.

2 Gel Time

The builder is to establish and implement a resin gel-time control system for the gel-time desired in production. This gel time is to be within the gel time upper and lower limits recommended by the resin manufacturer. Resin mixes are to be monitored and recorded to assure proper gel times. During layup, the temperature and humidity in the laminating area is to be recorded at regular intervals. The catalyst and gel time are to be adjusted to suit any changing conditions.

3 Barcol Hardness *(2024)*

Prior to removal from the mold, the laminate is to be checked with a Barcol hardness tester at a suitable number of locations to determine the degree of cure. The Barcol hardness number of the cured laminate measured on the surface without the gel coat is to be not less than 40 and in accordance with the resin manufacturer's data. When using a Barcol hardness tester, the minimum thickness is 1.5 mm ($^{1}/_{16}$ in.). Due to variation in hardness readings on reinforced plastics, the following is to be applied in accordance to ASTM D2583 or other standard if agreed upon with ABS:

i) For a Barcol reading 30 :29 readings, with the average in accordance with the standard.

ii) For a Barcol reading 40 :22 readings, with the average calculated in accordance with the standard.

5 Burnout and Thickness *(2024)*

The builder is to conduct and record the results of a number of burnout tests, in accordance with ASTM D2584 for determining the glass/fiber content in the laminate. Other standards will be accepted upon agreement with ABS. Thickness checks are also to be performed on cutouts or plugs that have been removed from laminates to make way for through-hull and through-deck fittings. The plugs are to be identified by their location in hull.

Each burnout test for glass-reinforced laminates is to be made on a sample that is at least 25 mm (1 in.) in diameter. A record is to be made of the cured laminate thickness and the glass content by weight. Fiber content measurements for carbon and aramid (Kevlar) fiber reinforced laminates are to be carried out by acid tests. The cured laminate thickness is to comply with the manufacturer's tolerances and as indicated on the approved plans.

A visual inspection by the ABS surveyor is to be carried immediately after the mold has been removed. Delamination, misplaced plies, excess resin, dry fabric, porosity and voids, marks and surface defects are to be recorded and quantified. During the visual checks the craftsmanship is assessed, and production errors or material quality issues are identified at early stage of the construction.

7 Void Content *(2024)*

Where the extent of voids in the laminate has been deemed suspect by the attending Surveyor, the void content of the laminate is to be tested in accordance with ASTM D2734.

The void content is not to exceed 4%. Where the void content is more than 2%, additional testing may be required.

9 Laminate Properties *(2024)*

Determination of laminate properties (specific gravity, glass content, tensile strength and modulus, flexural strength and modulus, shear strength, and, where glass content is less than 40% or more than 60%, interlaminar shear strength) is to be made on the basis of destructive qualification tests. The panels are to be produced by the fabricator under environmental conditions and using resin formulations and process techniques simulating the conditions, formulations and techniques to be used in actual production.

The fabricator is to lay up the test panels at an angle of about 45°. All panels are to be tested in the as-cured condition. All test results are to be reported. ABS review of laminate design will be predicated on the quality of laminate produced by the fabricator. Laminate properties derived from qualification testing of sample panels, which are to be witnessed as necessary by the Surveyor are to be included in the process description.

Test panels may be either laid up as a qualification test sample at the time of keel lay-up or may be taken from hull cut-outs or hull laminate extension tabs.

The performance tests associated with the laminate properties are shown in 2-6-5/9 TABLE 1.

TABLE 1
Tests for Physical Properties of FRP Composites *(2024)*

Type of Composites	*Properties*	*Test*
Laminate	Flexural Strength and Modulus	ASTM D790 or D790M or ISO 178
Laminate	Shear Strength, perpendicular and parallel to Warp	ASTM D732 85
Laminate and Sandwich Laminate	Glass Content	ASTM D2584 or ISO 1172
Laminate and Sandwich Laminate	Compressive Strength and Modulus	ASTM D695 or ISO 14126
Laminate and Sandwich Laminate	Tensile Strength and Modulus	ASTM D3039 or D638 or ISO
Laminate and Sandwich Laminate	Interlaminar Shear Strength	ASTM D3846 or ISO 14130
Sandwich Laminate – Core to Skin Bond strength	Flatwise Tensile Test	ASTM C297

Type of Composites	*Properties*	*Test*
Sandwich Laminate – Core Material	Shear Strength and Modulus	ASTM C273
Sandwich Laminate – Core Material	Water resistance – strength and modulus	4 weeks in salt water (DIN 50905) at 40°C, then ASTM C393

11 Test Results *(2024)*

One complete copy of the laboratory test report is to be forwarded to the ABS Engineering Office responsible for the hull plan approval. Where test results are less than the laminate design properties, this is to be drawn to the attention of the ABS Engineering Office. One copy of all test results is to be filed in the classification survey report or hull certification report.

In the case of advanced composites, one copy of all test results is to be forwarded to the responsible ABS Engineering Office.

PART 2

CHAPTER 6
Materials for Hull Construction – Fiber Reinforced Plastics (FRP)

SECTION 6
Repair

1 General *(2024)*

1.1 Objective

1.1.1 Goals

Materials are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR1	Products are to be manufactured to a documented process. The manufacturing process is to be capable of attaining the specified material properties.
MAT-FR10	The making process is to be capable of producing products within the specified chemical limits and quality requirements.
MAT-FR16	The constituent materials used in the construction are to be appropriate to achieve the specified material properties of the final composite structures.
MAT-FR17	Post curing treatment, when applicable, is to be capable of producing the specified material properties.

The functional requirements in the cross-referenced Rules are also to be met.

Commentary:

There are many failure mechanisms that could occur in materials which could be associated with improper manufacturing practices and lack of quality control.

End of Commentary

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 General *(2024)*

This Section specifies the requirements for repairs of defects during construction. These details are also applicable for repair of damaged laminates due to collisions, allisions or other extreme forces.

All repair work is to utilize the secondary bonding technique (see 2-6-3/9.13). Therefore, additional replacement material is required to achieve the original strength of the laminate. Details of the area to be repaired, the materials to be used (resins, reinforcing materials, cores, etc.) and the repair process is to be submitted for review. Damage to the gel-coat and/or skin coat is not part of the ABS survey unless it has an adverse effect on the laminate structural layers.

3 Materials

3.1 Resins

Isophthalic polyester, vinyl ester or epoxy resins are to be used for all repairs. Special consideration will be given for the use of other resins, provided they are used in accordance with the manufacturer's recommendations. In all cases, the shipyard is to demonstrate to the satisfaction of the attending Surveyor that the resin is capable of bonding to the cured laminate of the craft being repaired.

3.3 Fiber Reinforcements

The original, primary fiber reinforcement is to be used in repair, whenever practical. Where alternative reinforcements are used, they are to be similar in type and weight to those being replaced. Dissimilar fiber types are not to be used in a repair unless they were part of the original laminate.

5 Repair Procedures – Single Skin Laminate

5.1 Damage Assessment *(2024)*

Damages can be found either by visual inspection, probing or hammer sounding of the structure. Damage can be found from indicators such as the following:

i) Cracked or chipped paint or abrasion of the surface

ii) Distortion of a structure or support member

iii) Unusual build-up or presence of moisture, oil or rust

iv) Structure that appears blistered or bubbled and feels soft to the touch

v) Surface and penetrating cracks, open fractures and exposed fibers

vi) Gouges

vii) Debonding of joints

Nondestructive examination (NDE), such as Ultrasonics, Radiography, and Thermography are to be employed, as agreed with ABS.

For the proper inspection of suspect areas, the removal of insulation, outfitting or equipment may be required. The extent of damage is to be clearly indicated on the hull and is to be agreed upon by all parties prior to removal.

Where water is found in the laminate or core, the area is to be rinsed by fresh water and be allowed to dry for a minimum of 48 hours. Work is not to be performed on the laminate until the moisture is 0.5% by weight or less.

5.3 Removal of Damaged Laminate

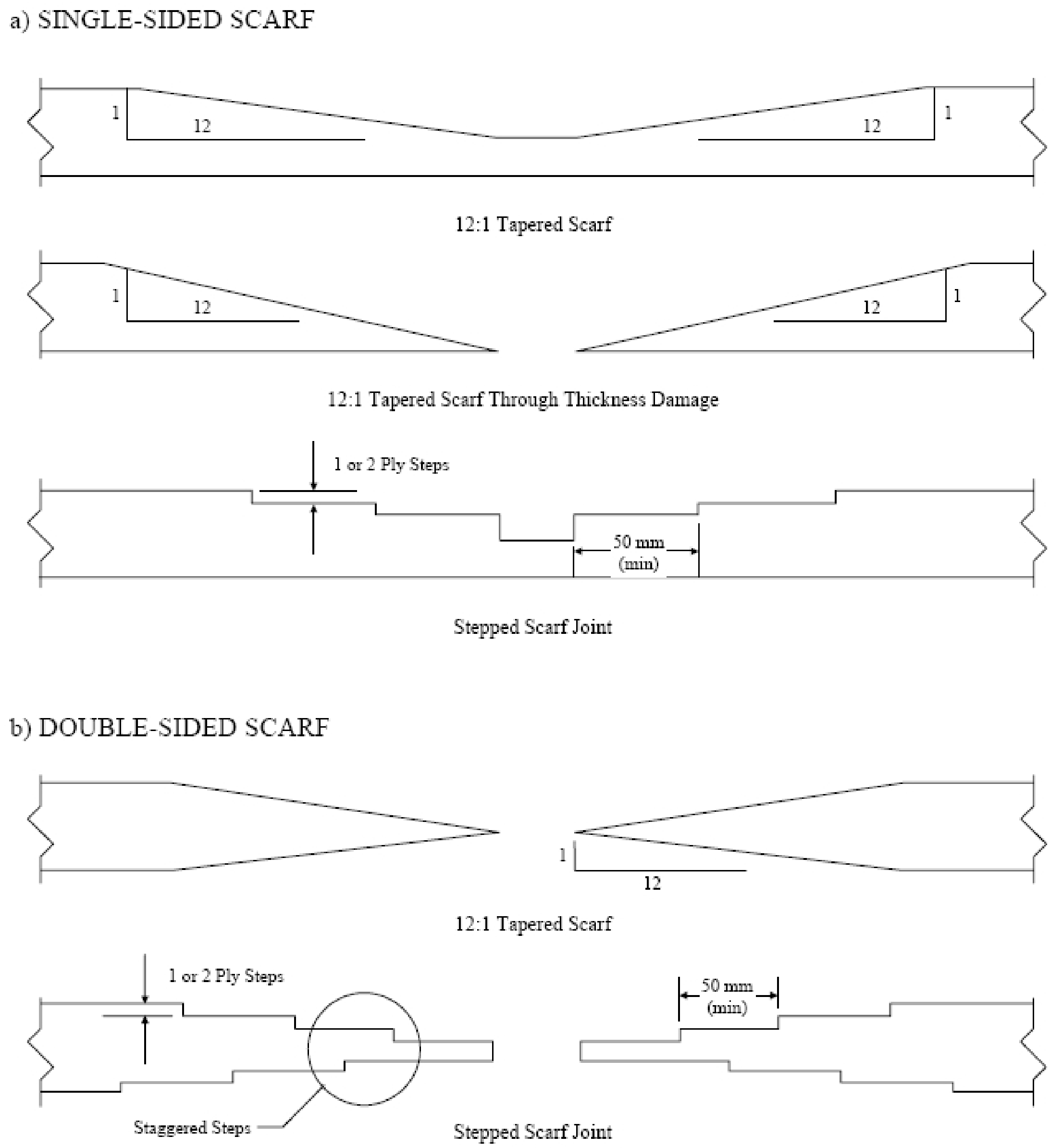
5.3.1 Damage Partially Through the Thickness

For damage extending partially through the thickness of a laminate, the damaged laminate can be removed using a course grit grinder. The damaged area is then to be shaped for repair using a fine grit grinder. See 2-6-6/5.3.2 FIGURE 1 for preparation details.

5.3.2 Damage Through the Thickness

For damage that extends through the thickness of the laminate, the damaged area can be cut away. The laminating surfaces are to be prepared as indicated in 2-6-6/5.3.1 and 2-6-6/5.3.2 FIGURE 1.

FIGURE 1
Scarf Joint Preparation

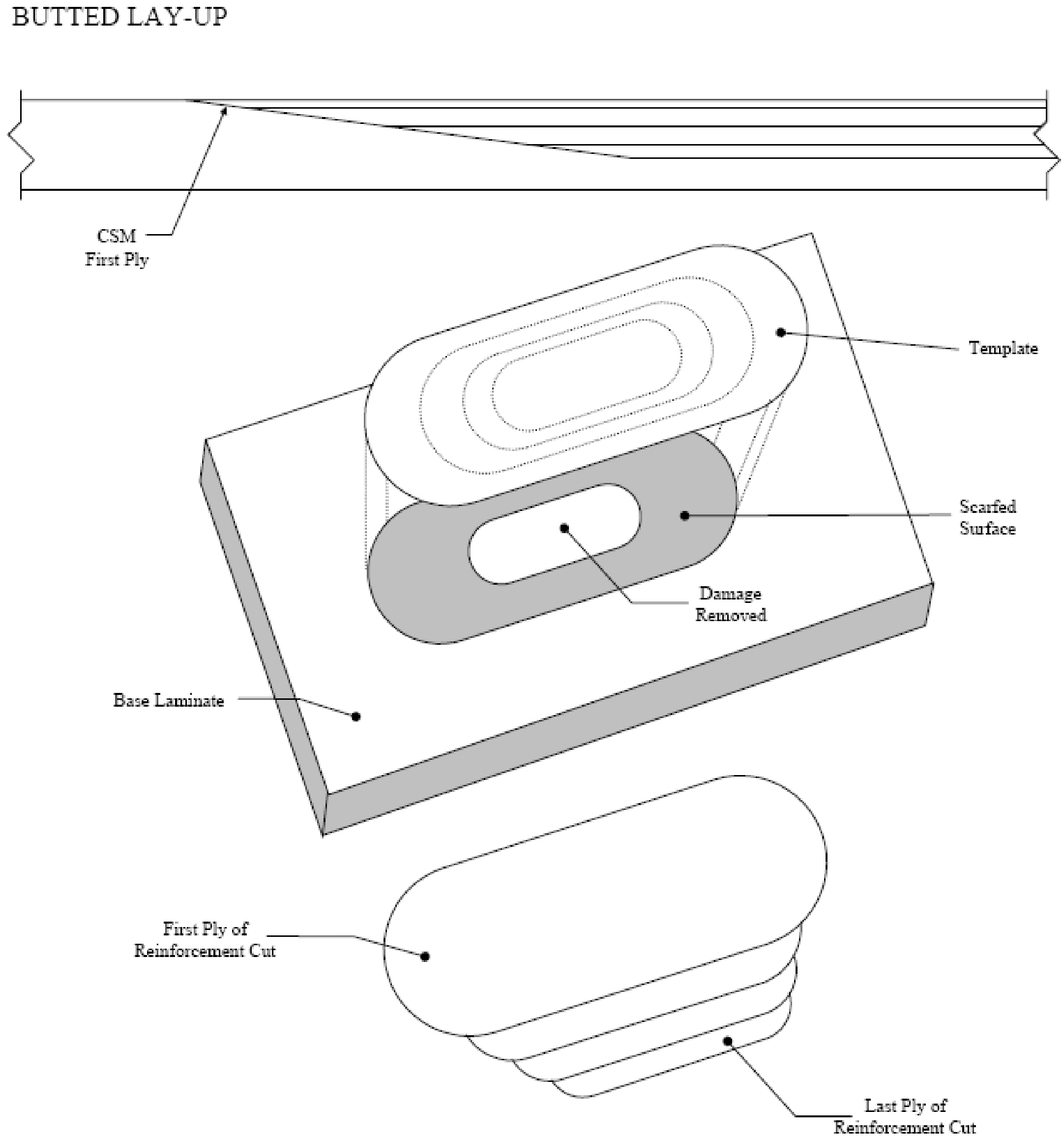


5.5 Laminating Procedures

5.5.1 General *(2024)*

All laminating procedures using secondary bonding are to comply with the requirements in 2-6-3/9.13 as applicable. The lay-up is to have the smallest ply first with each successive ply being larger, as indicated in 2-6-6/5.5.1 FIGURE 2. Each of the successive plies are to be slightly oversized and trimmed as it is being laminated in place. Care is to be taken in using undersized plies as this may create a resin pocket along the bond line. The fiber orientation is to be maintained during lamination. Alternative methods for laminating will be subject to special consideration.

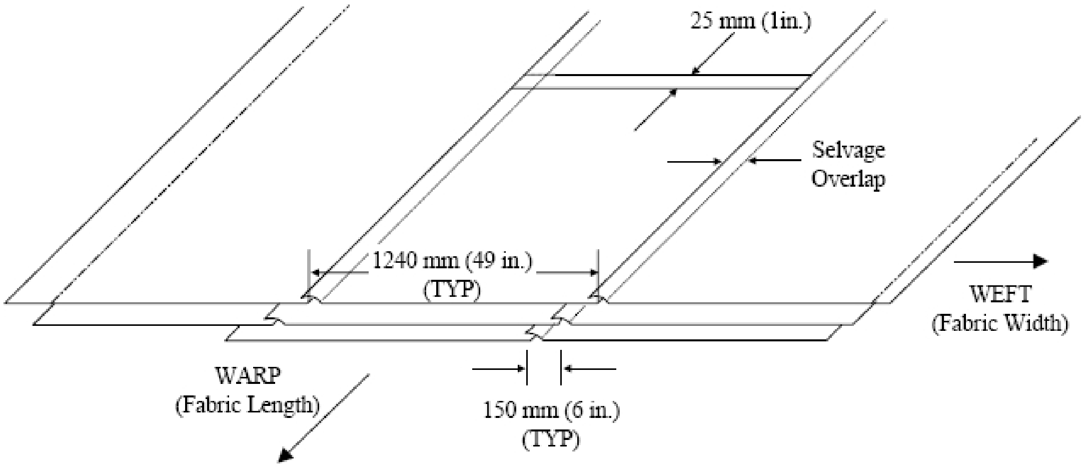
FIGURE 2
Repair Sequence



5.5.2 Overlap Requirements

Adjacent plies of reinforcement are to be overlapped when fitted with a selvage edge. Other reinforcements may be butt jointed. Edge joints in successive layers are to offset 150 mm (6 in.) relative to the underlying ply. Lengthwise joints are also to be staggered 150 mm (6 in.). The ply overlap is to be a minimum of 25 mm (1 in.). See 2-6-6/5.5.2 FIGURE 3.

FIGURE 3
Ply Overlap Requirements



5.7 Laminating Process *(2024)*

This layer is to cover the entire faying surface and is to be saturated in the laminating resin. The laminating procedures, as outlined in 2-6-3/9.7, are to be followed. When lamination is required on an inclined or overhead surface, precautions are to be taken so that the wet reinforcements do not fall. Acceptable laminating repairs can be seen in 2-6-6/5.7 FIGURE 4 through 2-6-6/5.7 FIGURE 11.

FIGURE 4
Partially Through Thickness Defect Repair

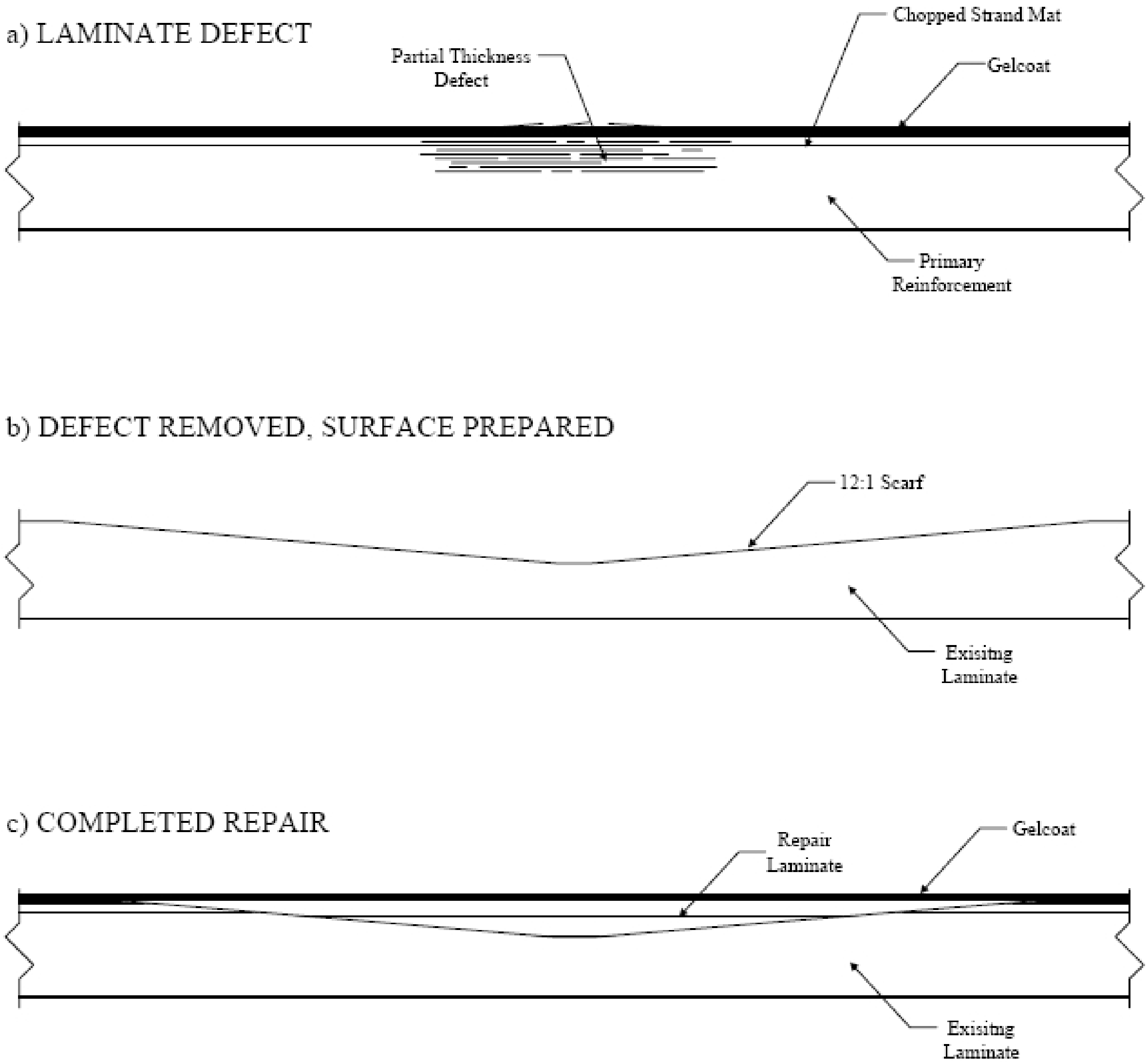
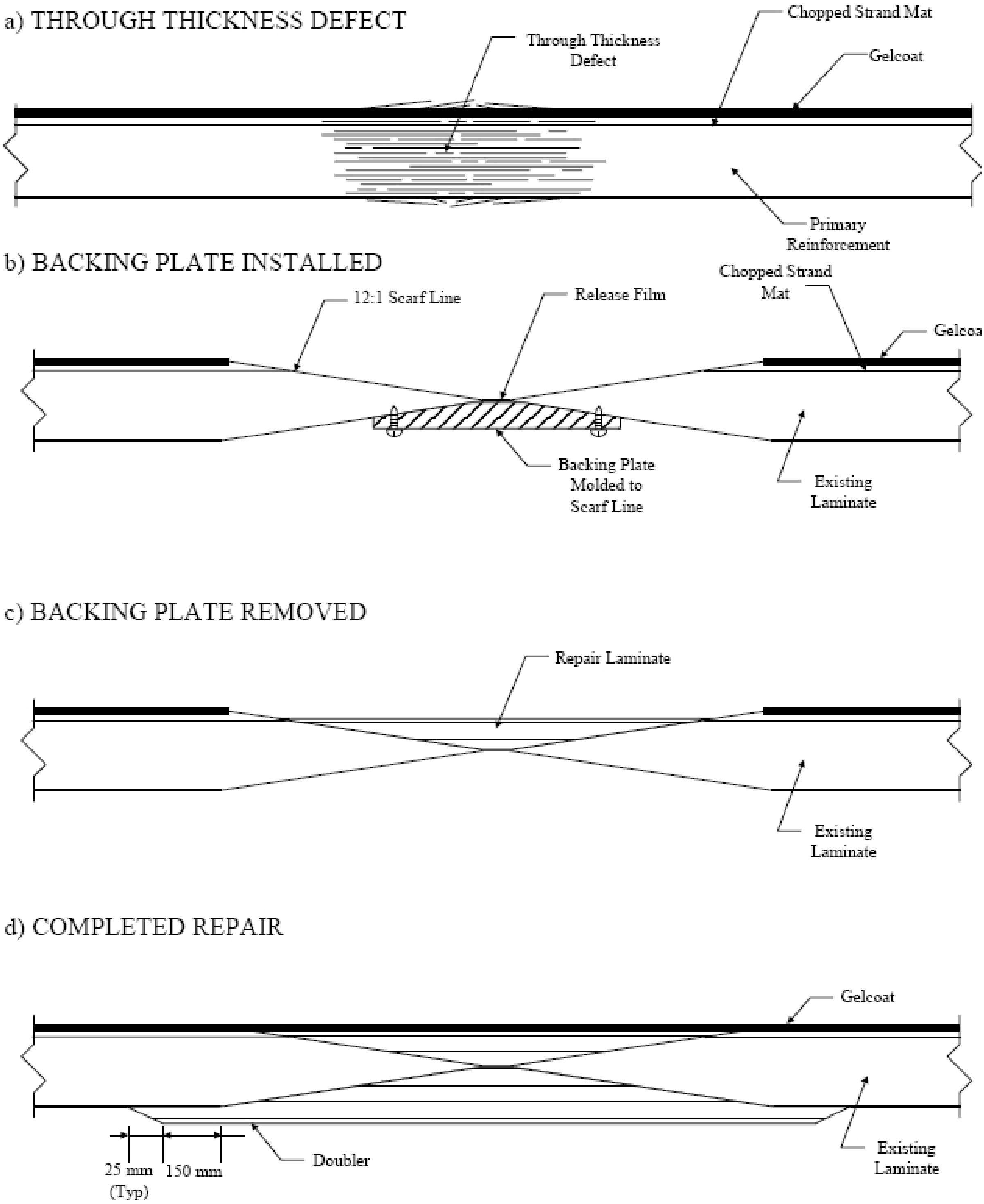
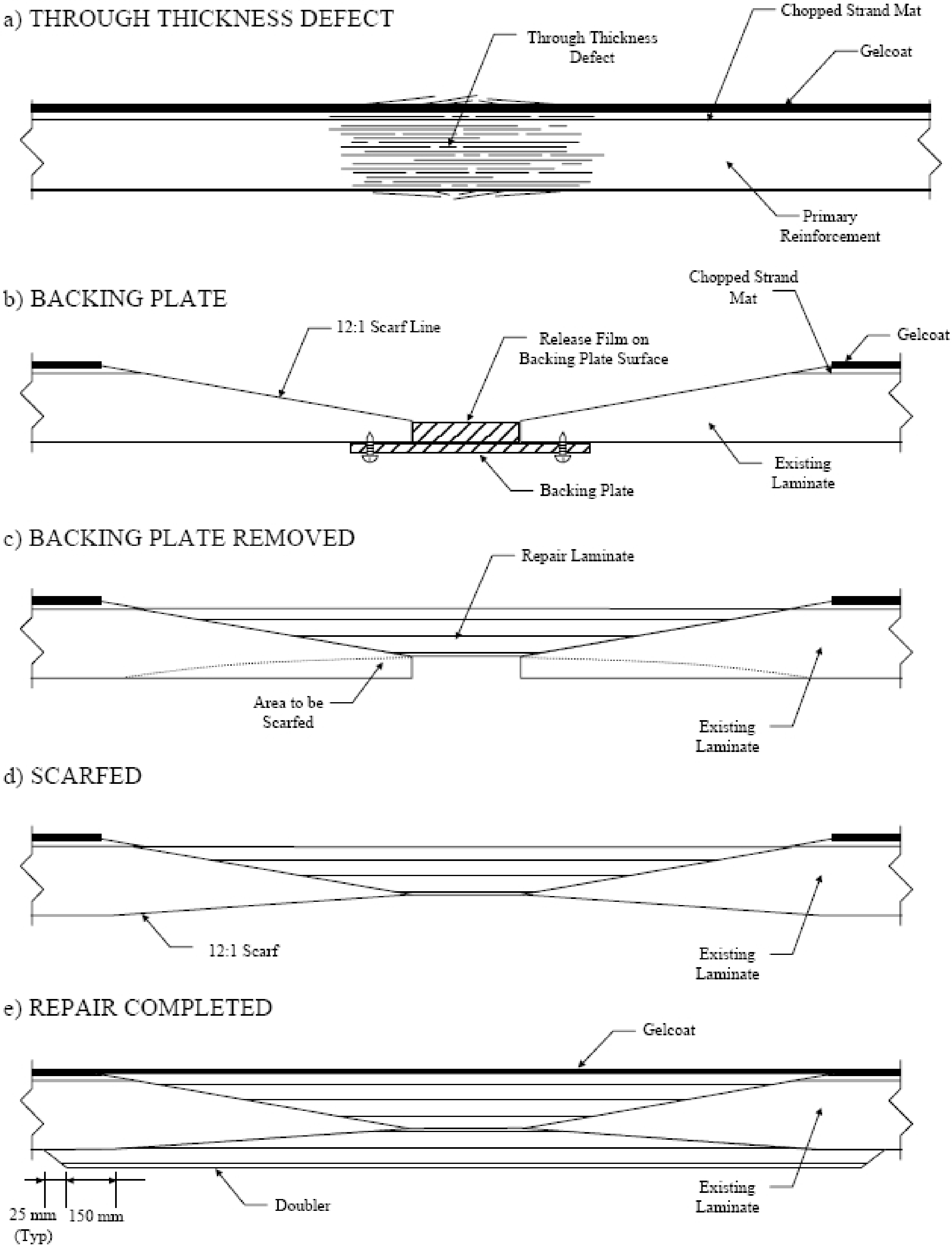


FIGURE 5
Double Sided Scarf Repair



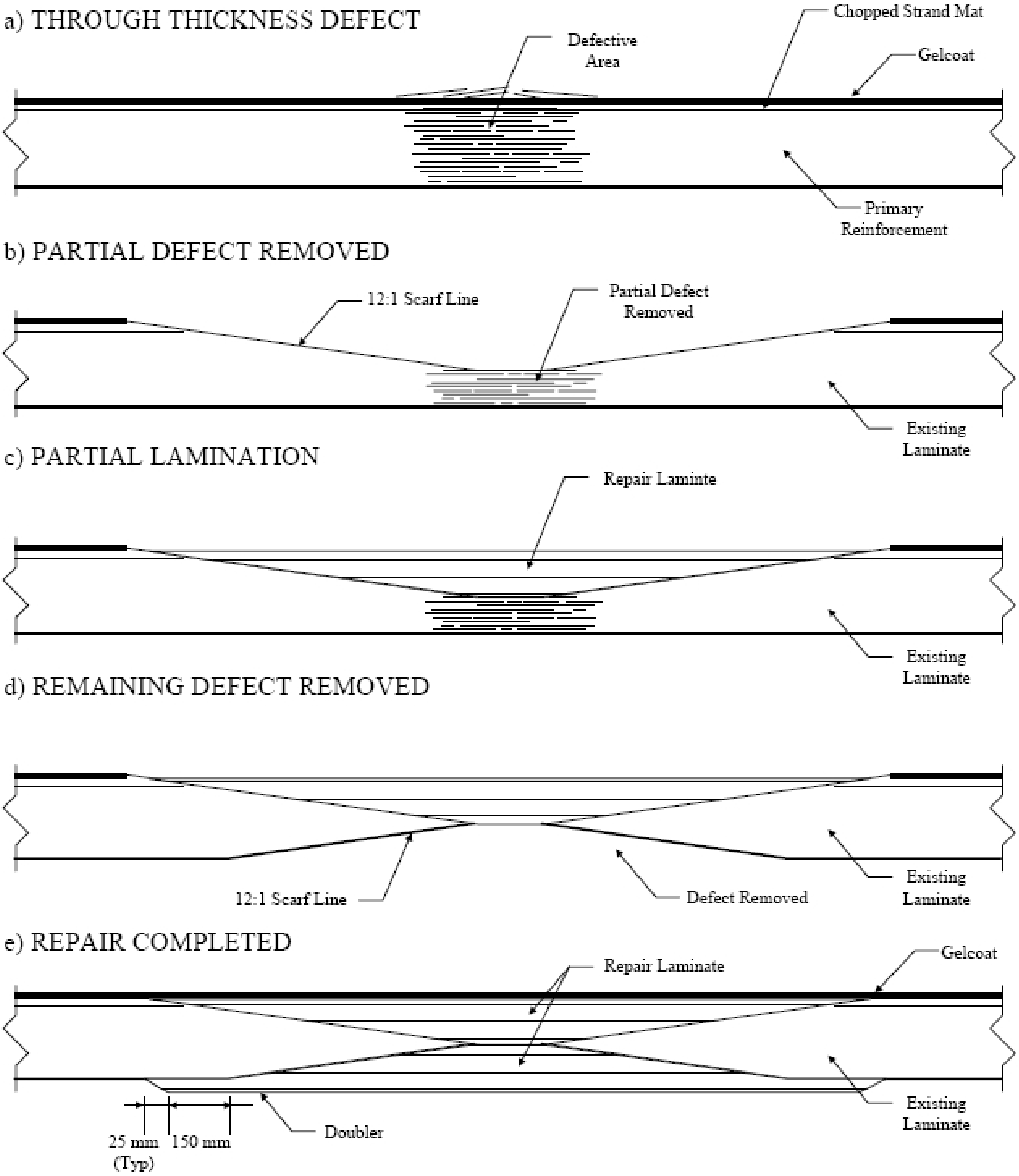
Note: Repair shown with additional plies onto non-molded side.

FIGURE 6
One Sided Scarf Repair – Backing Plate Installation



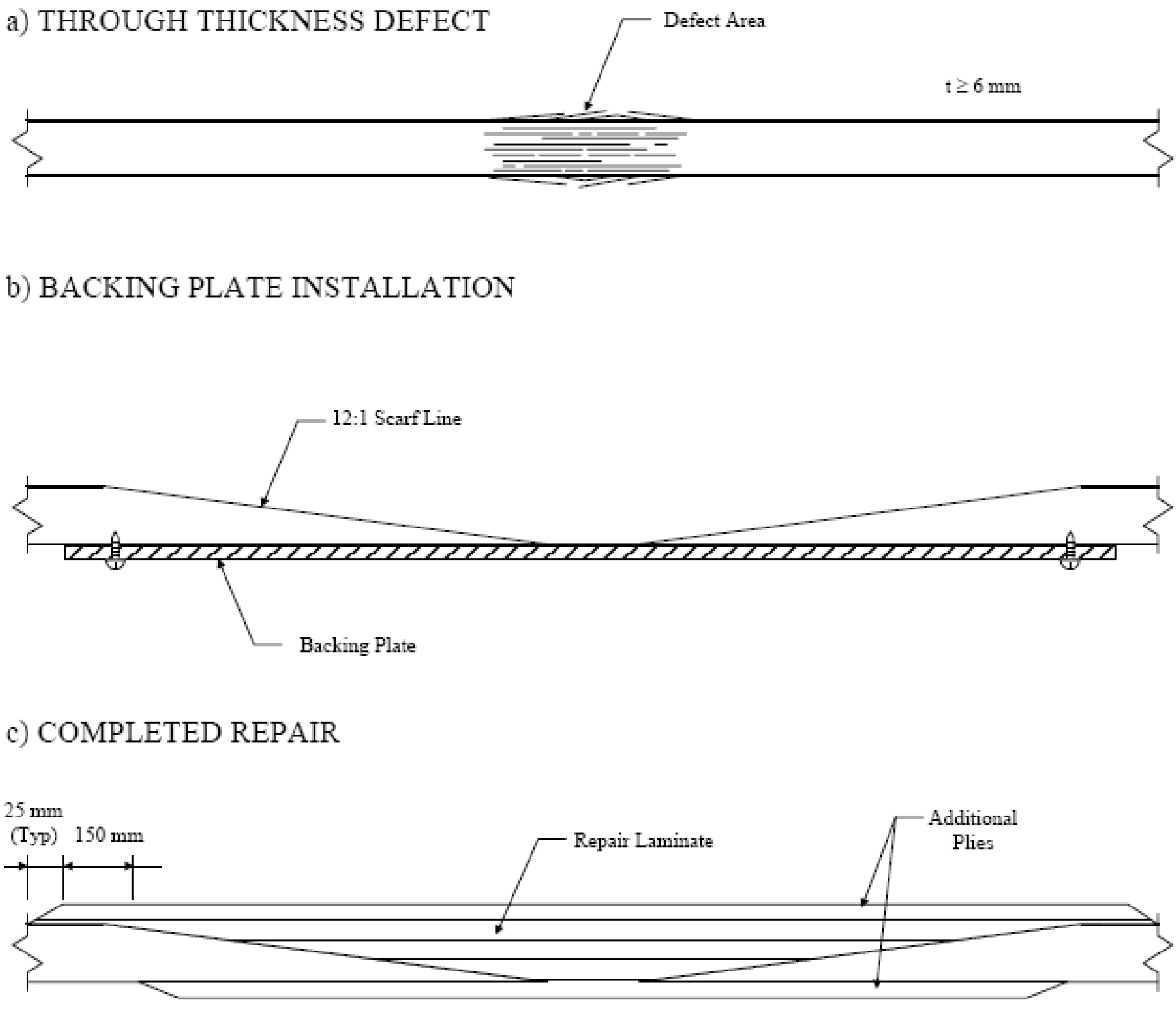
Note: Repair shown with additional plies onto non-molded side.

FIGURE 7
Repair Using Defective Section as Backing Plate



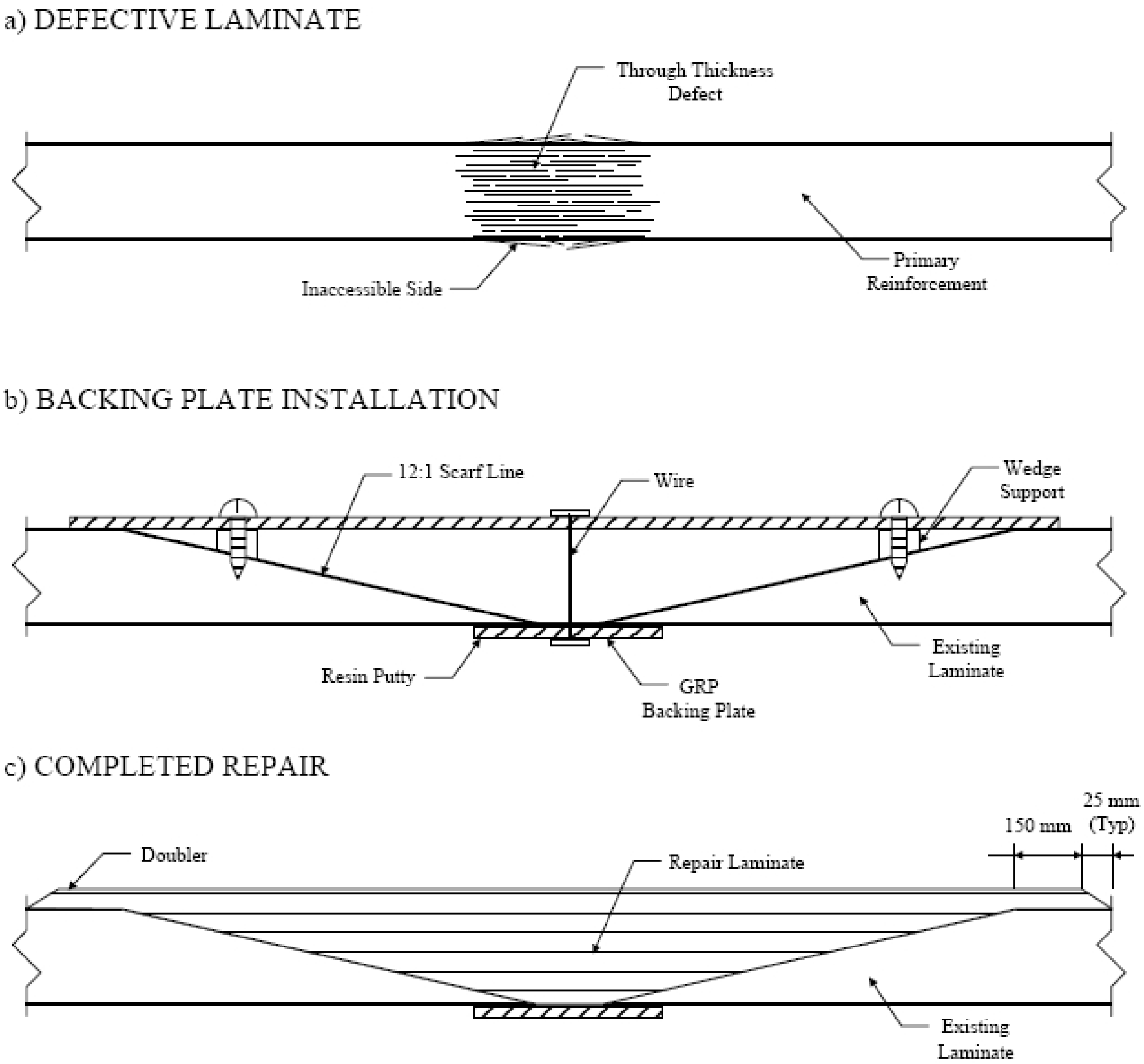
Note: Repair shown with additional plies onto non-molded side.

FIGURE 8
Single Sided Scarf Repair on Thin Laminate



Note: Repair shown with additional plies onto non-molded side.

FIGURE 9
Backing Plate Installation – Access from One Sided Repair



Note: Repair shown with additional plies onto non-molded side.

FIGURE 10
Repair in Way of Through Bolt Failure

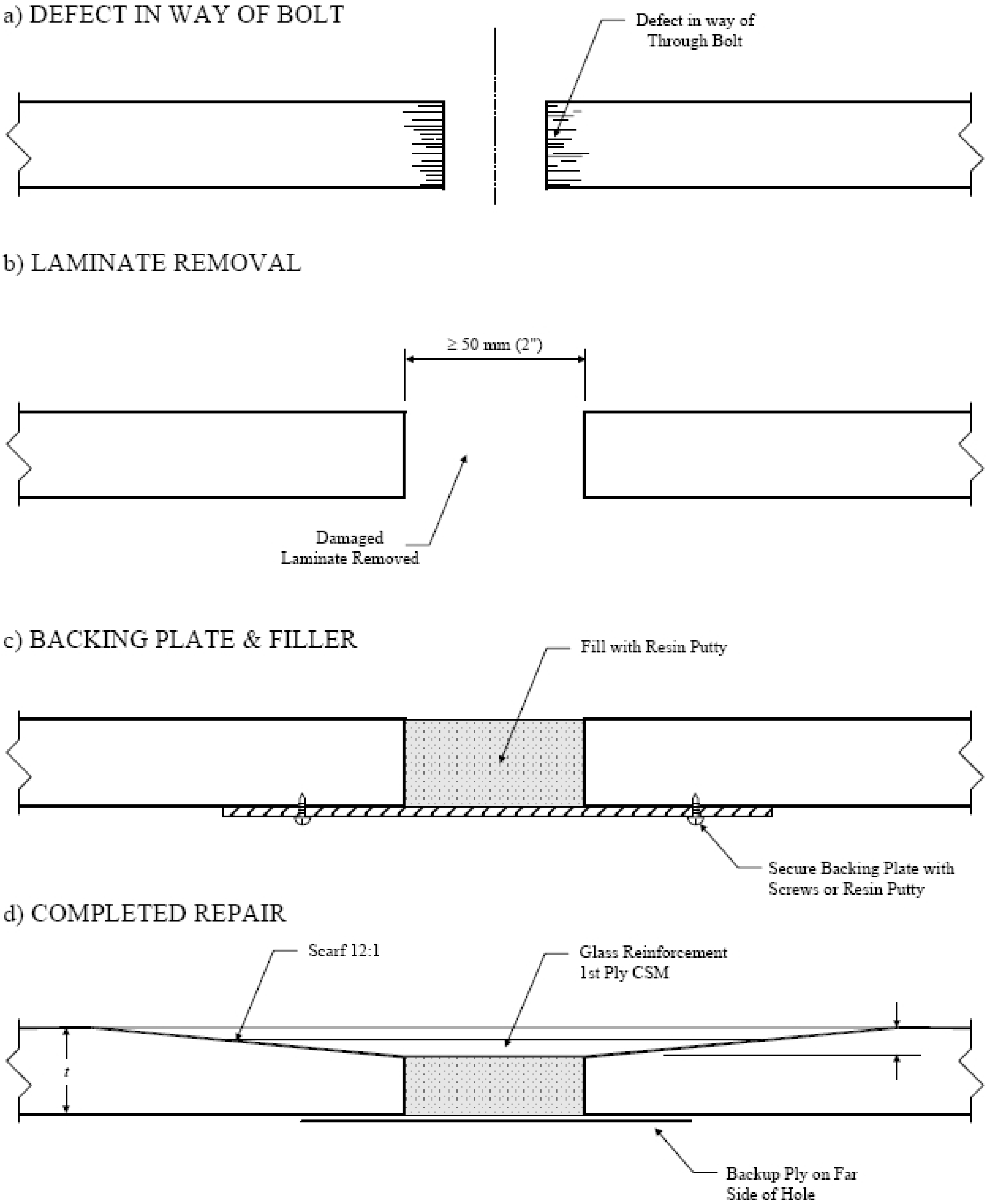
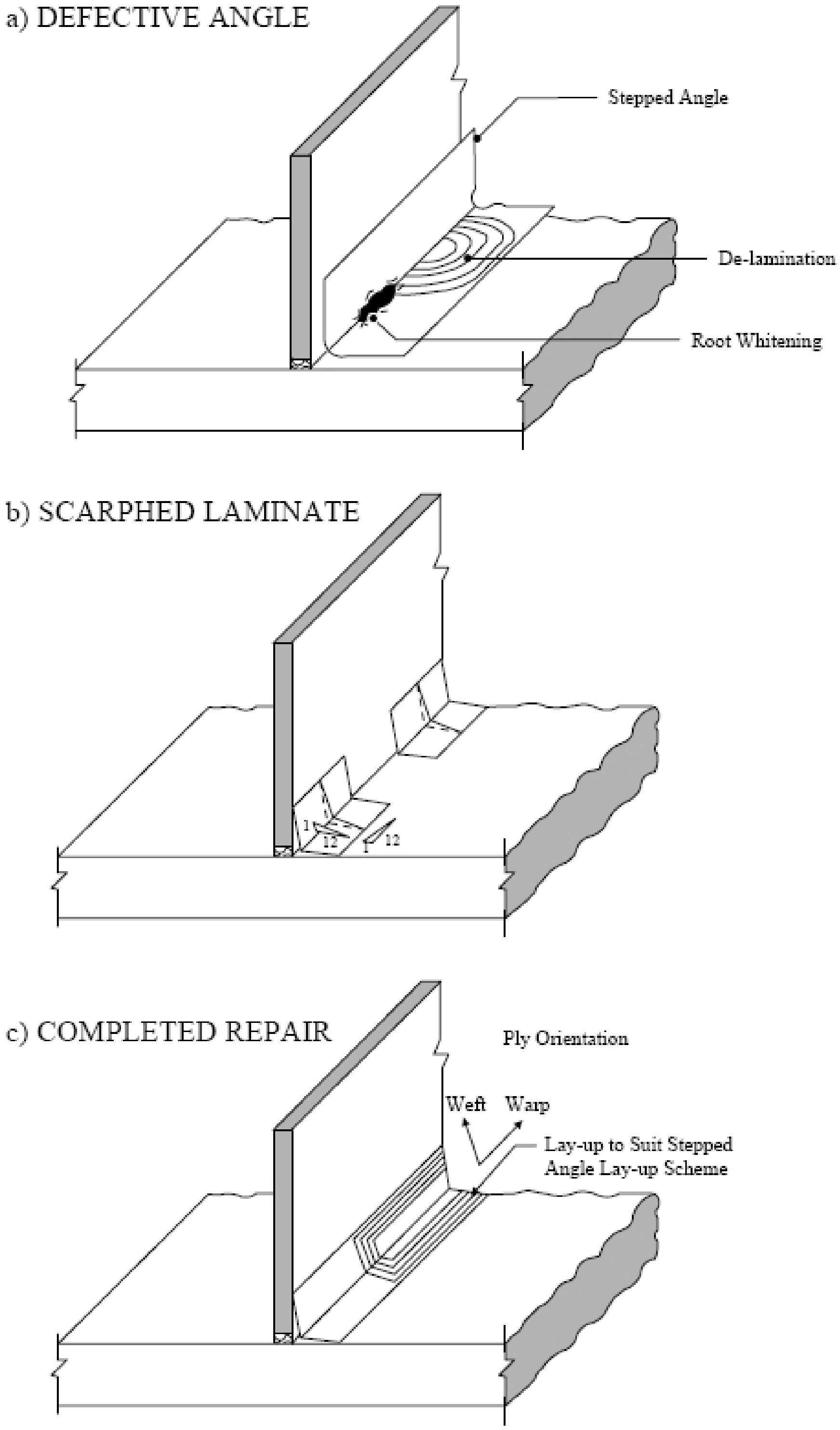


FIGURE 11
Stepped Angle Defect Repair



7 Repair Procedure – Sandwich Construction

7.1 Damage Assessment

The techniques outlined in 2-6-6/5.1 are to be applied to sandwich laminate. However, the extent of damage may extend far beyond the area of visible damage.

7.3 Removal of Damaged Laminate

The requirements in 2-6-6/5.3 are also applicable to sandwich laminates. The cut back area will be increasingly larger, proceeding from the outer skin to the inner skin.

7.5 Laminating Procedure and Process

In general, the skins of a sandwich laminate are to be as indicated in 2-6-6/5.5 and 2-6-6/5.7. The new core is to be similar in type and density to the core that is being replaced. The new core will need to be slightly thinner than the existing core to accommodate the additional repair laminate thickness. The laminating procedure outlined in 2-6-3/9.9 is to be followed.

9 Repair Acceptance

Prior to the acceptance and painting of the repair, the area is to be inspected for the following:

i) There are to be no open voids, pits, cracks, crazing, delaminations or embedded contaminates in the laminate.

ii) There is to be no evidence of resin discoloration or other evidence of extreme exotherm.

iii) There is to be no dry reinforcement as indicated by white laminate

iv) There are to be no wrinkles in the reinforcement and no voids greater than 12 mm ($^1/_2$ in.)

The surface of the repair is to be smooth and conform to the surrounding surface contour. The degree of cure is to be within 10% of the required BARCOL hardness, as indicated in 2-6-5/3.

PART 2

APPENDIX 1

Tests Required for Materials, and Responsibility for Verifying

CONTENTS

PART 2

APPENDIX 1

Tests Required for Materials, and Responsibility for Verifying

SECTION 1

List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying *(2018)*

1 Objective *(2024)*

This section includes welding filler metals selection for hull structural steels, with the intent to meet goals and functional requirements outlined in the cross-referenced sections.

3 Test and Test Data *(2024)*

i) **Witnessed Tests.** The designation (W) indicates that the Surveyor is to witness the testing unless the plant and product is approved under ABS's Quality Assurance Program.

ii) **Manufacturer's Data.** The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

iii) **Other Tests.** The designation (A) indicates 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 Rule requirements.

2-1-1 General	
2-1-1/17	Through Thickness Properties (W)

2-1-2 Ordinary-Strength Hull Structural Steel	
2-1-2/5.1	Ladle Analysis (M)
2-1-2/5.3	Product Analysis (M)
2-1-2/5.7.1	McQuaid - Ehn (M)
2-1-2/9.1	Tension Test (W)
2-1-2/11.1	Charpy V-notch Impact Test (W)

2-1-3/1 Higher-Strength Hull Structural Steel	
2-1-3/3	Ladle Analysis (M)
2-1-3/3	Tension Test (W)
2-1-3/3	Charpy V-notch Impact Test (W)

2-1-3/3	Product Analysis (M)
2-1-3/5	McQuaid - Ehn (M)

2-1-4 Materials for Low Temperature Service	
2-1-4/5	Ladle Analysis (M)
2-1-4/9.1	Tension Test (W)
2-1-4/9.3	Charpy V-notch Impact Test (W)

2-1-5 Hull Steel Castings	
2-1-5/3	Ladle Analysis (M)
2-1-5/7.1	Tension Test (W)
2-1-5/7.3	Charpy V-notch Impact Test (W)
2-1-5/13.11	Magnetic Particle Inspection (A)
2-1-5/13.11	Dye Penetrant Inspection (A)
2-1-5/13.11	Ultrasonic Inspection (A)

2-1-6 Hull Steel Forgings	
2-1-6/3	Ladle Analysis (M)
2-1-6/7.1	Tension Test (W)
2-1-6/7.3	Charpy V-notch Impact Test (W)
2-1-6/7.3	Brinell Hardness Test (BHN) (W)

2-1-7 Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks *(2017)*	
2-1-7/7	Ladle Analysis (M)
2-1-7/11	Tension Test (W)
2-1-7/11	Charpy V-notch Impact Test (W)
2-1-7/7	Product Analysis (M)
2-1-7/7	McQuaid-Ehn (M)
2-1-7/3.3 and 3.5	Corrosion Tests (A)

2-1-8 Extra High Strength Quenched and Tempered Steel ***(2018)***	
2-1-8/4	Ladle Analysis (M)
2-1-8/5	Tension Test (W)
2-1-8/5	Charpy V-notch Impact Test (W)
2-1-8/4	Product Analysis (M)
2-1-8/2	McQuaid-Ehn (M)
2-1-8/11	Ultrasonic Inspection (W)

2-2-1 Anchors	
2-2-1/7.1	Proof Test (W)
2-2-1/7.3	Product Test (W) - See 2-2-1/7.3.1 TABLE 1 and 2-2-1/7.3.1 TABLE 2

2-2-2 Anchor Chain	
2-2-2/13.2	Ladle Analysis (M)
2-2-2/13.5, 2-2-2/17.15 and 2-2-2/23.3	Tension Test (W)
2-2-2/13.7 and 2-2-2/23.3	Bend Test (W)
2-2-2/13.9, 2-2-2/17.15 and 2-2-2/23.3	Charpy V-notch Impact Test (W)
2-2-2/17.1, 2-2-2/17.11 and 2-2-2/23.13	Breaking Test (W)
2-2-2/17.1,2-2-2/17.13 and 2-2-2/23.15	Proof Test (W)
2-2-2/23.9	Magnetic Particle Inspection (A)
2-2-2/23.11	Brinell Hardness Test (W)

2-2-2/25 Unstudded Short-link Chain	
2-2-2/25.1	Ladle Analysis (M)
2-2-2/25.1	Tension Test (W)
2-2-2/25.1	Bend Test (W)
2-2-2/25.3	Breaking Test (W)
2-2-2/25.3	Proof Test (W)

2-3-2 General Requirements for All Grades of Steel Plates for Machinery, Boilers, and Pressure Vessels	
2-3-2/3.3.1	Ladle Analysis (M)
2-3-2/3.3.1	Product Analysis (M)
2-3-2/5.1	Test Specimens (W)
2-3-2/5.3	Tensile Properties (W)

2-3-3 Seamless Forged-Steel Drums	
2-3-3/1.5	Tension Tests (W)

2-3-4 Seamless-Steel Pressure Vessels	
2-3-4/3	Tension Test (W)
2-3-4/5	Flattening Test (W)
2-3-4/7	Hydrostatic Test (W)
2-3-4/9	Thickness Test (W)

2-3-5 Boiler and Superheater Tubes	
2-3-5/9	Chemical Composition (M)
2-3-5/17	Tensile Properties (W)
2-3-5/19	Flattening Test (W)

2-3-5/21	Reverse Flattening Test (W)
2-3-5/23	Flange Test (W)
2-3-5/25	Flaring Test (W)
2-3-5/27	Crush Test (W)
2-3-5/29	Hardness Test (W)
2-3-5/31	Hydrostatic Test (W)
2-3-5/33	Nondestructive Examination (A)
2-3-5/39	Thickness Test (A)

2-3-6 Boiler Rivet and Staybolt Steel and Rivets	
2-3-6/5	Tensile Properties (W)
2-3-6/7	Bending Properties (Bars) (W)
2-3-6/13.1	Bending Properties (Rivets) (W)
2-3-6/13.3	Flattening Test (W)

2-3-7 Steel Machinery Forgings	
2-3-7/1.3.7	Chemical Composition (M)
2-3-7/1.7.1	Tensile Properties (W)
2-3-7/1.7.3	Charpy V-notch Impact Test (W)
2-3-7/1.13.1	Surface Inspection of Tailshaft Forgings (W)
2-3-7/1.13.3	Ultrasonic Examination of Tail Shaft Forgings (A)
2-3-7/1.11	Hardness Test (W)

2-3-8 Hot-rolled Steel Bars for Machinery	
2-3-8/2.7	Those listed in Section 2-3-7 above

2-3-9 Steel Castings for Machinery, Boilers, and Pressure Vessels	
2-3-9/3	Chemical Composition (M)
2-3-9/7.1	Tensile Properties (W)
2-3-9/7.3	Charpy V-notch Impact Test (W)
2-3-9/15 and 2-3-9/17	Magnetic Particle or Dye Penetrant Inspection (W)

2-3-10 Ductile (Nodular) Iron Castings	
2-3-10/11	Tension Tests (W)
2-3-10/7	Chemical Composition (M)

2-3-11 Gray-iron Castings	
2-3-11/10	Tension Test (W)

2-3-12 Steel Piping	
2-3-12/9	Chemical Composition (M)

2-3-12/13	Product Analysis (M)
2-3-12/23	Tension Tests (W)
2-3-12/25	Bend Test (W)
2-3-12/27	Flattening Test (W)
2-3-12/29	Hydrostatic Test (W)
2-3-12/31	Nondestructive Examination (A)
2-3-12/37	Thickness Test (A)

2-3-13 Piping, Valves and Fittings for low Temperature Service [Below -18 °C (0 °F)]	
2-3-13/11	Chemical Composition (M)
2-3-13/13	Mechanical Test (M) [(W) for Piping]
2-3-13/15	Impact Properties (M) [(W) for Piping]

2-3-13 Valves on Vessels Intended to Carry Liquefied Gases in Bulk for Low Temperature Service [at or Below -55°C (-67°F)] ***(2006)***	
2-3-13/11	Chemical Composition (M)
2-3-13/13	Mechanical Test (W)
2-3-13/15	Impact Properties (W)

2-3-13 Valves on Vessels Intended to Carry Liquefied Gases in Bulk for Low Temperature Service [Above -55°C (-67°F)] ***(2006)***	
2-3-13/11	Chemical Composition (M)
2-3-13/13	Mechanical Test (M)
2-3-13/15	Impact Properties (M)

2-3-14 Bronze Castings	
2-3-14/3.3	Chemical Composition (M)
2-3-14/3.9	Tensile Properties (W)
2-3-14/7.5	Dye Penetrant Inspection (W)

2-3-15 Austenitic Stainless Steel Propeller Castings	
2-3-15/13	Dye Penetrant Inspection (W)
2-3-15/5	Chemical Composition (M)
2-3-15/7	Tensile Properties (W)

2-3-16 Seamless Copper Piping	
2-3-16/9	Chemical Composition (M)
2-3-16/11	Tension Test (W)
2-3-16/13	Expansion Test (W)
2-3-16/15	Flattening Test (W)

2-3-16/17	Hydrostatic Test (W) (M)
2-3-16/23	Dimensions (A)

2-3-17 Seamless Red-brass Piping	
2-3-17/7	Chemical Composition (M)
2-3-17/9	Expansion Test (W)
2-3-17/11	Flattening Test (W)
2-3-17/13	Mercurous Nitrate Test (M)
2-3-17/15	Bend Test (W)
2-3-17/17	Hydrostatic Test (W) (M)
2-3-17/23	Dimensions (A)

2-3-18 Seamless Copper Tube	
2-3-18/9	Chemical Composition (M)
2-3-18/11	Tension Test (W)
2-3-18/13	Expansion Test (W)
2-3-18/15	Flattening Test (W)
2-3-18/17	Hydrostatic Test (W) (M)
2-3-18/23	Dimensions (A)

2-3-19 Condenser and Heat Exchanger Tube	
2-3-19/9	Chemical Composition (M)
2-3-19/11	Tension Test (W)
2-3-19/13	Expansion Test (W)
2-3-19/15	Flattening Test (W)
2-3-19/17	Nondestructive Examination (A)
2-3-19/19	Hydrostatic Test (W) (M)
2-3-19/27	Dimensions (A)

2-3-20 Copper-Nickel Tube and Pipe	
2-3-20/9	Chemical Composition (M)
2-3-20/11	Tension Test (W)
2-3-20/13	Expansion Test (W)
2-3-20/15	Flattening Test (W)
2-3-20/17	Nondestructive Examination (A)
2-3-20/19	Hydrostatic Test (W) (M)
2-3-20/27	Dimensions (A)

2-3-21 Monel Pipe and Tube	
2-3-21/9	Chemical Composition (M)

2-3-21/11	Tension Test (W)
2-3-21/13	Flattening Test (W)
2-3-21/15	Flare Test (W)
2-3-21/17	Flange Test (W)
2-3-21/21	Hydrostatic Test (W) (M)
2-3-21/23	Nondestructive Examination (A)
2-3-21/29	Dimensions (A)

PART 2

APPENDIX 1

Tests Required for Materials, and Responsibility for Verifying

SECTION 2

Physical, Chemical, Mechanical Properties to be Considered for Design

(2024)

The following is a list of properties that are considered when selecting materials to meet the design requirements for the intended application.

1) Physical Properties typically considered when selecting materials for a given application

- ***a)*** Density
- ***b)*** Specific heat
- ***c)*** Electric resistivity
- ***d)*** Melting or boiling point
- ***e)*** Thermal conductivity
- ***f)*** Coefficient of thermal expansion
- ***g)*** Coefficient of friction

2) Chemical Composition is to be considered for corrosion resistance, weldability, final mechanical properties

3) Mechanical Properties to be considered for designing to a given load/force (such as tensile or compressive or shear or bending or torsion or bearing or hoop stress or buckling)

- ***a)*** Yield Strength
- ***b)*** Ultimate Tensile Strength
- ***c)*** Elongation
- ***d)*** Reduction of Area
- ***e)*** Modulus of Elasticity
- ***f)*** Toughness for a given designs service temperature (including at lower temperatures)

4) Hardness to be considered for wear/abrasion resistance.

5) Fracture Toughness Parameter (K, CTOD or J) can be considered to perform engineering critical assessment (ECA) to,

- ***a)*** Eestablish structural integrity of a structure (including life extension)
- ***b)*** Waive PWHT in certain cases

c) Determine acceptable flaw size

6) Fatigue properties (S-N Curves or Fatigue Crack Growth Rate (FCGR) curves) to be considered for designing to withstand cyclic loading

7) Formability is to be considered for ease of manufacturing and potential loss of ductility and toughness

8) Machinability is to be considered for ease of manufacturing

9) Weldability (Carbon Content, Carbon Equivalent) is to be considered when the items/components are welded

10) Other properties to be considered based on application and operating environment

a) Hardenability of steels, when designing high-strength materials or gears or materials with large cross sectional areas

b) Abrasion resistance, when materials are in contact and may result in loss of material due to mechanical action (repeated rubbing or wear)

c) Strain age properties, when materials are formed and welded and which may result in loss of ductility and toughness

d) For elevated design temperatures, calculations are to consider the effects of temperature on tensile properties. For steels, temperatures above 121°C (250°F)

e) Toughness at low temperatures, to avoid brittle fracture

f) Creep properties, when operating temperature is over 0.4 times the melting point of the metal

g) Corrosion resistance, when exposed to different fluids which lead to loss of material

h) Galvanic compatibility, when dissimilar metals are connected and come in contact with an electrolytic solution

i) Environmental Assisted Cracking (EAC) (such as Hydrogen Embrittlement, Stress Corrosion Cracking, Sulfide Stress Cracking) susceptibility, when materials are exposed to fluids such as Hydrogen, Carbon dioxide (CO_2), Ammonia, Sulfides, Chlorides, Oxides, and acids

PART 2

APPENDIX 2

Requirements for the Approval of Filler Metals

CONTENTS

PART 2

APPENDIX 2

Requirements for the Approval of Filler Metals

SECTION 1

General

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of welding consumables, with the intent to meet the goals and functional requirements outlined in the cross-referenced sections.

1.2 Condition of Approval

The scope and conditions of classification contained in Part 1A, Chapter 1 of the ABS *Rules for Conditions of Classification (Part 1A)* are applicable to the approval of welding filler metals, insofar as they are appropriate. Approval will be for each plant of each manufacturer carrying out its own quality control inspection and certification.

1.3 Approval Procedure *(1 October 1993)*

Welding filler metals intended for hull construction will be approved by ABS, subject to compliance with the requirements and test schedules as outlined herein. The requirements are based on the following:

1.3.1

Guarantee by the manufacturer of the minimum properties

1.3.2

Inspection of the manufacturing facility by an ABS Surveyor

1.3.3

Testing of selected samples

The test assemblies are to be prepared and tested in the presence of an ABS Surveyor. The Surveyor is to be satisfied that the manufacturer's plant and method of filler metal production are capable of ensuring reasonable uniformity in production. ABS is to be notified of any alterations proposed to be made in the production of filler metals.

1.5 Aluminum Filler Metals

Approval of aluminum filler metals is covered in Section 2-A2-5.

3 Grading

3.1 ABS Grades *(1 July 2019)*

Filler metals are divided into three groups based on the steel for which they are intended.

Ordinary-Strength Steel (2-1-2/15.9 TABLE 1 through 2-1-2/15.9 TABLE 4)	No suffix.
Higher-Strength Steel (2-1-3/7.3 TABLE 1 through 2-1-3/7.3 TABLE 4)	Suffix Y and Y400
Extra High-Strength Steel (2-1-8/4.1 TABLE 4A and 2-1-8/5.11 TABLE 5A)	Suffix YQ420 through YQ960

Each group is further divided into multiple levels based on the strength and/or toughness, 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 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2.

3.3 Other Standards *(2024)*

At the option of the manufacturer, filler metals may be approved to a recognized national standard. The required tests and procedures for such approval are to be in accordance with the specified standard. In addition, annual inspection and testing are to be carried out for continued approval.

3.5 Special Properties

Welding filler metals may be approved 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 Manufacturer's Guarantee *(1 October 1994)*

Each plant of the manufacturer is to file an application for each filler metal indicating the following:

- Specification and Grade/Classification
- Electrode (wire) size and welding position
- Flux or shielding gas
- Current/Polarity
- Recommended volts and amperage
- Guaranteed all-weld-metal chemical and mechanical properties
- Guaranteed hydrogen content (for H15, H10, H5, Y or Y400 designation)

7 Plant Inspection

7.1 Initial Inspection

Before marketing the product, each plant manufacturing welding filler metals submitted for ABS approval is to be inspected by an ABS Surveyor to satisfy himself that the facilities, production method, quality assurance procedures, etc., in that plant are adequate to maintain uniform and acceptable quality in production.

The Surveyor is also to satisfy himself that the testing machines are maintained in an accurate condition and that a record of periodical calibration is maintained up to date.

Where a plant approved by ABS intends to commence production of a new product, plant inspection may be required for the facilities, production methods, and quality control procedures for the new product.

7.3 Annual Inspection *(2024)*

Each plant manufacturing ABS-approved welding filler metals is to be inspected by an ABS Surveyor annually. These inspections are to be completed and reported within one year after the initial approval date, and repeated annually so as to provide at least an average of one annual inspection per year. The extent of the inspection is as indicated in 2-A2-1/7.1. Special consideration for equivalent arrangements may be accepted subject to ABS technical assessment and approval.

9 Test Requirements

9.1 General

When the plant inspection required in 2-A2-1/7 is completed, 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 specimens are to be in accordance with the following:

9.3 Test Plate Material

9.3.1 Deposited Metal Test and Diffusible Hydrogen Test *(2010)*

Except as indicated below, any grade of ordinary-strength or higher-strength hull structural steel may be used for the preparation of all test assemblies.

For the deposited metal test assemblies of YQ Grades, fine grain structural steel compatible with the properties of the weld metal is to be used. Alternatively, other steel may be used, provided the groove is buttered with the filler metal or, if deposited metal testing is carried out with a process not suitable for buttering, buttering may be carried out using another process and a filler metal of equivalent chemical composition.

9.3.2 Butt Weld Test and Fillet Weld Test *(1 July 2019)*

For butt weld test assembly and fillet weld test assembly, 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

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

(XXX/ZZ = 420/43, 460/47, 500/51, 550/56, 620/63, 690/70, 890/91, and 960/98)

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).

9.3.3 Ordinary and Higher-strength Filler Metals (Dual Approvals) *(2024)*

The required deposit metal test assemblies may be made using either ordinary or H32/36 higher-strength hull structural steel. The required butt weld test assemblies are to be made 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 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

Dual approval of Y400 grade filler metals will be subject to ABS technical assessment and approval.

9.3.4 Electroslag or Electrogas Welding for Higher-Strength Steel *(2005)*

For unrestricted approval, the test plate is to contain niobium close to its maximum allowable limit of 0.05%. Where such a plate is not used, the filler metal approval may be restricted to plates other than niobium treated.

11 Welding Conditions

The welding conditions used, such as amperage, voltage, travel speed, etc., are to be held within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the welding of the test assemblies, unless specified otherwise by the applicable standard of 2-A2-1/3.3.

13 Chemical Analysis *(2009)*

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer and is to include the content of all significant alloying elements (e.g., those identified in an AWS filler metal specification). Results of the analysis is not to exceed the limit values specified in the standard or by the manufacturer, the narrower tolerances being applicable in each case.

15 Deposited Metal Tension Test

15.1 Specimen Type and Preparation

The deposited metal tension test specimens are to be machined to the dimensions indicated in 2-A2-1/33 FIGURE 1, care being taken that the longitudinal axis coincides with the center of the weld and the mid-thickness of the plate.

15.3 Hydrogen Removal

The tension test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for hydrogen removal, prior to testing.

15.5 Test Requirements *(1 October 1994)*

The values of tensile strength, yield stress and elongation are to be recorded. The results are to conform to the requirements of 2-A2-1/33 TABLE 1.

17 Butt Weld Tension Test

17.1 Specimen Type and Preparation

The butt weld tension test specimens are to be machined to the dimensions indicated in 2-A2-1/33 FIGURE 2. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

17.3 Test Requirements *(1 October 1994)*

The results are to conform to the tensile strength requirement of 2-A2-1/33 TABLE 1. The position of the fracture is to be reported.

17.5 Retest *(2024)*

See requirements indicated in 2-A2-1/33.

19 Impact Test

19.1 Specimen Type and Preparation *(2024)*

The impact test specimens are to be of the Charpy V-notch type and machined to dimensions indicated in 2-A2-1/33 FIGURE 3. The test specimens are to be cut with their longitudinal axis perpendicular to the weld and are to be taken:

i) At mid thickness of the weld in the deposit metal and butt weld test assemblies with multi-pass welds

ii) From the middle of the second (2nd) run for two-run technique welds

iii) From 2 mm ($^5/_{64}$ in.) maximum below one surface in the electroslag or electrogas welds

The notch is to be positioned in the center of the weld, unless specified otherwise in 2-A2-3/19 and 2-A2-4/17. The notch is to be cut perpendicular to the surface of the plate. Where the test temperature is other than ambient, the test temperature of the test pieces at the moment of breaking is to be controlled to within ±2°C (±3.6° F) of the required temperature.

19.3 Test Requirements *(2015)*

The average value of three specimens is to equal or exceed the required average value indicated in 2-A2-1/33 TABLE 2, according to the applicable grade and welding technique. Only one individual value may be below the required average value, provided it is not less than 70% of the required average value.

19.5 Retest

When the results fail to meet the above requirements but conditions (2-A2-1/19.5.2) and (2-A2-1/19.5.3) below are complied with, three additional specimens may be taken from the same assembly and the results added to those previously obtained to form a new average. The retest is acceptable, if for the six specimens, all of the following conditions are met.

19.5.1

The new average is not less than the required average.

19.5.2

No more than two individual values are below the required average.

19.5.3

No more than one individual value is below 70% of the required average.

If the test is unsatisfactory, further tests may be made, at the discretion of the Surveyor, on a new assembly. In such cases, all required tests, including those previously found satisfactory, are to be carried out.

21 Butt Weld Bend Test

21.1 Specimen Type and Preparation

The butt weld 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 exceeding 2 mm ($^5/_{64}$ in.).

21.3 Test Requirements *(1 July 2019)*

The test specimens are to be bent through an angle of 120 degrees around a pin or mandrel having the following diameter:

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.
YQ890	Six times the thickness of the specimen.
YQ960	Seven times the thickness of the specimen.

For a face bend, the face of the weld is to be in tension during testing and for a root bend, the root of the weld is to be in tension during testing. The specimens 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 electroslag or electrogas welded test assemblies, side bend tests are to be used in lieu of root and face bend tests.

21.5 Alternative Test for YQ-Grades *(1997)*

For YQ-Grade, a bending elongation test in accordance with 2-A2-1/33 FIGURE 4 may be accepted. For this alternative, the bending elongation on gauge length $Lo = Ls + t$ (Ls= width of weld, t= specimen thickness) is to meet the minimum elongation requirements in 2-A2-1/33 TABLE 1.

21.7 Retest *(2024)*

See requirements indicated in 2-A2-1/33.

23 Diffusible Hydrogen Test *(1997)*

23.1 Optional or Required Test *(1 July 2019)*

Any ABS grade welding consumables not required to undergo diffusible hydrogen testing as specified below may, at the option of the manufacturer, be submitted for testing. A suffix indicating the hydrogen amount will be added to those welding consumables to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

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 are to be submitted to a hydrogen test. Test results are to meet the requirements for the following notations, except that Y-grade electrodes with a diffusible hydrogen content greater than H10 and Y-grade flux-cored wires with a diffusible hydrogen content greater than H15 will be specially identified, as indicated in 2-A2-1/23.7, 2-A2-2/11.3, and 2-A2-4/13.1.3.

Y-Grade shielded metal arc electrodes	H10
Y-Grade flux-cored wires	H15
YQ420/460/500 Grades	H10
YQ550/620/690/890/960 Grades	H5

23.3 Test Methods *(2005)*

The diffusible hydrogen content of the weld metal is to be determined 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.

The thermal conductivity deduction (TCD) method, such as that described in BS-6693 Appendix C, is also acceptable provided the equipment is calibrated against another standard such as AWS A4.3 or ISO 3690.

23.5 Alternative Test Method

In lieu of the test methods indicated in 2-A2-1/23.3, a recognized alternate procedure may be considered for Grades other than YQ. The following glycerine method will be acceptable.

Four test specimens 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 may be any grade of hull structural steel and are to be weighed to the nearest 0.1 gm before 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 approximately 150 amperes.

The electrodes, prior to welding, can be subjected to the normal drying process recommended by the manufacturer. Within thirty seconds of the completion of the welding of each specimen, the slag is to be removed and the specimen quenched in water having a temperature of approximately 20°C (68°F). After an additional 30 seconds the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerin. The glycerin is to be kept at a temperature of 45°C (113°F) during the test. All four test specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.

The specimens are to be kept immersed in the glycerin for a period of 48 hours and after removal are to be cleaned in water or suitable solvent, dried, and weighed to the nearest 0.1 gram to determine the amount of weld deposited. 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.

23.7 Test Requirements *(2005) (2024)*

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 exceed the following:

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 ABS technical assessment and approval for use with higher-strength steel”.

25 Special Tests

25.1 Nondestructive Testing

The welded assemblies may be subjected to radiographic or ultrasonic examination to ascertain any discontinuities in the weld prior to testing.

25.3 Additional Tests

ABS may specify any additional tests as may be necessary.

27 Licensee Approvals *(2007)*

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 carried out 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, if 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 to this fact. However, in case of 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.

29 Annual Check Tests *(2024)*

The facilities and associated quality control systems, where approved filler metals are manufactured, are subject to an annual inspection in accordance with 2-A2-1/7.3. Annual check tests are to be conducted in accordance with 2-A2-2/13;2-A2-3/15 and 2-A2-3/19.3;2-A2-4/15; or 2-A2-4/17.3, whichever is applicable for the welding process. Test data are to conform to the applicable requirements. whichever is applicable for the welding process. Test data are to conform to the applicable requirements. These 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 an average of one annual test per year. Special consideration for equivalent arrangements may be accepted subject to with ABS technical assessment and approval.

29.1 Upgrading and Uprating *(1 October 1993)*

Upgrading and uprating of welding filler metals will be considered at the manufacturer's request. Tests from butt weld assemblies and, where applicable, a diffusible hydrogen test will be required in addition to the normal annual check tests. The data is to conform to the applicable requirements. See also 2-A2-2/13.3, 2-A2-3/15.3, 2-A2-3/19.5, 2-A2-4/15.3 and 2-A2-4/17.5.

29.1.1 Upgrading

Upgrading refers to notch toughness and, consequently, 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.

29.1.2 Uprating *(2010)*

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 2-A2-1/9.3.3. For uprating to YQ grades of SMAW electrodes, fillet testing is to be conducted per 2-A2-2/9.

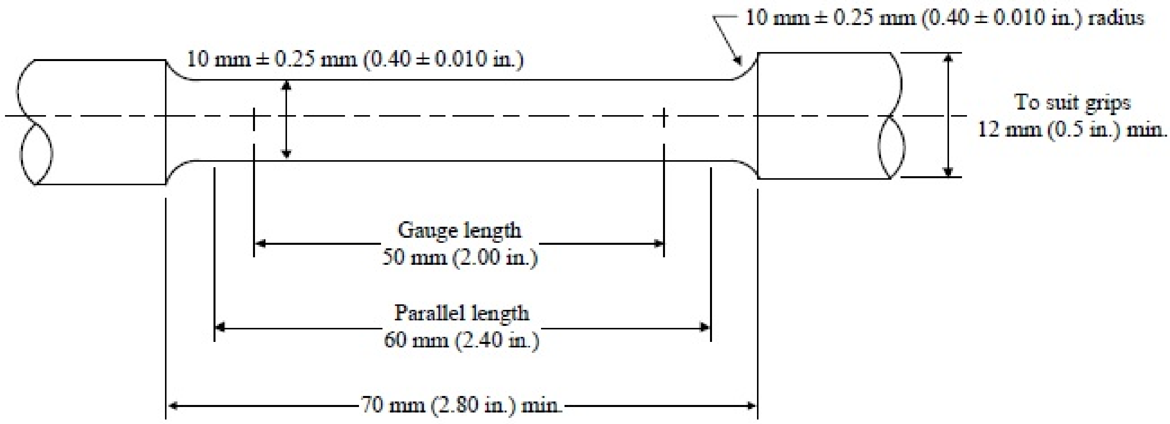
31 Quality Assurance Program *(1 October 1993)*

Where an ABS-approved Quality Assurance Program is maintained and a periodical audit is carried out satisfactorily, the attendance of the Surveyor at the annual check test may be waived, provided the results of the annual check test are examined by the Surveyor and found in accordance with the applicable requirements.

33 Retests *(2024)*

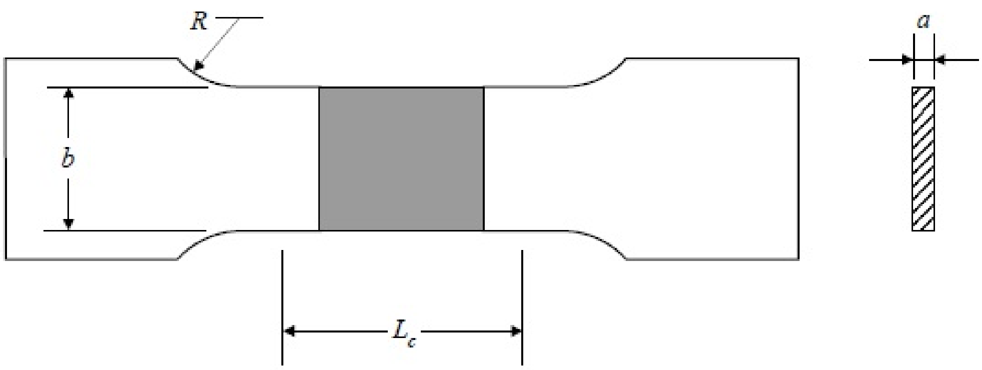
Where the result of a tensile or bend test does not comply with the requirements, duplicate test specimens of the same type are to be prepared and satisfactorily tested. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the number of runs) as the original assembly, only the duplicate re-test specimens need to be prepared and tested. Otherwise, all test specimens are to be prepared for re-testing. Testing of the new assembly is to include CVN testing. See 2-A2-1/19.5 for impact retests.

FIGURE 1
Deposited Metal Tension Test Specimen *(2014)*



Note: The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1% larger in diameter than the center (controlling dimension)

FIGURE 2
Butt Weld Tension Test Specimen (2005)



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 $t \le 2$ mm

b = 25 mm for $t > 2$ mm

L_c = width of weld + 60 mm

R > 25 mm

FIGURE 3
Charpy V-Notch Impact Test Specimen

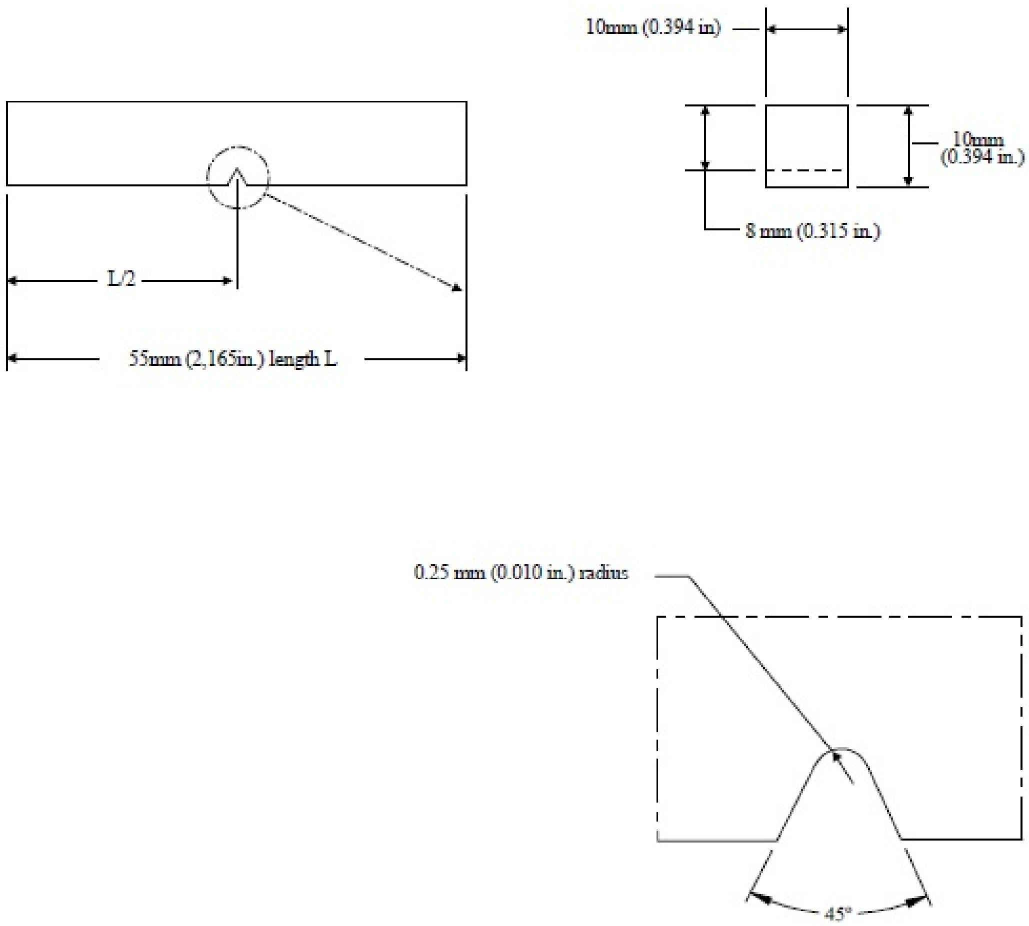


FIGURE 4
Bending Elongation Test *(1997)*

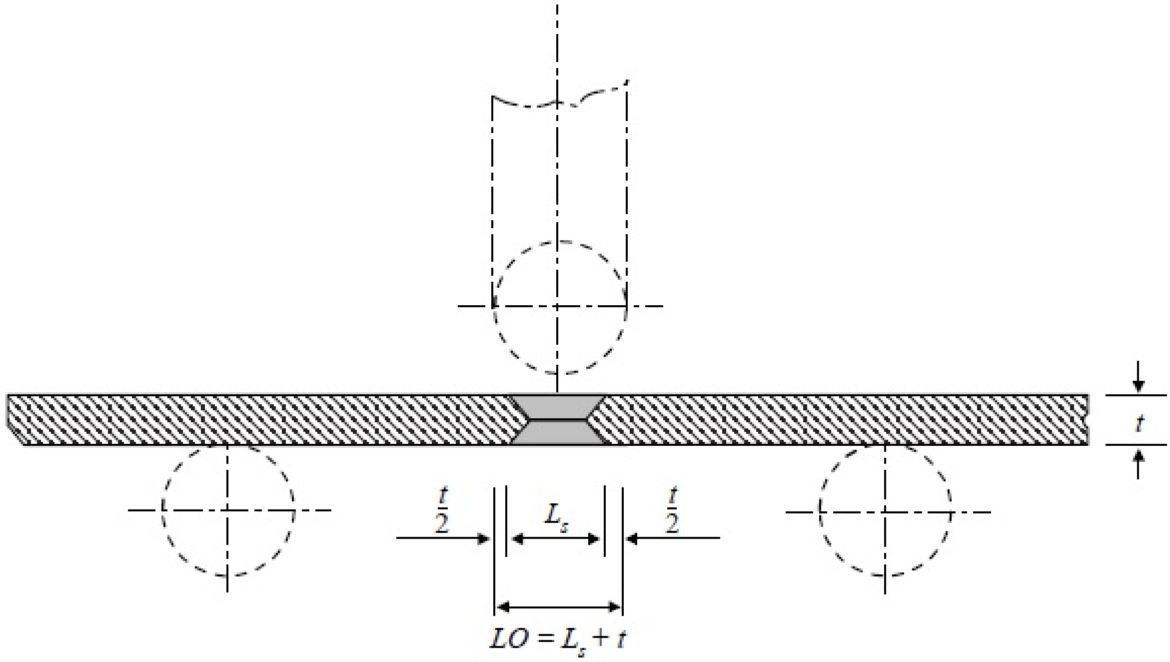


TABLE 1
Tension Test Requirements *(1 July 2019)*

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 WF WG/SA WG/A ESEG	DM DM/M, DM/TM, BW/T, BW/TM DM DM/M, DM/TM, BW/T, BW/TM BW			BW BW/M, BW/T, BW/TM BW BW/M, BW/T, BW/TM BW
Required Properties				
*Grade*3*	*Longitudinal Specimen*			*Transv. Specimen(1999)*
	Tensile Strength N/mm² (kgf/mm², ksi)	*Yield Point, min. N/mm²(kgf/mm², ksi)*	*Elongation min. %*	*Tensile Strength, min. N/mm² (kgf/mm², ksi)*
1, 2 & 3 *(2006)*	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)
XYQ890(4)	940/1100 (96/112, 136/160)	890 (91, 129)	14	940 (96, 136)
XYQ960(4)	980/1150 (100/117, 142/167)	960 (98, 139)	13	980 (100, 142)

Abbreviations:

MW:	Covered Electrode for Manual Welding	A:	Automatic
WF:	Wire-flux Combination	M:	Multi-run
WG:	Wire-gas Combination	T:	Two run*2
ESEG:	Electroslag or Electrogas	TM:	Two run & Multi-run*2
SA:	Semi-automatic	DM:	Deposited Metal Test
		BW:	Butt Weld Test

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. See 2-A2-1/33 TABLE 2. (1999)

4 X = 3, 4 or 5. See . (1999)

5 Specifications for extra high strength steels, for which these XYQ grades of welding consumables are intended, may be found in Section 2-1-8.

TABLE 2
Impact Test Requirements *(1 July 2019)*

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

ESEG		—	BW/V
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)	See 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)
	XYQ890 (2)	69 (7.0, 51)	69 (7.0, 51)
	XYQ960 (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)	—

Notes:

1 Grade 1Y not applicable to MW and WG/SA.

2 Specifications for extra high strength steels, for which these XYQ grades of welding consumables are intended, may be found in Section 2-1-8.

Abbreviations (2016):

F: Flat V: Vertical
H: Horizontal OH: Overhead
(See also 2-A2-1/33 TABLE 1.)

PART 2

APPENDIX 2

Requirements for the Approval of Filler Metals

SECTION 2

Electrodes for Shielded Metal Arc Welding

1 General

1.1 Objective *(2024)*

This section includes requirements for approval of welding consumables, with the intent to meet the goals and functional requirements outlined in the cross-referenced sections.

1.3 Scope *(2024)*

The annual check test is to consist of two deposited metal test assemblies welded and tested in accordance with 2-A2-2/5.

3 Chemical Analysis *(2024)*

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

5 Deposited Metal Test Assemblies

5.1 Test Assembly *(2005)*

Two deposited metal test assemblies, as indicated in 2-A2-2/13.3 FIGURE 1, are to be welded 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. If an electrode is produced in one size only or if the largest size produced is 4 mm ($^5/_{32}$ in.) or less, one test assembly is sufficient. The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm ($^5/_{64}$ in.) and not more than 4 mm ($^5/_{32}$ in.) thick. 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 being welded, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

5.3 Test Specimens *(1 October 1994)*

One tension and one set of three impact specimens are to be prepared from each deposited metal test assembly, as indicated in 2-A2-2/13.3 FIGURE 1 and the results are to conform to the requirements of of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade and welding technique.

7 Butt Weld Test Assemblies

7.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 2 is to be welded in each position (flat, vertical-up, vertical-down, overhead and horizontal) for which the electrode is recommended by the manufacturer, except that those electrodes meeting the requirements for flat and vertical positions are to be considered as also complying with the requirements for the horizontal position. Where the electrode is only to be approved in the flat position, one additional test assembly is to be welded in that position.

7.3 Welding Procedure *(1996)*

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

Flat. First run using 4 mm ($^{5}/_{32}$ in.) electrodes; remaining runs except last two layers with 5 mm ($^{3}/_{16}$ in.) or above according to the normal welding practice with the electrodes; 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.

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.

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.

Vertical down. The electrode diameter used is to be as recommended by the manufacturer.

For all assemblies, the back weld is to be made with 4 mm ($^{5}/_{32}$ in.) electrodes in the welding position appropriate to each test sample, after removing the root run to clean metal. For electrodes suitable only for flat position welding, the test assemblies may be turned over to carry out the back weld.

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

7.5 Test Specimens *(2008)*

One tension, one face bend, one root bend are to be prepared from each butt weld test assembly together with one set of three impact specimens from the flat and vertical test assemblies, as indicated in 2-A2-2/13.3 FIGURE 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/33 FIGURE 1 and 2-A2-1/33 TABLE 1 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

9 Fillet Weld Test Assemblies

9.1 General *(2005)*

For gravity fillet welding electrodes (including combination gravity/manual electrodes), fillet weld testing is required in addition to deposited metal testing. Butt weld testing is not required. For gravity welding electrodes (including combination gravity/manual electrodes) intended for both fillet and butt welding, fillet weld testing is required in addition to deposited metal and butt weld testing. Gravity welding equipment is to be used in welding fillet weld test assemblies. Such fillet weld tests are to be carried out and tested in accordance with 2-A2-2/9.3 through 2-A2-2/9.7 using gravity welding equipment and the longest size electrode manufactured.

The following applies to SMAW electrodes other than gravity electrodes: An electrode other than YQ Grades is considered approved for fillet welding in position for which the butt weld test of 2-A2-2/7 was satisfactory. Electrodes meeting the flat butt weld requirements are to be considered as complying with the requirements for horizontal fillet (HF) welds. Where an electrode is submitted for approval for fillet welds only, the butt weld tests indicated in 2-A2-2/7 may be omitted and fillet weld tests are to be carried out and tested in accordance with 2-A2-2/9.3 through 2-A2-2/9.7.

9.3 Test Assemblies

One fillet weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 3, is to be welded in each position for which the electrode is recommended by the manufacturer.

9.5 Welding Procedure

The length *L* of the fillet test assemblies is to be sufficient to allow for the tests required in 2-A2-2/9.7 and is to provide for at least the deposition of the entire length of the electrode being tested. The first side is to be welded using the maximum size electrode manufactured and the second side using the minimum size of electrode manufactured that is recommended for fillet welds. The fillet size is to be determined by the electrode size and the welding current employed during testing. The fillet weld is to be carried out with the longest size electrode using the welding equipment and technique recommended by the manufacturer. The current used while conducting the test, and the manufacturer's recommended current range are to be reported for each electrode size and welding position.

9.7 Test Specimens

9.7.1 Macrographs and Hardness Tests *(1 October 1994)*

Each fillet weld test assembly is to be sectioned, as indicated in 2-A2-2/13.3 FIGURE 3 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. Hardness readings are to be made on each section. The number and location of hardness readings are to approximate those indicated in 2-A2-2/13.3 FIGURE 4. The hardness of the weld is to be determined and is to meet 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.

The hardness of the heat affected zone (HAZ) and base metal are also to be determined and reported for information only.

9.7.2 Breaking Test

One of the remaining sections of the fillet weld is to have the weld, on the side welded first, gouged or machined 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 examined and there is to be no evidence of incomplete penetration or internal cracking and they are to be reasonably free from porosity.

11 Low Hydrogen Approval *(1997)*

11.1 Ordinary-Strength Filler Metals *(1997)*

Electrodes which have satisfied the requirements of Grades 2 and 3 may, at the option of the manufacturer, be subjected to a hydrogen test, as specified in 2-A2-1/23.3. A suffix indicating the hydrogen amount is to be added to the grade number of those electrodes to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

11.3 Higher-Strength Filler Metals *(2009)*

Electrodes which are submitted for approval according to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400, 4Y400, or 5Y400 are to be subjected to a hydrogen test and are to meet the requirement specified in 2-A2-1/23.7 for the H10 suffix. Such suffix, however, is not to be added to the grade. Electrodes meeting H5 requirements are to be so identified. Electrodes meeting the higher-strength requirements, except for hydrogen test, require special approval for use on higher strength steel for each user and are to be so identified in the list of approved electrodes.

11.5 YQ Grade Filler Metals *(2005)*

Electrodes which are submitted for approval according to YQ Grades are to be subjected to a hydrogen test, as specified in 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements are to be so identified. Otherwise, the H-suffix is not to be added to the grade.

13 Annual Check Tests

13.1 General *(1 October 1993)*

The annual check test is to consist of two deposited metal test assemblies welded and tested in accordance with 2-A2-2/5.

13.3 Upgrading and Uprating *(2008)*

Upgrading of electrodes are considered at the manufacturer's request. In addition to the two deposited metal tests indicated in 2-A2-2/13.1, a butt weld test assembly is to be welded as indicated in 2-A2-2/7 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 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 2-A2-1/9.3.3 and 2-A2-2/7. In addition, the diffusible hydrogen test required by the grade or suffix referred to in 2-A2-2/11.1 and 2-A2-2/11.3 is to be conducted.

FIGURE 1
Deposited-Metal Test Assembly for Manual and Gas-Metal Arc Welding

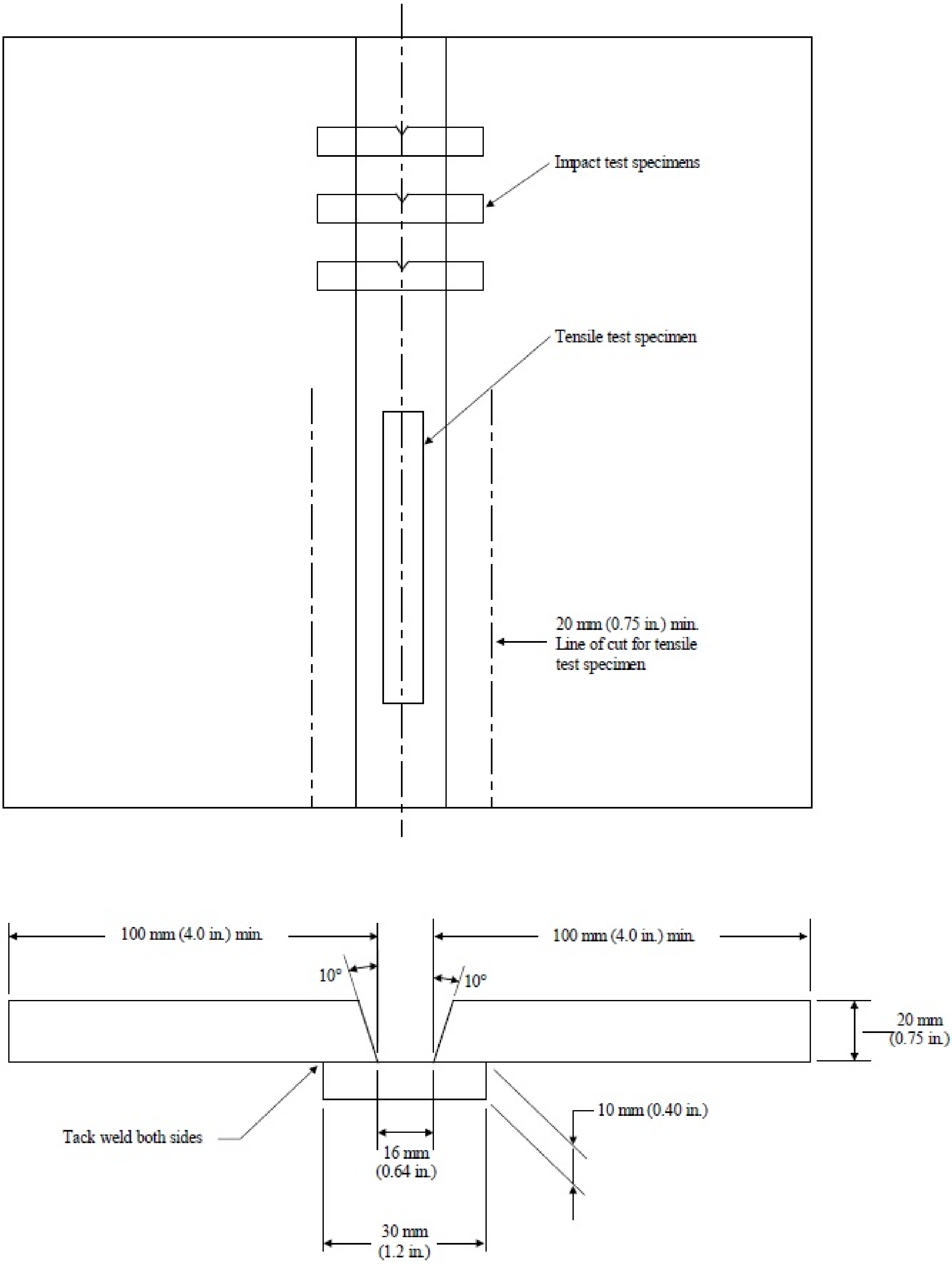


FIGURE 2
Butt-Weld Test Assembly for Manual and Gas-Metal Arc Welding

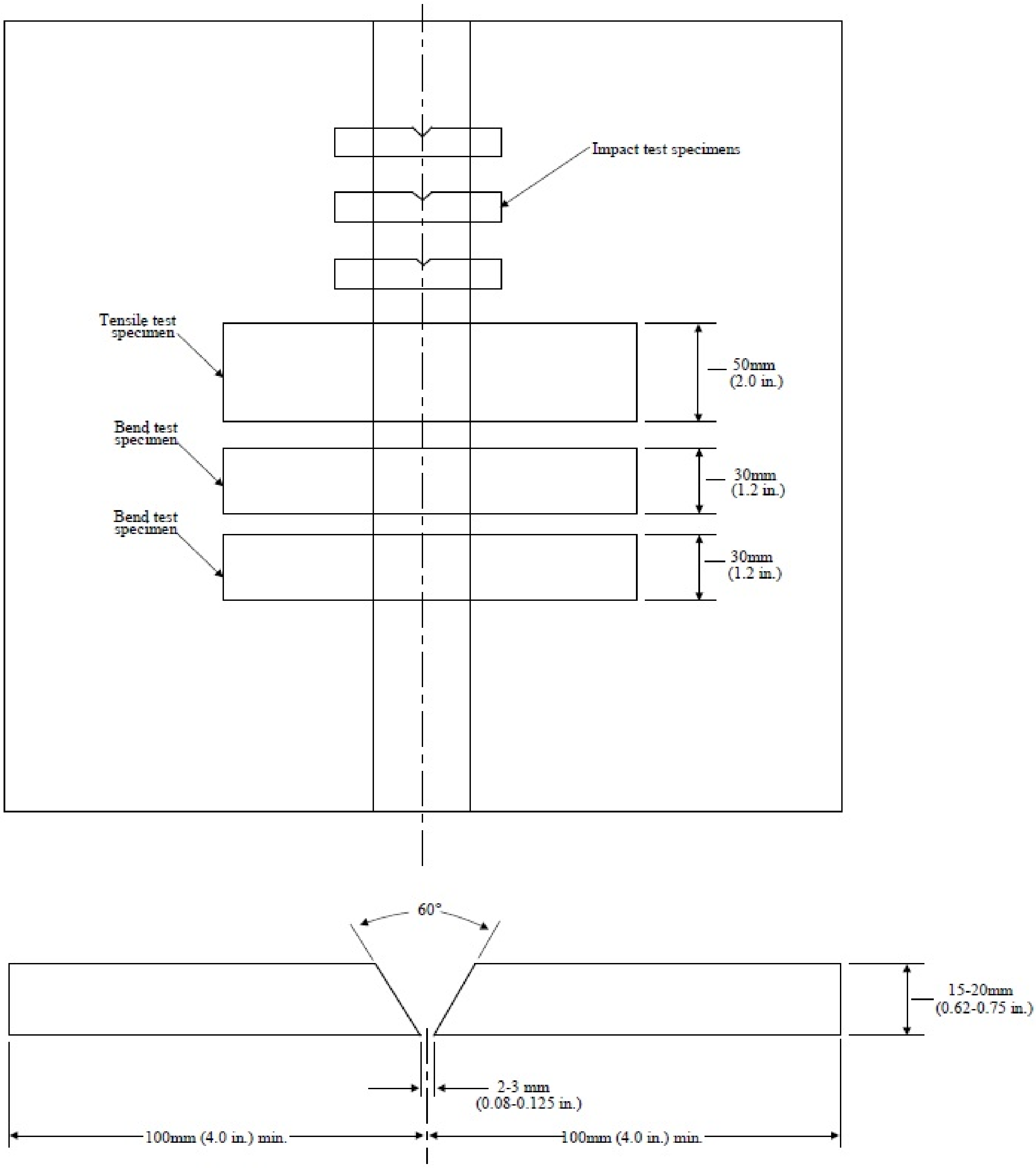


FIGURE 3
Fillet-Weld Test Assembly

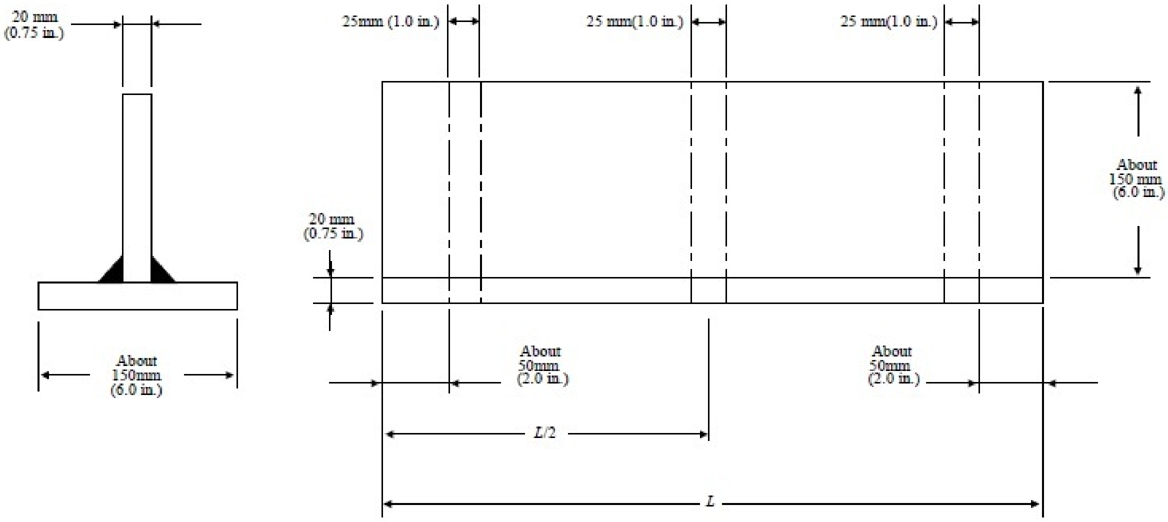
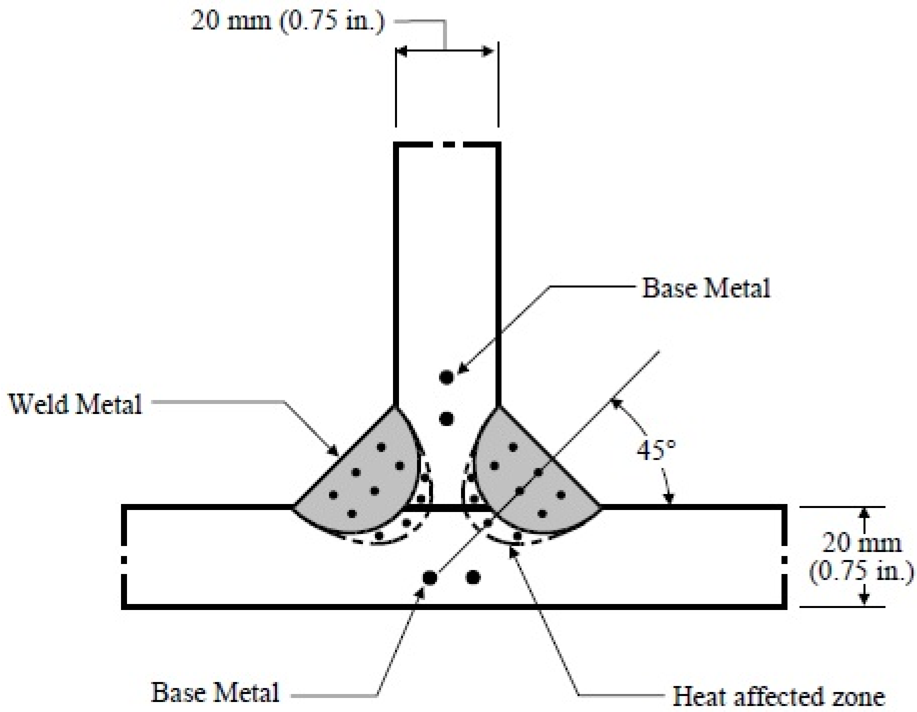


FIGURE 4
Fillet Weld Hardness Test Locations



PART 2

APPENDIX 2
Requirements for the Approval of Filler Metals

SECTION 3
Wire-Flux Combinations for Submerged Arc Welding

1 General *(1997)*

1.1 Objective *(2024)*

This section includes requirements for approval of welding consumables, with the intent to meet the goals and functional requirements outlined in the cross-referenced sections.

1.3 Scope *(2024)*

This test program is intended for the approval of automatic or semi-automatic, single-electrode submerged arc welding with following two categories:

- For use with the multi-run technique
- For use with the two run technique (one pass each side)

Commentary:

For YQ Grades automatic welding, a multi-run technique is contemplated.

Application for high heat input process, such as automatic welding two-run technique, may be considered under 2-A2-1/3.5 and approval by a technical office.

End of Commentary

Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out.

The suffix **T**, **M**, or **TM** is to be added to the grade to indicate two-run technique, multi-run technique, or both techniques, respectively.

When approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

When approval for use with the two-run technique is requested, two butt weld test assemblies are to be carried out.

3 Chemical Analysis *(2024)*

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

5 Deposited Metal Test Assemblies for Multi-run Technique

5.1 Test Assembly *(2005)*

One deposited metal test assembly, as indicated in 2-A2-3/19.5 FIGURE 1 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 after completion of each run, the flux and welding slag are to be removed. 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 conform with normal good welding practice for multi-run welding. The welded test assembly is not to be subjected to heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

5.3 Test Specimens *(1 October 1994)*

Two tension and one set of three impact specimens are to be prepared from the deposited metal test assembly, as indicated in 2-A2-3/19.5 FIGURE 1 and the results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade and welding technique.

7 Butt Weld Test Assemblies for Multi-run Technique

7.1 Test Assembly

One butt weld test assembly, as indicated in 2-A2-3/19.5 FIGURE 2 is to be welded in the flat position using the wire size recommended by the manufacturer. The welding conditions are to be essentially the same as those indicated in 2-A2-3/5.1 for deposited metal test assembly. The back weld is to be applied in the flat position after removing the root run to clean metal. After being welded, the test assembly is not to be subjected to any heat treatment.

7.3 Test Specimens

Two tension, two face bend and two root bend together with one set of three impact specimens are to be prepared from the butt weld test assembly, as indicated in 2-A2-3/19.5 FIGURE 2, and the results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

9 Butt Weld Assemblies for Two-run Technique

9.1 Test Assemblies (2005)

Two butt weld test assemblies, as indicated in 2-A2-3/19.5 FIGURE 3 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 2-A2-3/19.5 FIGURE 3. At the request of the manufacturer, small deviations in the edge preparation may be allowed. The root gap is not to exceed 1.0 mm (0.04 in.). 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 accordance 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 being welded, the test assemblies are not to be subjected to any treatment.

9.3 Test Specimens *(1 October 1994)*

Two tension, one face bend, one root bend, and one set of three impact specimens are to be prepared from each butt weld assembly, as indicated in 2-A2-3/19.5 FIGURE 3 and 2-A2-3/19.5 FIGURE 4, and the results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/23.1. The edges of all test specimens and also the discards are to be examined to confirm complete fusion and interpenetration of the welds.

9.5 Longitudinal All-Weld-Metal Tension Test *(1 October 1994)*

Where the combination 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 2-A2-3/19.5 FIGURE 3, and machined to the dimensions indicated in 2-A2-1/33 FIGURE 1, care being taken that the longitudinal axis 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. The test specimen may be subjected to a temperature not exceeding 250°C (482°F) for up to 16 hours for hydrogen removal, prior to testing. The results of the tests are to conform to the requirements of 2-A2-1/33 TABLE 1.

11 Fillet Weld Tests

Where a wire-flux combination is submitted for approval for fillet welds only, then the butt weld tests may be omitted, and fillet weld tests are to be carried out and tested in accordance with the applicable parts of 2-A2-4/11.3 to 2-A2-4/11.7.

13 Low Hydrogen Approval *(1997)*

13.1 YQ Grade Wires -Flux Combination *(2005)*

All wire-flux combination of this grade are to be submitted to the diffusible hydrogen test, as required by 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements are to be so identified. Otherwise, the H-suffix is not to be added to the grade.

15 Annual Check Tests

15.1 General *(1996)*

The annual check tests for each approved technique are to consist of the following.

Multi-run Technique. One deposited metal test assembly is to be welded in accordance with 2-A2-3/5.1. One tension and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-3/5.3.

Two-run Technique. One butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded in accordance with 2-A2-3/9.1. One transverse tension, one face bend, one root bend, and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-3/9.3 and 2-A2-3/9.5. One longitudinal tension test specimen is also to be prepared where wire-flux combination is approved solely for the two-run technique.

15.3 Upgrading and Uprating *(2008)*

Upgrading of wire-flux combinations is considered at the manufacturer's request. For multi-run technique, in addition to the deposited metal test indicated in 2-A2-3/15.1, one butt weld test assembly is to be welded, as indicated in 2-A2-3/7 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 indicated in 2-A2-3/15.1, except the test assembly is to be fabricated using the maximum thickness approved.

Uprating refers to the extension of approval to also cover welding of higher-strength steels (dual approvals). For this purpose butt weld tests are to be carried out as required in 2-A2-3/7 and 2-A2-3/9, and 2-A2-1/9.3.3, as applicable.

17 Multiple Electrodes

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

19 Electroslag Welding *(1996)*

19.1 General *(1997)*

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.

The results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

19.3 Annual Tests *(1996)*

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 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

19.5 Upgrading and Uprating *(1996)*

Upgrading and uprating are considered at the manufacturer's request. Full tests as indicated in 2-A2-3/19.1 are required.

The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

FIGURE 1
Deposited-Metal Test Assembly for Submerged Arc Welding -Multi-run Technique and Automatic Gas-Metal Arc Welding

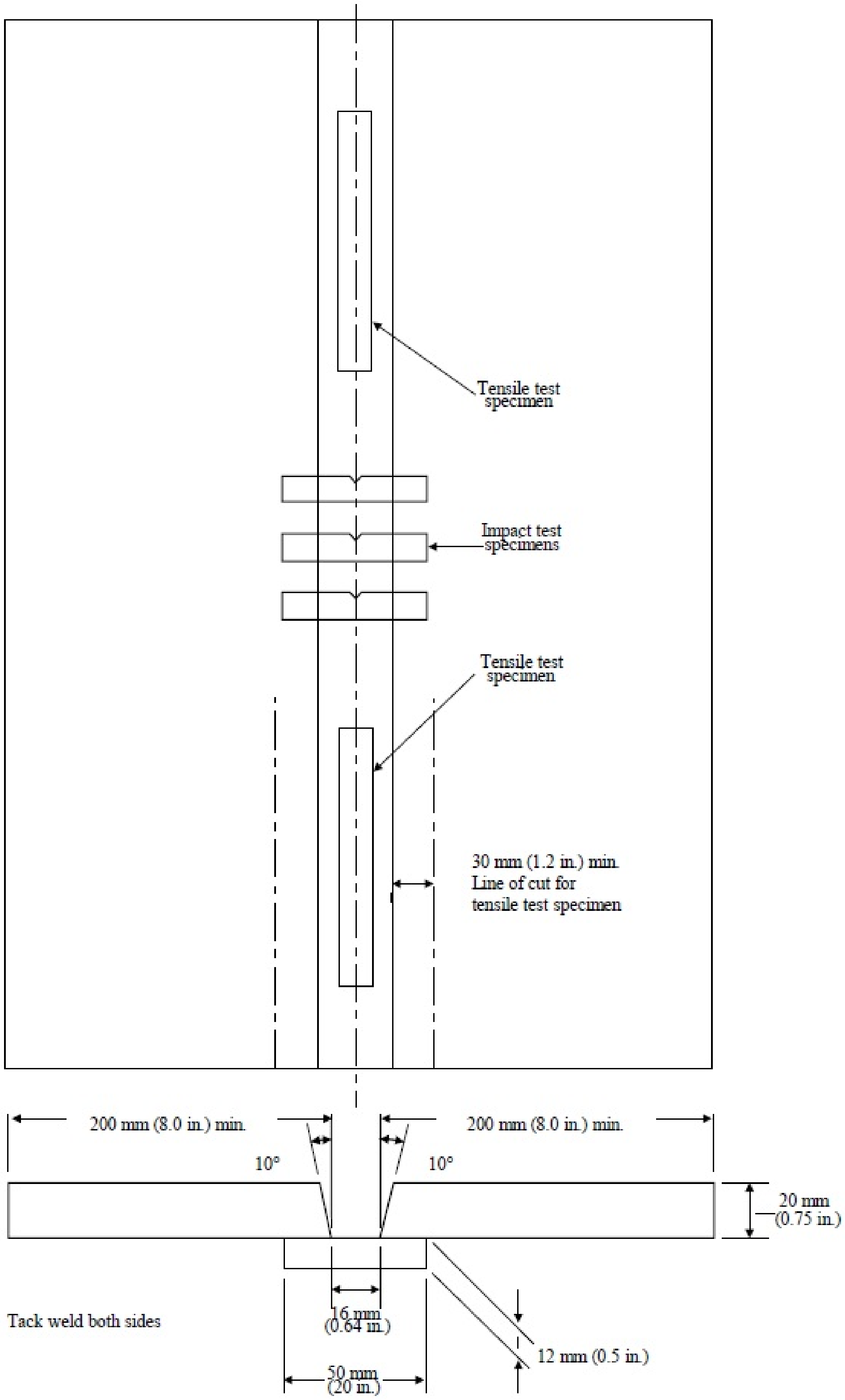


FIGURE 2
Butt-Weld Test Assembly for Submerged Arc Welding – Multi-run Technique *(2008)*

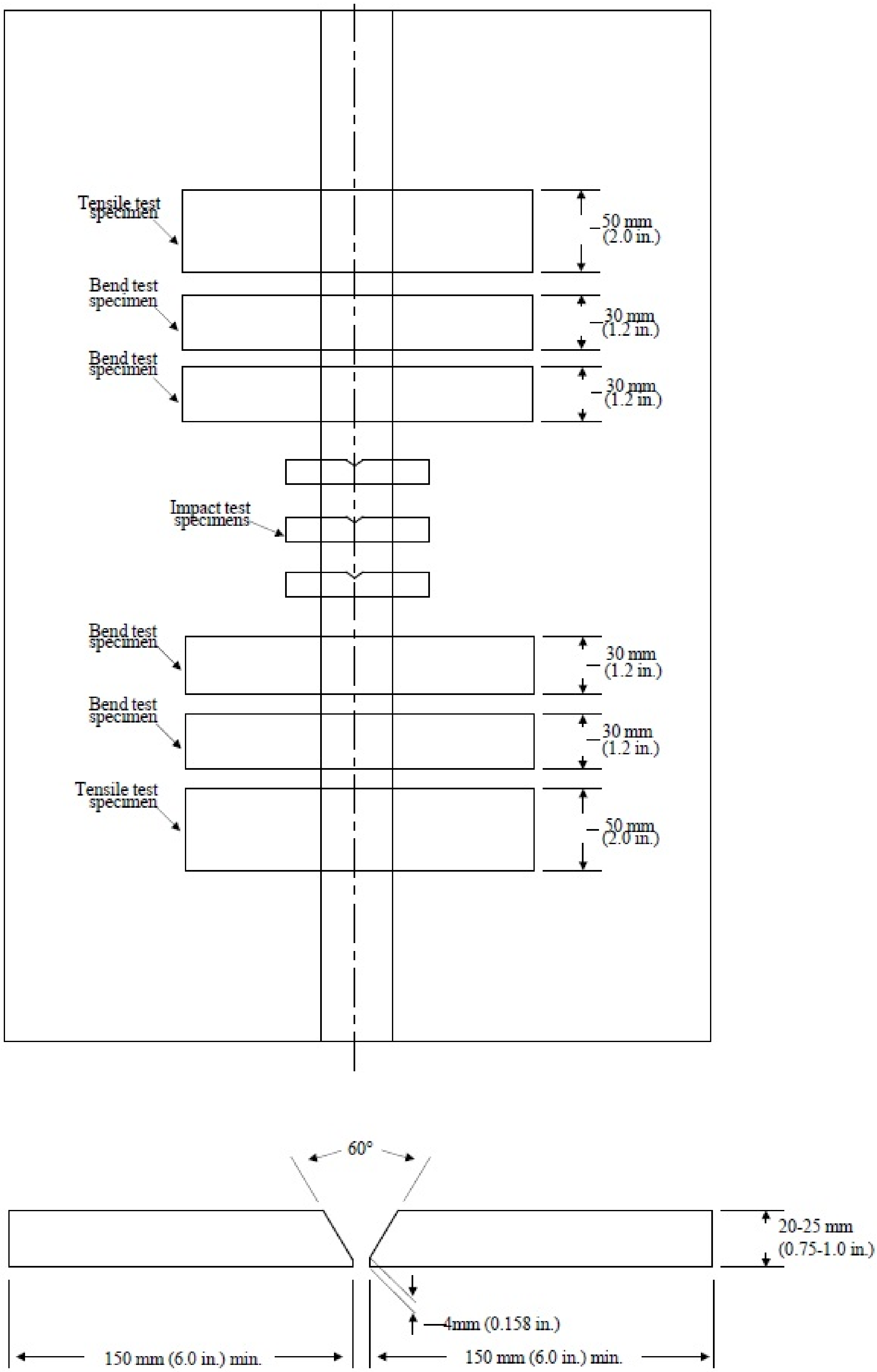
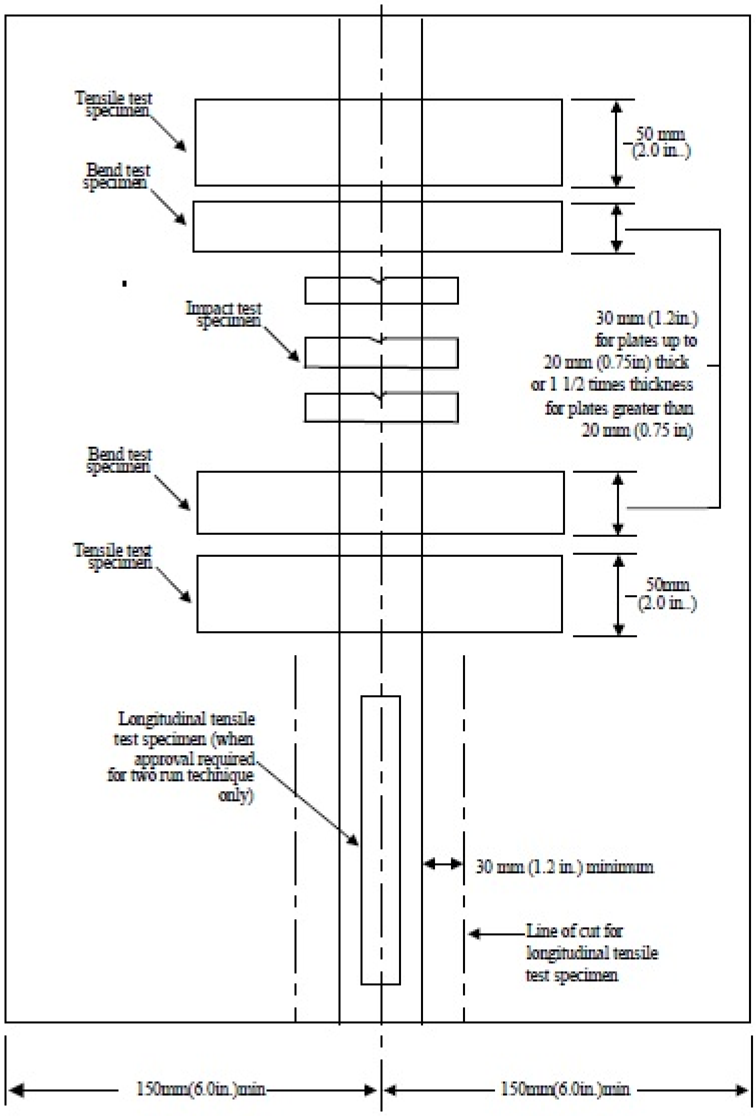
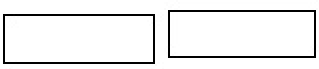


FIGURE 3
Butt-Weld Test Assembly for Submerged Arc Welding -Two-run Technique *(2009)*



				Grades of Steel	
Plate Thickness	*Preparation*	*Maximum sizes of wire*	*Wire Flux Grade*	*Ordinary Strength*	*Higher Strength*
12-15 mm (0.5-0.62 in)		5 mm (0.20 in)	1, 1Y	A	AH32/36

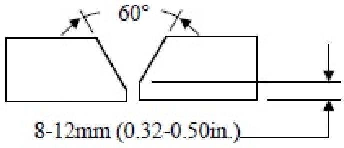
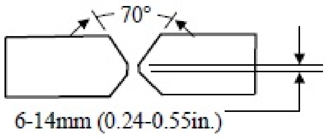
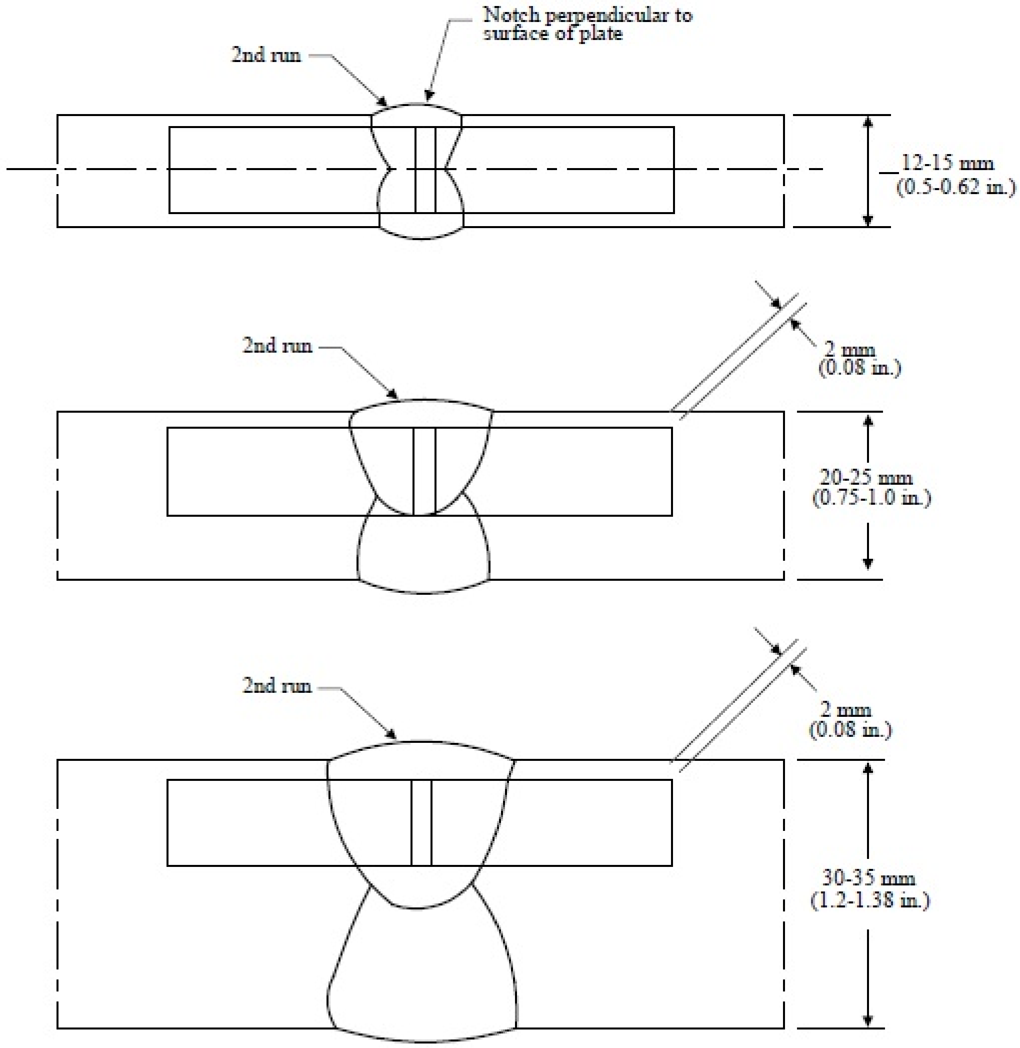
			1, 1Y	A	AH332/36
20-25 mm (0.75-1.0 in)		6 mm (0.25 in)	2, 2Y	A/B/D	AH/DH32/36
			2Y400	-	AH/DH40
			3, 3Y	A/B/D/E	AH/DH/EH32/36
			3Y400	-	AH/DH/EH40
			4Y	-	AH/DH/EH/FH32/36
			4Y400, 5Y400	-	AH/DH/EH/FH40
30-35 mm (1.2-1.38 in)		7 mm (0.28 in)	2, 2Y	A/B/D	AH/DH32/36
			2Y400	-	AH/DH40
			3, 3Y	A/B/D/E	AH/DH/EH32/36
			3Y400	-	AH/EH/EH40
			4Y	-	AH/DH/EH/FH32/36
			4Y400, 5Y400	-	AH/DH/EH/FH40

FIGURE 4
Butt-Weld Impact Specimen Location for Submerged and Gas-Metal Arc Welding -Two-run Technique



PART 2

APPENDIX 2

Requirements for the Approval of Filler Metals

SECTION 4

Wire and Wire Gas Combinations for Gas Metal Arc Welding and Flux Cored Wires for Flux Cored Arc Welding

1 General *(1997)*

1.1 Objective *(2024)*

This section includes requirements for approval of welding consumables, with the intent to meet the goals and functional requirements outlined in the cross-referenced sections.

1.3 Scope *(2024)*

1.3.1

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.

1.3.2 *(2024)*

The tension and impact test requirements for the semi-automatic welding technique and those for the automatic welding technique are indicated separately in 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade.

- The suffix **SA** is to be added to the grade to indicate approval for manual semi-automatic welding or machine-automatic gas-metal arc welding.
- The suffix **A** is to be added to the Grade to indicate approval for machine automatic welding only.
- An additional suffix **T** is to be added to the grade to indicate approval for two-run (one pass each side) technique for machine automatic welding.

1.3.3

Wire-gas combinations and flux cored wires approved for semi-automatic welding may be used for automatic welding under the procedure recommended by the manufacturer, except that for the two-run automatic technique, testing in accordance with 2-A2-4/9 is required.

Commentary:

For YQ Grades, semi-automatic or automatic welding, a multi run technique is contemplated.

Application for high heat input process, such as semi-automatic or automatic welding two-run technique, may be considered under 2-A2-1/3.5 and approval by technical office.

End of Commentary

3 Shielding Gas Compositions *(2024)*

The trade name of the shielding gas, when used, as well as its composition, is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests.

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 2-A2-4/3 TABLE 1.

TABLE 1
Compositional Limits of Designated Groups of Gas Types and Mixtures *(2008)*

Group		*Gas composition (Vol.%)*			
		CO_2	*O_2*	*H_2*	*Ar*
M1	1	>0 to 5	--	>0 to 5	Rest (1, 2)
	2	>0 to 5	--	--	Rest (1, 2)
	3	--	>0 to 3	--	Rest (1, 2)
	4	>0 to 5	>0 to 3	--	Rest (1, 2)
M2	1	>5 to 25	--	--	Rest (1, 2)
	2	--	>3 to 10	--	Rest (1, 2)
	3	>5 to 25	>0 to 8	--	Rest (1, 2)
M3	1	>25 to 50	--	--	Rest (1, 2)
	2	--	>10 to 15	--	Rest (1, 2)
	3	>5 to 50	>8 to 15	--	Rest (1, 2)
C	1	100	--	--	--
	2	Rest	>0 to 30	--	--

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 Approval for Semi-automatic Welding *(2024)*

5.1 Deposited Metal Test Assemblies *(2024)*

5.1.1 Test Assemblies *(2009)*

Two deposited metal test assemblies, as indicated in 2-A2-2/13.3 FIGURE 1, are to be welded in the flat position, one using the smallest size wire intended for approval, and the other using the largest size intended for approval. If a wire is produced in one size only or if the largest size produced is 1.2 mm (0.045 in.) or less, one test assembly is sufficient. The weld metal is to be deposited in single or multi-run layers according to recommended practice and the thickness of each layer of weld metal is to be between 2 mm (5/64 in.) and 6 mm (15/64 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 being welded, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

5.1.2 Test Specimens

One tension and one set of three impact specimens are to be prepared from each deposited metal test assembly, as indicated in 2-A2-2/13.3 FIGURE 1 and the results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

5.1.3 Chemical Anlaysis *(2024)*

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

5.3 Butt Weld Test Assemblies *(2024)*

5.3.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 2, 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 are to 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.

5.3.2 Welding Procedure *(2009)*

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

Flat. First run using the smallest size wire intended for approval; 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.

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 being welded, the test assemblies are not to be subjected to any heat treatment.

5.3.3 Test Specimens *(2005)*

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, as indicated in 2-A2-2/13.3 FIGURE 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

7 Approval for Automatic Welding *(2024)*

7.1 Deposited Metal Test Assemblies *(2024)*

7.1.1 Test Assembly *(2008)*

For automatic welding, one test assembly, as indicated in 2-A2-3/19.5 FIGURE 1 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 2-A2-1/15.3.

7.1.2 Test Specimens

Two tension and one set of three impact specimens are to be prepared from the test assembly, as indicated in 2-A2-1/33 FIGURE 1, and the results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

7.1.3 Chemical Analysis *(2024)*

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

7.3 Butt Weld Test Assemblies *(2024)*

7.3.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 2, 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 is to 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.

7.3.2 Welding Procedure *(2009)*

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

Flat. First run using the smallest size wire intended for approval; 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.

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 being welded, the test assemblies are not to be subjected to any heat treatment

7.5 Test Specimens *(2005)*

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, as indicated in 2-A2-2/13.3 FIGURE 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

9 Approval for Two-run Technique *(2024)*

9.1 Butt Weld Test Assemblies *(2024)*

Two butt weld test assemblies, as indicated in 2-A2-4/17.5 FIGURE 1 are to be welded 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 being welded, the test assemblies are not to be subjected to any heat treatment.

9.3 Test Specimens *(1996)*

Two tension, one face bend, one root bend and one set of three impact specimens are to be prepared from each butt weld test assembly, as indicated in 2-A2-4/17.5 FIGURE 1 and 2-A2-3/19.5 FIGURE 4. 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 tension and impact tests are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade. The results of bend tests are to meet the requirements of 2-A2-1/21.3. The edges of all test specimens and also the discards are to be examined to ensure complete fusion and interpenetration of the welds.

9.5 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 2-A2-4/17.5 FIGURE 1 and machined to the dimensions indicated in 2-A2-1/33 FIGURE 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. 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, prior to testing. The results of the test are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 for the applicable grade.

11 Approval for Fillet Weld Tests *(2024)*

11.1 General *(2018)*

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 2-A2-4/7 was satisfactory. A wire-gas combination or flux cored wire meeting the flat butt weld requirements is to 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 2-A2-4/7 and 2-A2-4/9 may not be required, and fillet weld tests are to be carried out and tested in accordance with 2-A2-4/11.3 through 2-A2-4/11.7.

11.3 Test Assemblies

One fillet weld test assembly, as indicated in 2-A2-2/13.3 FIGURE 3, is to be welded in each welding position for which the wire is recommended by the manufacturer.

11.5 Welding Procedure

The length *L* of the fillet weld test assemblies is to be sufficient to allow for the tests prescribed in 2-A2-2/9.5. 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 is to 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.

11.7 Test Requirements

The results of hardness and breaking tests are to meet the requirements 2-A2-2/9.7.

13 Approval for Low Hydrogen *(2024)*

13.1 Flux Cored Wire

13.1.1 Welding Conditions for Test Assemblies *(2005)*

When flux cored wires undergo diffusible hydrogen testing as indicated in 2-A2-4/13.1.2, 2-A2-4/13.1.3 and 2-A2-4/13.1.4 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.

13.1.2 Ordinary Strength Wires *(2005)*

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 2-A2-1/23.3 or 2-A2-1/23.5. A suffix indicating the hydrogen amount is to be added to the grade number to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

13.1.3 YQ-Grade Wires *(2005)*

All flux-cored wires of this grade are to be submitted to the diffusible hydrogen test, as required by 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix is not to be added to the grade.

13.1.4 Higher Strength Wires *(2024)*

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 2-A2-1/23.3 or 2-A2-1/23.5. Diffusible hydrogen test results are to meet the requirement specified in 2-A2-1/23.7 for the H15 suffix. Such suffix, however, is not to be added to the grade. Flux cored wires meeting H5 or H10 requirements are to be so identified. Electrodes meeting the higher-strength requirements, except for the hydrogen test, are to require ABS technical assessment and approval for use on higher strength steel for each user and are to be so identified in the list of approved consumables.

15 Annual Check Tests

15.1 General *(2011)*

The annual check tests for each approved technique are to consist of the following:

Semi-automatic and Automatic. One deposited metal test assembly is to be welded using a wire of diameter within the range approved in accordance with 2-A2-4/5.1 or 2-A2-4/5.3 as applicable. One tension and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-4/5.3 or 2-A2-4/5.7, as applicable.

Two-run Automatic Technique. One butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded in accordance with 2-A2-4/9.1. The wire diameter used 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 in accordance with 2-A2-4/9.3 and 2-A2-4/9.5. A longitudinal tension test is not required for wires also approved for multi-run technique.

15.3 Upgrading and Uprating *(2008)*

Upgrading of wire-gas combinations and flux cored wires is to be considered at the manufacturer's request. For semi-automatic and automatic welding, in addition to the deposited metal test indicated in 2-A2-4/15.1, butt weld test assembly is to be welded as indicated in 2-A2-4/7 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 to also cover welding of higher-strength steels (dual approvals). For this purpose butt weld tests are to be carried out as required in 2-A2-4/7 or 2-A2-4/9, and 2-A2-1/9.3.3, as applicable. In addition, the diffusible hydrogen test required by the grade or suffix referred to 2-A2-4/13.1.2 and 2-A2-4/13.1.4 is to be conducted.

17 Approval for Electrogas Welding *(2024)*

17.1 General *(1997)*

Where approval is requested for wire-gas combinations other than YQ Grades, (with or without consumable nozzles or self-shielding gas) for use in electrogas 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.

The results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

17.3 Annual Tests *(1996)*

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 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

17.5 Upgrading and Uprating *(1996)*

Upgrading and uprating are to be considered at the manufacturer's request. Full tests as indicated in 2-A2-4/17.1 are to be required.

The test results are to conform to the requirements of 2-A2-1/33 TABLE 1 and 2-A2-1/33 TABLE 2 according to the applicable grade and welding technique.

FIGURE 1
Butt-Weld Test Assembly for Gas-Metal Arc Welding -Two-run Technique

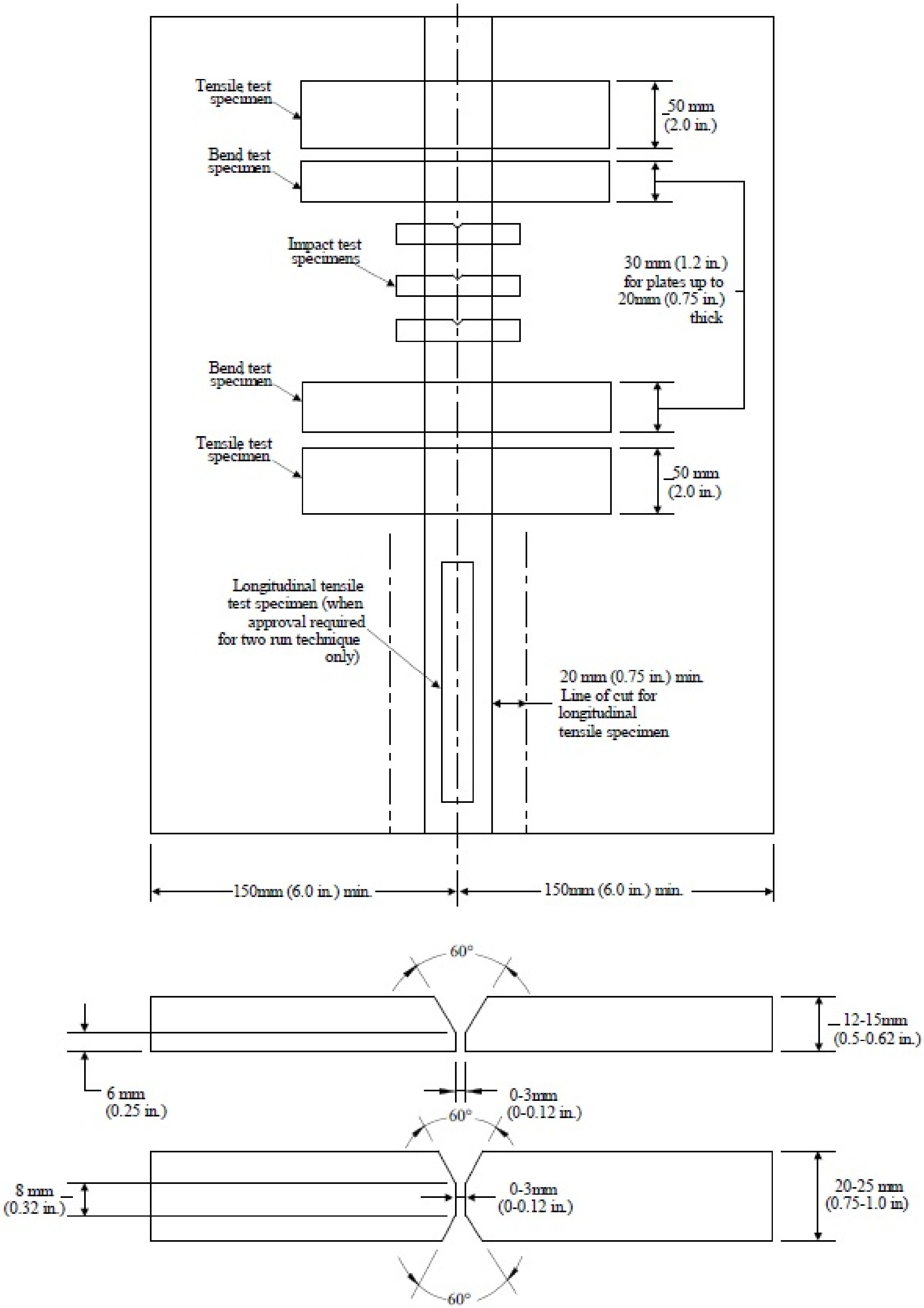
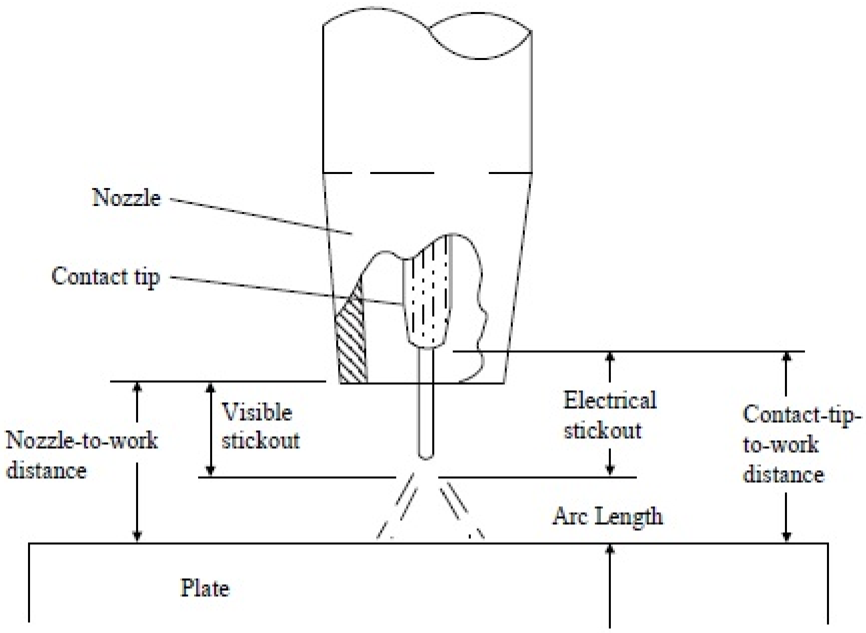


FIGURE 2
Contact Tip to Work Distance *(2005)*



PART 2

APPENDIX 2

Requirements for the Approval of Filler Metals

SECTION 5

Requirements for the Approval of Aluminum Filler Metals *(2018)*

1 General

1.1 Objective *(2024)*

This section includes the requirements for the approval of aluminum filler metals, with the intent to meet goals and functional requirements outlined in the cross-referenced sections.

1.3 Scope *(2024)*

These requirements give the conditions of approval and inspection for welding consumables to be used in hull construction and marine structures using aluminum alloys according to Part 2, Chapter 5. Where no special requirements are given herein (e.g., for the approval procedure or for welding of test assemblies and testing), those of Sections 2-A2-1through 2-A2-4 apply in analogous manner.

The welding consumables preferably to be used for aluminum alloys concerned are divided into two categories as follows:

W = Wire electrode, and wire-gas combinations for GMAW, GTAW, or PAW

R = Rod-gas combinations for GTAW

1.3 Grading, Designation

1.3.1

Consumables are graded as indicated in 2-A2-5/1.3.1 TABLE 1, in accordance with the alloy type and strength level of base materials used for approval tests.

TABLE 1
Consumable Grades and Base Materials for the Approval Test *(2009)*

Consumable Quality Grade (Symbol)	*Base Materials for Tests*	
	Alloy Designation	
	Numerical	*Chemical Symbol*
RA/WA	5754	AlMg3
RB/WB	5086	AlMg4

Consumable Quality Grade (Symbol)	*Base Materials for Tests*	
	Alloy Designation	
	Numerical	*Chemical Symbol*
RC/WC	5083	AlMg4.5Mn0.7
	5383	AlMg4.5Mn0.9
	5456	AlMg5
	5059	-----
RD/WD	6005A	AlSiMg(A)
	6061	AlMg1SiCu
	6082	AlSi1MgMn

Note: Approval on higher strength AlMg base materials covers also the lower strength AlMg grades and their combination with AlSi grades.

1.3.2

Approval of a wire or a rod will be granted in conjunction with a specific shielding gas according to 2-A2-5/1.3.2 TABLE 2 ordefined in terms of composition and purity of "special" gas to be designated with group sign "S". The composition of the shielding gas is to be reported. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in 2-A2-5/1.3.2 TABLE 2, subject to the agreement of ABS.

TABLE 2
Compositional Limits of Shielding Gases and Mixtures to be Used

Group	*Gas composition (Vol.%)*	
	Argon	*Helium*
I-1	100	---
I-2	---	100
I-3	Rest	> 0 to 33
I-4	Rest	> 33 to 66
I-5	Rest	> 66 to 95
S [1]	Special gas, composition to be specified; see 2-A2-5/1.3.2	

Note:

1 Gases of other chemical composition (mixed gases) may be considered as "special gases" and covered by a separate test.

1.5 Manufacture, Testing and Approval Procedure

Manufacturer's plant, production methods, and quality control measures are to be such as to confirm reasonable uniformity in manufacture; see also Part 2, Appendix 2.

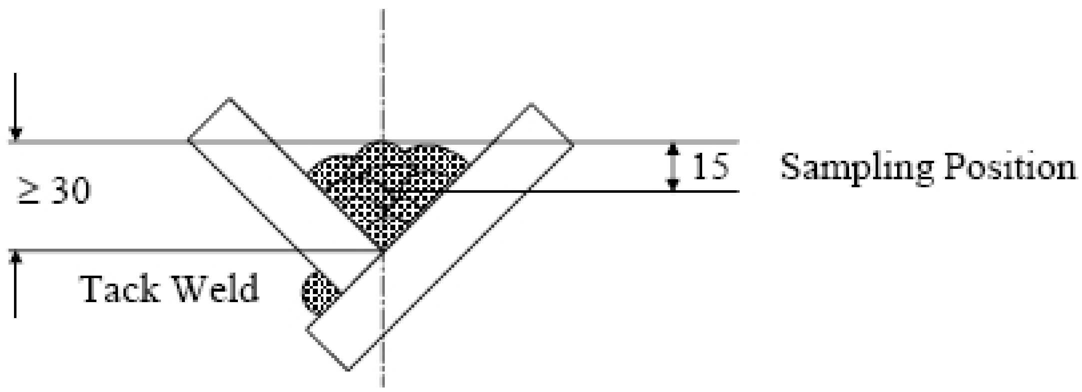
Testing and approval procedure is to be in accordance with Section 2-A2-1 for the individual categories (types) or welding consumables, shielding gases, and gas mixtures mentioned in 2-A2-5/1.3 above.

3 Testing and Required Properties

3.1 Testing of the Deposited Weld Metal

For testing the deposited weld metal chemical composition, a test piece according to 2-A2-5/3.1 FIGURE 1 is to be prepared. The size depends on the type of the welding consumable (and on the welding process) and is to give a sufficient amount of pure weld metal for chemical analysis. The base metal used is to be compatible with the weld metal with respect to chemical composition.

FIGURE 1
Deposited Weld Metal Test Assembly



The chemical composition of the deposited weld metal is to be determined and certified in a manner analogous to that prescribed in 2-A2-1/13. The results of the analysis is to not exceed the limit values specified by the manufacturer.

3.3 Testing of Butt Weld Assemblies

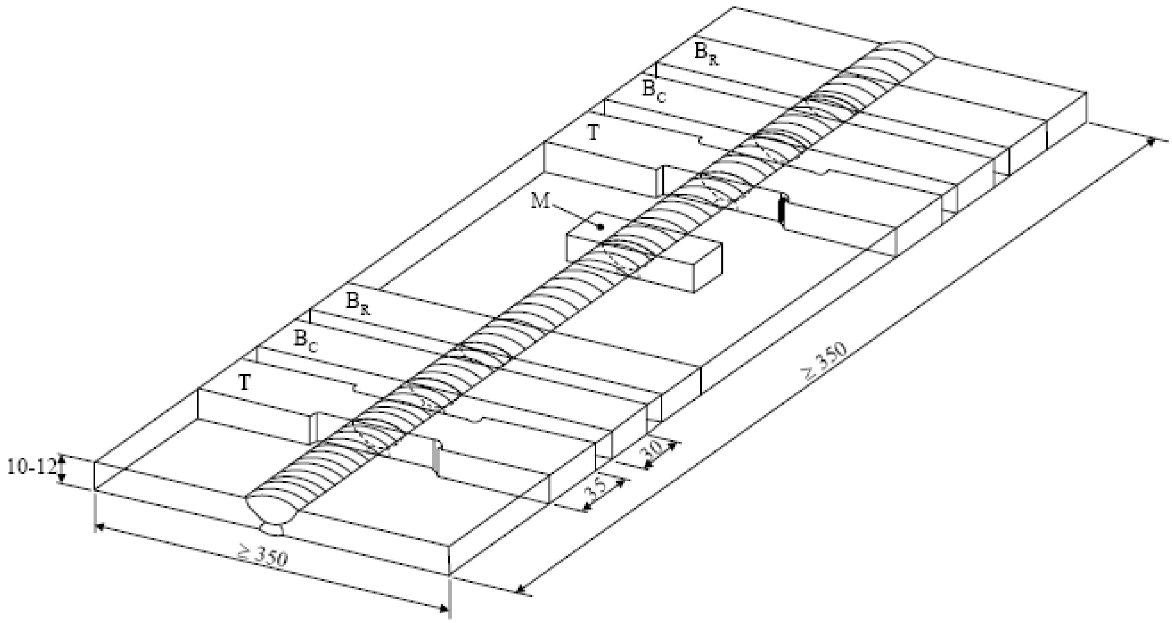
Testing of the welded joints is to be performed on butt-weld test assemblies according to 2-A2-5/3.3 FIGURE 2 and 2-A2-5/3.3 FIGURE 3, made from materials as given in 2-A2-5/1.3.1 TABLE 1, in an analogous manner to 2-A2-1/17 and 2-A2-4/7.

Butt weld test assemblies according to 2-A2-5/3.3 FIGURE 2 with a thickness of 10 to 12 mm ($^3/_8$ to $^1/_2$ in.) are to be prepared for each welding position (flat, horizontal, vertical-up, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for flat and vertical-up positions will be considered as also complying with the requirements for horizontal position.

Additionally, one test assembly according to 2-A2-5/3.3 FIGURE 3 with thickness of 20 to 25 mm ($^3/_4$ to 1 in.) is to be welded in the flat position only.

FIGURE 2
Butt Weld Test Assembly for Out-of-position Welding

T	=	Flat tensile test specimen
B_C	=	Face bend test specimen
B_R	=	Root bend test specimen
M	=	Macrographic section



Notes:

1 Edge preparation is to be single V or double V with 70° angle.

2 Back sealing runs are allowed in single V weld assemblies.

3 In case of double V assembly, both sides is to be welded in the same welding position.

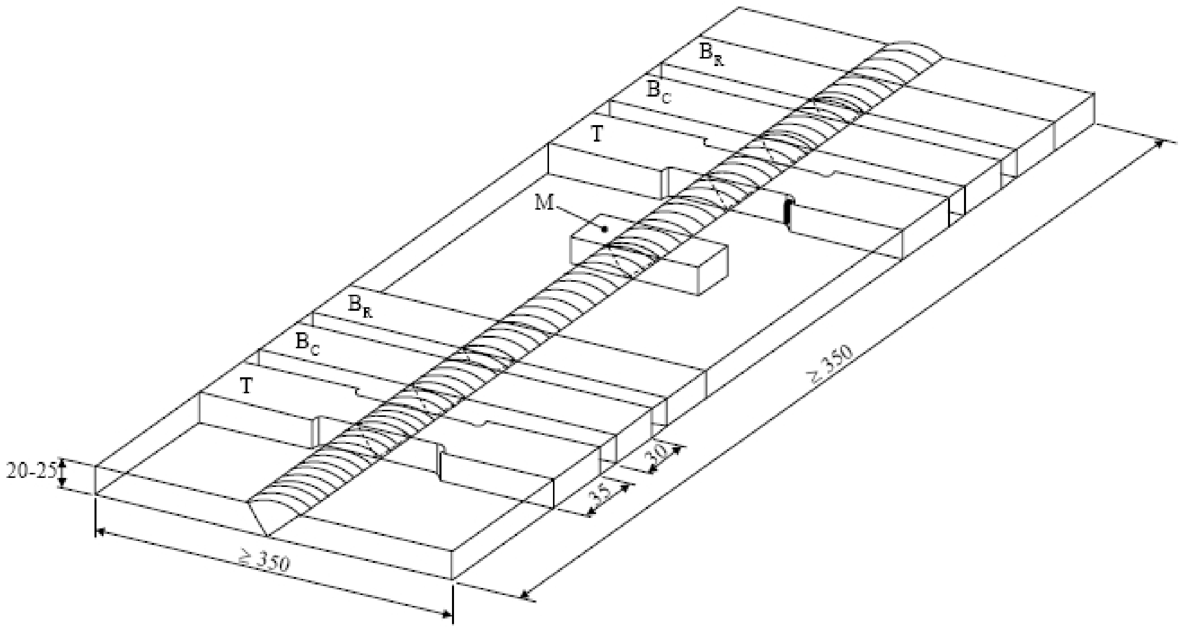
FIGURE 3
Additional Butt Weld Test Assembly in Flat Position *(2024)*

T = Flat tensile test specimen

B_C = Face bend test specimen

B_R = Root bend test specimen

M = Macrographic section



Notes:

1 Edge preparation is to be single V with 70° angle.

2 Back sealing runs are allowed.

On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment. Grade D assemblies are to be allowed to naturally age for a minimum of 72 hours after completion of welding before testing is carried out.

Test specimens shown in 2-A2-5/3.3 FIGURE 2 and 2-A2-5/3.3 FIGURE 3 and described in Section 2-A2-4 is to be taken from the butt weld test assemblies.

The mechanical properties are to meet the requirements stated in 2-A2-5/3.3 TABLE 3. The provisions of Section 2-A2-1 apply in analogous manner to the performance of the tests, including requirements for annual check tests and retesting. The position of the fractures is to be stated in the report. The macrographic specimen is to be examined for imperfections such as lack of fusion, cavities, inclusions, pores, and cracks.

TABLE 3
Requirements for the Transverse Tensile and Bend Tests *(2009)*

Grade	*Base Material Used for the Test*	*Tensile strength R_m, N/mm^2 (ksi) min.*	*Former Diameter*	*Bending angle [1] [degrees] min.*
RA/WA	5754	190 (27.5)	3*t*	180
RB/WB	5086	240 (35)	6*t*	
RC/WC	5083	275 (40)	6*t*	
	5383 or 5456	290 (42)	6*t*	
	5059	330 (47)	6*t*	
RD/WD	6005A, 6021, 6082	170 (24.5)	6*t*	

Note:

1 *(2009)* During testing, the test specimen is not to reveal any one single flaw greater than 3 mm in any direction. Flaws appearing at the corners of a test specimen are to be ignored in the evaluation unless there is evidence that they result from lack of fusion.

5 Annual Check Tests

Annual check tests are to entail the preparation and testing of the deposited weld metal test assembly as prescribed in 2-A2-5/3.1 FIGURE 1 and of the flat position butt weld test assembly according to 2-A2-5/3.3 FIGURE 2.

PART 2

APPENDIX 3

Application of Filler Metals to ABS Steels

CONTENTS

PART 2

APPENDIX 3

Application of Filler Metals to ABS Steels

SECTION 1

Application of Filler Metals to ABS Steels *(2014)*

1 Objective *(2024)*

This section includes welding filler metals selection for hull structural steels, with the intent to meet goals and functional requirements outlined in the cross-referenced sections.

A chart indicating acceptable ABS filler metal grades for welding various ABS grades of hull steel is given below.

(2021)

ABS Hull Structural Steel		*Acceptable ABS 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 *(2009)**		
	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
	EH32/36	3Y, 3Y400, 4Y, 4Y400, 5Y400
	FH32/36	4Y, 4Y400, 5Y400
	AH40, DH40	2Y400, 3Y400, 4Y400, 5Y400
	EH40	3Y400, 4Y400, 5Y400
	FH40	4Y400, 5Y400
Extra High Strength		
	XQ43	ZYQ420, ZYQ460***, ZYQ500***
	XQ47	ZYQ460, ZYQ500***
	XQ51	ZYQ500, ZYQ550***

ABS Hull Structural Steel		*Acceptable ABS Filler Metal Grade*
	XQ56	ZYQ550, ZYQ620***
	XQ63	ZYQ620, ZYQ690***
	XQ70	ZYQ690
	XQ91	ZYQ890****
	XQ98	ZYQ960****

Note:

For X = A or D, Z = 3, 4 and 5

For X = E, Z = 4 and 5

For X = F, Z = 5

The tensile strength range of ABS ordinary strength hull structural steel is 400-520 N/mm^2, (41-53 kgf/mm^2, 58-75 ksi). The tensile strength range for ABS H32/H36 higher strength hull structural steel is 440-620 N/mm^2 (45-63 kgf/mm^2, 64-90 ksi). For ABS 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 ABS 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 levels 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 higher strength filler metal grades are divided into two levels according to whether the process used is automatic or manual. The specific value requirements may be found in 2-A2-1/33 TABLE 1.

* *(2008)* Non-low hydrogen type electrode and wire approvals for welding higher strength steels (denoted by * in the list) are subject to satisfactory procedure tests at the user's plant. Use of non-low hydrogen electrodes and wires on higher strength steels is limited to steels with carbon equivalent of 0.41% or less (see 2-1-3/7.1). Furthermore, 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. Weld on the first side is to be allowed to cool to ambient temperature before the second side weld is made. Three macrosections (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.

*** See 2-4-1/5.7.2 concerning overmatching of electrodes for quenched and tempered steels.

**** For grades YQ890 and YQ960, where the design requirements permit an undermatching weld joint, then welding consumables within the scope of these Rules with lower tensile properties can be considered subject to ABS agreement and Manufacturer's recommendations. If undermatching is applied, then a note is to made on the drawing or document. If there are locations where undermatching can not be applied, then these locations should be indicated. In cases where the design requires the tensile properties to meet the base metal, YQ890 and YQ960 consumables may still be applied based on actual test results meeting the minimum requirements.

PART 2

APPENDIX 4

Procedure for the Approval of Manufacturers of Hull Structural Steel (2003)

CONTENTS

PART 2

APPENDIX 4

Procedure for the Approval of Manufacturers of Hull Structural Steel (2003)

SECTION 1

Procedure for the Approval of Manufacturers of Semi-Finished Products for Hull Structural Steel *(2010)*

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of manufacturers with the intent to meet goals and functional requirements outlined in the cross referenced sections.

1.3 Scope *(2024)*

In accordance with 2-1-1/1.2, this Section provides specific requirements for the approval of manufacturers of semi-finished products such as ingots, slabs, blooms and billets for hull structural steels. Slabs, blooms, and billets can also be supplied in the partially-rolled condition.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products under effective process and production and inspection controls in operation, as required in 2-1-1/1.2.2.

Manufacturers approved for the supply of semi-finished products will be permitted to supply products within their scope of approval for further processing at approved works.

1.5 Approval Process *(2024)*

The below activities are involved in the granting of ABS approval.

i) Submission of information (as noted in 2-A1-1/3) for ABS Engineering review.

ii) Qualification tests (as noted in 2-A1-1/5) are to be carried out under ABS Survey witness, along with a plant survey of the works.

iii) Following a review of qualification test results and plant survey checksheet, ABS Engineering will issue the approval letter and certificate.

3 Approval Application

3.1 Documents to be Submitted

3.1.1 Initial Approval

The manufacturer is to submit to ABS request of approval together with proposed approval test program (see 2-A4-1/5.1) and general information relative to:

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

3.1.1(b) Organization and Quality

- Organizational chart
- Staff employed
- Organization of the quality control department and its staff employed
- 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.

3.1.1(c) Manufacturing facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of semi-finished products
- Equipment for systematic control during fabrication

3.1.1(d) Details of inspections and quality control facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for nondestructive examinations
- List of quality control procedures

3.1.1(e) Type of Products (ingots, slabs, blooms, billets), Types of Steel (normal or higher strength), Range of Thickness and Target Material Properties as Follows:

- Range of chemical composition and target 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 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 intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

3.1.1(f) Steelmaking

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

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

3.1.1(h) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by ABS is to be included.

3.1.2 Changes to the Approval Conditions

Where any one or more of the following cases 2-A4-1/3.1.2(a) through 2-A4-1/3.1.2(c) are applicable, the manufacturer is to submit to ABS the documents required in 2-A4-1/3.1.1 together with the request of changing the approval conditions,

3.1.2(a)
Change of the manufacturing process (steel making, casting, steel making plant, caster)

3.1.2(b)
Change of the maximum thickness (dimension)

3.1.2(c)
Change of the chemical composition, added element, etc.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4-1/5.1).

5 Approval Tests

5.1 Extent of the approval tests

The extent of the test program is specified in 2-A4-1/5.11. The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, product thicknesses and types to be tested or complete 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) 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

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

5.3 Approval Test Program

Where the number of tests differs from those shown in 2-A4-1/5.11, the program is to be confirmed by ABS before the commencement of the tests.

5.5 Approval Survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required.

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

5.7 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 one test product with the minimum thickness to be approved are, in general, to be selected for each kind of product (ingots, slabs, blooms/billets).

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

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified C_{eq} or P_{cm} values and grain refining micro-alloying additions.

5.9 Position of the Test Samples

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

5.11 Tests on Base Material *(2012)*

5.11.1 Type of Tests *(2022)*

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

i) Chemical analysis. The analysis is to be complete including micro alloying elements.

ii) Sulphur prints and photomacrograph (acid etched) pictures. Alternatively, non-metallic inclusion content may be proposed in lieu of Sulphur prints.

In addition, for initial approval and for any upgrade of the approval, ABS will require full tests indicated in 2-A4-2/5 to be performed at rolling mill on the minimum thickness semi-finished product.

In case of a multi-caster work, full tests on finished products are to be carried out for one caster and reduced tests (chemical analysis, sulphur print, and photomacrograph picture) for the others. The selection of the caster are to be based on the technical characteristics of the casters to be evaluated on case by case basis to be performed at rolling mill on products manufactured from the minimum thickness semi-finished product.

5.11.2 Test Specimens and Testing Procedure

The test specimens and testing procedures are to be, as a rule, in accordance with Section 2-1-1 with particular attention to the following:

5.11.2(a) Chemical analyses.

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

5.11.2(b) Sulphur Prints and Photomacrograph (Acid Etched) Pictures.

Sulphur prints and photomacrograph pictures are to be taken from product edges which are perpendicular to the axis of the ingot or slab (full transverse cross-section). These sulphur prints and photomacrograph pictures are to be approximately 600 mm long, taken from the center of the edge selected (i.e., on the ingot centerline) and are to include the full product thickness.

5.11.2(c) Non-Metallic Inclusion Content. (2022)

The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution is to be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or ASTM E45 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer.

7 Results

Before the approval, all test results are evaluated for compliance with the Rules. Depending upon the finding, limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All information required under 2-A4-2/3, applicable to the products submitted to the tests, is to be collected by the manufacturer and incorporated into a single document including all test results and operation records relevant to steel making, casting, and when applicable, rolling and heat treatment of the tested products.

9 Certification

9.1 Approval

Upon satisfactory completion of the survey, approval will be granted by ABS.

The following information is to be stated on the approval certificate:

i) Type of products (ingots, slabs, blooms, billets)

ii) Steelmaking and casting processes

iii) Thickness range of the semi-finished products

iv) Types of steel (normal or higher strength)

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

9.3 List of Approved Manufacturers

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

11 Renewal of Approval *(2024)*

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period.

The following information is to be submitted to renew the approval.

i) Statistical data for the last 5 years including the chemistry, mechanical properties for the grade or grades approved by ABS.

ii) Any non-conformances during production of ABS grades and the respective corrective and preventive actions.

iii) A written confirmation stating there were no changes to the manufacturing process since last ABS approval.

iv) A copy of the latest certificate of compliance of the quality system with IS0 9001 or 9002 equivalent.

The Surveyor's report confirming the above information is to be made available to the ABS Engineering/ Materials department for review and issuance of renewal letter/certificate.

Where 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 instance, the extension of approval will be backdated to the original renewal date.

Manufacturers who have not produced the approved types 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 evaluated by ABS and found acceptable for renewal.

13 Withdrawal of the Approval

The approval may be withdrawn before the expiry of the validity period in the following cases:

i) In-service failures traceable to product quality

ii) Nonconformity of the product revealed during fabrication and construction

iii) Discovery of failure of the manufacturer's quality system

iv) Changes made by the manufacturer, without prior agreement of ABS, to the extent of the approval defined at the time of the approval

v) Evidence of major nonconformities during testing of the products.

PART 2

APPENDIX 4
Procedure for the Approval of Manufacturers of Hull Structural Steel (2003)

SECTION 2
Procedure for the Approval of Manufacturers of Rolled Hull Structural Steel *(2010)*

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of manufacturers with the intent to meet goals and functional requirements outlined in the cross referenced sections.

1.3 Scope *(2024)*

In accordance with 2-1-1/1.2, this Appendix provides specific requirements for the approval of manufacturers of rolled hull structural steel.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products under effective process and production and inspection controls in operation including programmed rolling.

1.5 Approval Process *(2024)*

The below activities are involved in the granting of ABS approval.

i) Submission of information (as noted in 2-A4-2/3) for ABS Engineering review.

ii) Qualification tests (as noted in 2-A4-2/5) are to be carried out under ABS Survey witness, along with a plant survey of the works.

iii) Following a review of qualification test results and plant survey checksheet, ABS Engineering will issue the approval letter and certificate.

3 Approval Application

3.1 Documents to be Submitted

3.1.1 Initial Approval

The manufacturer is to submit to ABS request of approval together with proposed approval test program (see 2-A4-2/5.1) and general information relative to:

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

3.1.1(b) Organization and Quality

- Organizational chart
- Staff employed
- Organization of the quality control department and its staff employed
- 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.

3.1.1(c) Manufacturing Facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

3.1.1(d) Details of Inspections and Quality Control Facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for non destructive examinations
- List of quality control procedures

3.1.1(e) Type of Products (plates, sections, coils), Grades of Steel, Range of Thickness and Target Material Properties as Follows:

- Range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- Target maximum carbon equivalent according to IIW 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 intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

3.1.1(f) Steelmaking

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation and alloying practice
- Desulphurisation and vacuum degassing installations, if any

- Casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided, as appropriate.
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

3.1.1(g) Reheating and Rolling

- Type of furnace and treatment parameters
- Rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures
- Descaling treatment during rolling
- Capacity of the rolling stands

3.1.1(h) Heat Treatment

- Type of furnaces, heat treatment parameters and their relevant records
- Accuracy and calibration of temperature control devices

3.1.1(i) Programmed Rolling.

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

- Description of the rolling process
- Normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them
- Control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

3.1.1(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)

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

3.1.1(l) (2010) Approval already granted by other IACS Member Societies and documentation of approval tests performed.

3.1.2 Changes to the Approval Conditions

Where any one or more of the following cases 2-A4-2/3.1.2(a) through 2-A4-2/3.1.2(e) are applicable, the manufacturer is to submit to ABS the documents required in 2-A4-2/3.1.1 together with the request of changing the approval conditions,

3.1.2(a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)

3.1.2(b) Change of the maximum thickness (dimension)

3.1.2(c) Change of the chemical composition, added element, etc.

3.1.2(d) Subcontracting the rolling, heat treatment, etc.

3.1.2(e) (2010) Use of the slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4-2/5.1).

5 Approval Tests

5.1 Extent of the Approval Tests *(2022)*

The extent of the test program is specified in 2-A4-2/5.11 and 2-A4-2/5.13. The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, steel plate or tubular 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

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

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 2-A4-2/5.11 and 2-A4-2/5.13. A reduction or complete omission 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, grain refining and micro-alloying elements, steel making and casting process;

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

5.3 Approval Test Program

Where the number of tests differs from those shown in 2-A4-2/5.11 and 2-A4-2/5.13, the program is to be confirmed by ABS before the commencement of the tests.

5.5 Approval Survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required.

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

5.7 Selection of the Test Product

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

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

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified C_{eq} or P_{cm} values and grain refining micro-alloying additions.

5.9 Position of the Test Samples *(2022)*

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

The position of the samples to be taken in the length of the rolled product, "piece", defined in 5C-8-6/1 (ABS) of the *Marine Vessel Rules*, (top and/or bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in 2-A4-2/5.11.1 TABLE 1.

The position of the samples in the width of the product is to be in compliance with 5C-8-6/3.5.1 (ABS) of the *Marine Vessel Rules*.

5.11 Tests on Base Material

5.11.1 Type of Tests

The tests as indicated in 2-A4-2/5.11.1 TABLE 1 are to be carried out.

TABLE 1
Tests for Rolled Products Manufacturer Approval *(2024)*

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)

Type of Test	*Position of the Samples and Direction of the Test Specimen* (1)	*Remarks*			
Impact tests(3) on non aged specimens for grades:	Top and bottom – longitudinal	Testing temperature (0°C)			
A, B, AH32, AH36, AH40		+20	0	-20	
D, DH32, DH36, DH40		0	-20	-40	
E, EH32, EH36, EH40		0	-20	-40	-60
FH32, FH36, FH40		-20	-40	-60	-80
A, B, AH32, AH36, AH40	Top – transverse (4)	+20	0	-20	
D, DH32, DH36, DH40		0	-20	-40	
E, EH32, EH36, EH40		-20	-40	-60	
FH32, FH36, FH40		-40	-60	-80	
Impact tests (3) on strain aged specimens (5) for grades:	Top - longitudinal	Testing temperature (0°C)			
AH32, AH36, AH40		+20	0	-20	
D, DH32, DH36, DH40		0	-20	-40	
E, EH32, EH36, EH40		-20	-40	-60	
FH32, FH36, FH40		-40	-60	-80	
Chemical analysis (%) (6)	Top	Complete analysis including micro alloying elements			
Sulfur prints and photomacrographs	Top	Non-metallic inclusion count per ISO 4967 or ASTM E45 or equivalent standards may be proposed in lieu of Sulfur prints.			
Micro examination	Top	Grain size determination. Ferrite and/or prior austenite grain size is to be determined.			
Grain size determination	Top	For fine grain steel only			
Drop weight test (4)	Top	For grades E, EH32, EH36, EH40, EQ43-70, FH32, FH36, FH40, FQ43-70 only			
Through thickness tensile tests	Top and bottom	For grades with improved through thickness properties only			

Notes:

1 For hot rolled strips see 2-A4-2/5.11.2

2 Longitudinal direction for sections and plates having width less than 600 mm

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

4 Not required for sections and plates having width less than 600 mm

5 *(2012)* 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 2-1-2/11 and 2-1-2/15.9 TABLE 4, 2-1-3/7.3 TABLE 4, and 2-1-8/5.11 TABLE 5A of these Rules, as applicable, additional testing may be requested.

6 Besides product analysis, ladle analysis is also required

5.11.2 Test Specimens and Testing Procedure

The test specimens and testing procedures are to be, as a rule, in accordance with Section 2-1-1 with particular attention to the following:

5.11.2(a) Tensile Test (2022)

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

5.11.2(b) Impact Test (2022)

- For plates made from hot rolled strip, one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- For plates and tubulars having thickness higher than 40 mm (1.575 in.), one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- For plates and tubulars having thickness higher than 100 mm (3.937 in.), impact specimens are to be taken with the axis located at quarter depth and mid-thickness
- In addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

5.11.2(c) Chemical Analyses.

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

5.11.2(d) Sulphur Prints and Photomacrograph (Acid Etched) Pictures (2012).

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

5.11.2(e) Micrographic Examination. (2024)

The micrographs are to be representative of the full thickness. For thick products, at least three examinations are to be made at surface, one quarter and mid-thickness of the product.

All photomicrographs are to be taken at ×100 magnification and where ferrite grain size exceeds ASTM 10, additionally at ×500 magnification. Ferrite and/or prior austenite grain size is to be determined for each photomicrograph

5.11.2(f) Drop Weight Test.

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

5.11.2(g) Through Thickness Tensile Test.

The test is to be performed in accordance with 2-1-1/17.

The test results are to be in accordance, where applicable, with the requirements specified for the different steel grades in Part 2, Chapter 1.

5.11.3 Other Tests

Additional tests such as CTOD test, large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2, Chapter 1, or when deemed necessary by ABS.

5.13 Weldability Tests

5.13.1 General *(2022)*

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

5.13.2 Preparation and Welding of the Test Assemblies

The following tests are to be carried out:

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

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

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that impact specimens will result in the longitudinal direction.

The edge preparation is preferably to be 1/2 V or K.

The welding procedure is to be in accordance with the normal welding practice used at the yards for the type of steel in question.

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

5.13.3 Type of Tests

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

5.13.3(a)

One (1) cross weld tensile test

5.13.3(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.

5.13.3(c) *(2022)*

Hardness tests HV 10 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the 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 350 HV10.

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

5.13.4 Other Tests

Additional tests such as cold cracking tests (CTS, Cruciform, Implant, Tekken, Bead-on plate), CTOD, or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2, Chapter 1, or when deemed necessary by ABS.

7 Results

Before the approval, all test results are evaluated for compliance with the Rules. Depending upon the finding, limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All information required under 2-A4-2/3, applicable to the products submitted to the tests, is to be collected by the manufacturer and incorporated into a single document including all test results and operation records relevant to steel making, casting, rolling and heat treatment of the tested products.

9 Certification

9.1 Approval

Upon satisfactory completion of the survey, approval will be granted by ABS.

9.3 List of Approved Manufacturers

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

11 Renewal of Approval *(2024)*

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period.

The following information is to be submitted to renew the approval.

i) Statistical data for the last 5 years including the chemistry, mechanical properties for the grade or grades approved by ABS.

ii) Any non-conformances during production of ABS grades and the respective corrective and preventive actions.

iii) A written confirmation stating there were no changes to the manufacturing process since last ABS approval.

iv) A copy of the latest certificate of compliance of the quality system with IS0 9001 or 9002 equivalent

The Surveyor's report confirming the above information is to be made available to the ABS Engineering/ Materials department for review and issuance of renewal letter/certificate.

Where 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 instance, the extension of approval will be backdated to the original renewal date.

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 grades of products during the period are evaluated by ABS and found acceptable for renewal.

13 Withdrawal of the Approval

The approval may be withdrawn before the expiry of the validity period in the following cases:

i) In-service failures traceable to product quality

ii) Non conformity of the product revealed during fabrication and construction

iii) Discovery of failure of the manufacturer's quality system

iv) Changes made by the manufacturer, without prior agreement of ABS, to the extent of the approval defined at the time of the approval

v) Evidence of major non conformities during testing of the products.

PART 2

APPENDIX 4

Procedure for the Approval of Manufacturers of Hull Structural Steel (2003)

SECTION 3

Procedure for the Approval of Manufacturers of Extra High Strength Steels *(2018)*

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of manufacturers with the intent to meet goals and functional requirements outlined in the cross referenced sections.

1.3 Scope *(2024)*

In accordance with 2-1-1/1.2, this section provides specific requirements for the approval of manufacturers of rolled extra high strength steels.

All materials are to be manufactured at works which have been approved by ABS for the type, delivery condition, grade and thickness of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products under effective process and production and inspection controls in operation including programmed rolling.

1.5 Approval Process *(2024)*

The below activities are involved in the granting of ABS approval.

i) Submission of information (as noted in 3) for ABS Engineering review.

ii) Qualification tests (as noted in 5) are to be carried out under ABS Survey witness, along with a plant survey of the works.

iii) Following a review of qualification test results and plant survey checksheet, ABS Engineering will issue the approval letter and certificate.

3 Approval Application

3.1 Documents to be Submitted

3.1.1 Initial Approval

The manufacturer is to submit to ABS a request for approval together with a proposed approval test program (see 2-A4-3/5.1) and general information relative to:

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

3.1.1(b) Organization and Quality

- Organizational chart
- Number of staff employed
- Organization of the quality control department and its staff employed
- 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.

3.1.1(c) Manufacturing Facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

3.1.1(d) Details of Inspections and Quality Control Facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for nondestructive examinations (NDE)
- List of quality control procedures

3.1.2 Manufacturing Specification

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

- Range of chemical composition, aim analyses and associated control limits, including grain refining, nitrogen binding, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and delivery condition, the different ranges are to be specified, as appropriate.
- In addition, where zirconium, calcium and rare earth metals have been used during steel making for grain refinement and, or inclusion shape control and modification, the contents of these elements are to be specified in the manufacturing specification.
- Target maximum carbon equivalent according to IIW formula or CET formula and/or target P_{cm} content and associated control limits.
- 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 CVN). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

3.1.2(b) Steelmaking (if applicable)

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- The steel mill is to have a documented process for quality of scrap control. The quality of scrap is to be established at the time of qualification.
- Deoxidation, grain refining, nitrogen binding and alloying practice
- Desulphurisation, dehydrogenation, dephosphorization, sulphide treatment, ladle refining and vacuum degassing installations, if any
- Casting methods: ingot (bottom or top poured, ingot shape) or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided, as appropriate.
- Casting/solidification cooling rate control
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

3.1.2(c) Reheating and Rolling

- Type of furnace and treatment parameters
- Rolling: reduction ratio of ingot/slab/bloom/billet to finished product thickness, rolling and finishing temperatures for each grade/thickness combination.
- Descaling treatment during rolling
- Capacity of the rolling stands

3.1.2(d) Heat Treatment

- Type of furnaces, heat treatment parameters for products to be approved and their relevant records
- Accuracy and calibration of temperature control devices
- The methods used to determine austenitizing temperature, re-crystallization temperature and Ar3 temperature.
- Description of quenching and tempering process, if applicable.

3.1.2(e) Programmed Rolling.

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

- Description of the rolling process
- The methods used to determine austenitizing temperature, re-crystallization temperature and Ar3 temperature.
- Control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

3.1.2(f) (2022)

Recommendations for fabrication and welding, in particular, for products delivered in the NR/CR, TM or QT condition

- Cold and hot working recommendations, if needed, in addition to the normal practice used in the shipyards and workshops
- Minimum and maximum heat input and proposed pre-heat/interpass temperature

3.1.2(g)

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

3.1.2(h)

Approval already granted by other IACS Member Societies and documentation of approval tests performed.

3.1.3 Changes to the Approval Conditions

The manufacturer has to submit to ABS the documents required in 2-A4-3/3.1.1 together with the request of changing the approval conditions, in the case of the following 3.1.3(a) through 3.1.3(e), as applicable

3.1.3(a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)

3.1.3(b) Change of the maximum thickness (dimension)

3.1.3(c) Change of the chemical composition, added element, etc.

3.1.3(d) Subcontracting the rolling, heat treatment, etc.

3.1.3(e) Use of the ingots, slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4-3/5.1).

5 Approval Tests

5.1 Extent of the Approval Tests

The extent of the test program is specified in 2-A4-3/5.11 . The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete 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 where available the long term statistical 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, the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.

iv) For extra high tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided that the target analyses, the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.

An increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 2-A4-3/5.11 . A reduction or complete omission of the approval tests may be considered, taking into account previous approval as follows:

- The rolled steel manufacturer has already been approved for the rolling process and heat treatment using other approved semi-finished products characterized by the same thickness, steel grade, grain refining and micro-alloying elements, steel making (deoxidation) and casting process;
- The semi-finished products have been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

5.3 Approval Test Program

Where the number of tests differs from those shown in 2-A4-3/5.11, the program is to be confirmed by ABS before the commencement of the tests.

5.5 Approval Survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required during his/her visit for approval.

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

5.7 Selection of the Test Product

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

In addition, for initial approval, ABS will require selection of one test product of representative thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified C_{eq}, CET or P_{cm} values and grain refining micro-alloying additions.

In cases where chemistry changes with increase in thickness, qualification tests are to be carried out on the different chemistries.

5.9 Position of the Test Samples and Specimens

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar and tubular) corresponding to the top and bottom of the ingot, or, in the case of continuous casting, one at each end of the product.

The position of the samples to be taken in the length of the rolled product, "piece", defined in 5C-8-6/1(ABS) of the *Marine Vessel Rules*, (top and bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in 2-A4-3/5.11.1 TABLE 1.

The position of the samples in the width of the product is to be in compliance with 5C-8-6/3.5.1 (ABS) of the *Marine Vessel Rules.*

5.11 Tests on Base Material

5.11.1 Type of Tests

The tests as indicated in 2-A4-3/5.11.1 TABLE 1 are to be carried out.

TABLE 1
Tests on Base Material *(2024)*

Type of Test	*Position and direction of test specimens*	*Remarks*			
1 Chemical analysis(ladle and product[1])	Top	a) Contents of C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Ti, B, Zr, Cu, As, Sn, Bi, Pb, Ca, Sb, O, H are to be reported. b) Carbon equivalent calculation, and/or c) P_{cm} calculation, as applicable.			
2 Segregation examination and Photomacrographs	Top	a) Segregation examination and assessment is to be detailed and acceptance standards submitted b) Photomacrographs are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. c) Sulphur prints may be required by ABS			
3 Micrographic examination[2]	Top	a) Grain size determination. Ferrite and/or prior austenite grain size is to be determined. b) All photomicrographs are to be taken at x 100 and 500 magnification. c)Non-metallic inclusion contents/Cleanliness The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution is to be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer.			
4 Tensile test	One sample at each end of the product-longitudinal and transverse direction	Yield strength (ReH), Tensile strength (Rm), Elongation (A5), Reduction in Area (RA) and Y/T ratio are to be reported.			
5a Charpy Impact tests on unstrained specimens for grades[4]	One set[3] of samples at each end of the product (Top and Bottom)	Testing temperature (°C)			
AQ	Longitudinal and transverse direction	+20	0	-20	
DQ		0	-20	-40	
EQ		0	-20	-40	-60
FQ		-20	-40	-60	-80
5b Charpy Impact tests on strain aged specimens for grades[4, 5]	Top	Deformation of 5% + 1 hour at 250°C			
AQ	Longitudinal and transverse direction	+20	0	-20	
DQ		0	-20	-40	
EQ		0	-20	-40	-60
FQ		-20	-40	-60	-80

Type of Test	*Position and direction of test specimens*	*Remarks*
6 Drop weight test	Top	The test is to be performed only on plates in accordance with ASTM E208.The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.
7 Through thickenss tensile tests	One sample at each end of the product (Top and Bottom)	Testing in accordance with 2-1-1/17, • In case of thickness up to 75 mm, improved through thickness property is optional • In case of thickness greater than 75 mm, through thickness testing is to be carried out
8 CTOD testing	Top	The test is to be performed at -10C on plate and seamless tubulars in accordance with ISO 12135 or equivalent.
9 Ultrasonic Examination		EN 10160 – Acceptance Level S1/E1 (Z grade) or ASTM A578 level C;S2/E3 for Leg, rack and chord plates; Other products to be agreed with manufacturer. *(Materials intended for leg, racks and chords are to have a designation "R" after the Grade i.e., EQ70-R)*
10 Weld ability test (6)	Ref 2-A4-3/5.11.3	
a) Butt Weld Assembly as-welded	Top	Cross weld tensile, Charpy impact test on FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.
b) Butt Weld Assembly (PWHT), if applicable	Top	Cross weld tensile, Charpy impact test on FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.
c) Cold cracking tests as such CTS-Test, Y-groove test U-groove test or Implant test or Alternative tests	Top	National and International recognized standards such as ISO 17642-2, ISO17642-3, GB/T4675.1 and JIS Z 3158.

Notes:

1) The product analysis may be taken from the tensile specimen. The deviation of the product analysis from the ladle analysis are to be permissible in accordance with the limits given in the manufacturing specification.

2) The Micrographs are to be representative of the full thickness. For thick products, at least three examinations are to be made at surface, 1/4*t* and 1/2*t* of the product.

3) One set of three Charpy V-Notch per sample

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

5) Strain ageing test is to be carried out on the thickest plate. (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 2-1-8/5.11 TABLE 5A as applicable, additional testing may be requested.)

6) Weldability is to be carried out in the thickest plate.

5.11.2 Test Specimens and Testing Procedure

The test specimens and testing procedures are to be, as a rule, in accordance with Section 2-1-1 with particular attention to the following:

5.11.2(a) Tensile Test (2022)

- For plates made from hot rolled strip, one additional tensile specimen is to be taken from the middle of the strip constituting the coil.
- For plates having thickness higher than 40 mm (1.575 in.), when the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, multiple flat specimens, representing collectively the full thickness, can be used. Alternatively two round specimens with the axis located at one quarter and at mid-thickness can be taken.
- For tubulars, supplied in QT condition, test samples are to be taken from either end of the product.

5.11.2(b) Impact Test (2022)

- For plates made from hot rolled strip, one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- For plates having thickness higher than 40 mm (1.575 in.), one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- For plates having thickness higher than 100 mm (3.937 in.), impact specimens are to be taken with the axis located at quarter depth and mid-thickness
- For tubulars, supplied in QT condition, test samples are to be taken from either end of the product.
- In addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

5.11.2(c) CTOD Tests.

CTOD test specimens are to be taken from full thickness of the plate or seamless tubulars, with the notch in the through thickness direction. Three tests are to be performed at –10°C. CTOD test is to be carried out in accordance with ISO 12135 or equivalent.

Alternative CTOD specimen dimensions can be agreed with ABS.

5.11.2(d) Other Tests.

Additional tests on parent plate such as large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of Part 2 or when deemed necessary by ABS.

5.11.3 Weldability Test - Butt Weld Test

5.11.3(a) For 43 to 51 Grade Steels. (2022)

Weldability tests are to be carried out on samples of the thickest plate. Testing on higher grades can cover the lower strength and toughness grades.

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

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

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

Alternative heat inputs can be agreed with ABS.

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

5.11.3(b) For 56 to 98 Grade Steels.

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

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

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

Alternative heat inputs can be agreed with ABS.

Option: If the manufacturer requests to include the approval for Post Weld Heat Treated (PWHT) condition, 1x additional butt weld test assembly welded with a maximum heat input proposed by the manufacturer for the approval same as test assembly *ii)* is to be post-weld heat treated (PWHT) prior to testing. See 2-A4-3/5.11.3(e).

5.11.3(c) Butt Weld Test Assembly.

The butt weld test assemblies of plates are to be prepared with the weld seam parallel to the final plate rolling direction.

The butt weld test assemblies of long products, sections and seamless tubular in any delivery condition are to be prepared with the weld seam transverse to the rolling direction.

5.11.3(d) Bevel Preparation.

The bevel preparation can be 1/2V or K based on thickness.

The welding procedure can be in accordance with the normal welding practice used for the type of steel in question.

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

5.11.3(e) Post-weld Heat Treatment Procedure. (2022)

i) Steels delivered in N/NR/CR or TM/TM+AcC/TM+DQ condition are to be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes), where the minimum and maximum temperatures are to be established.

ii) Steels delivered in QT condition are to be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes) where the minimum and maximum temperatures are to be established and should generally be at least 14°C (25°F) below the tempering temperature, unless otherwise agreed at the time of approval.

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

5.11.3(f) Type of Tests.

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

i) 1 cross weld tensile test - 1 full thickness test sample or sub-sized samples cut from the full thickness cross section.

ii) 1 set of 3 Charpy V-notch impact specimens transverse to the weld seam and 1-2 mm below the surface with the notch located at the fusion line and at a distance 2, 5 and 20 mm from the straight fusion line. An additional set of 3 Charpy test specimens at root is required for each aforementioned position for plate thickness t ≥ 50 mm. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade.

iii) Hardness tests HV10 across the weldment. The indentations are to be made along a 1- 2 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

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

  The maximum hardness value is not to be higher than 350HV10 for grade steels 43 to 47; not be higher than 420HV10 for 51 to 70; and not be higher than 450HV10 for 91 and 98.

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

iv) *CTOD test*. CTOD test specimens are to be taken from butt weld test assembly specified in 2-A4-3/5.11.3(a).ii) or 2-A4-3/5.11.3(b).ii). CTOD test is to be carried out in accordance with EN ISO 15653 or equivalent.

- The specimen geometry *(B = W)* is permitted for plate thickness up to 50 mm. For plate thicker than 50 mm, subsidiary specimen geometry (50 × 50 mm) is permitted, which is to be taken 50 mm in depth through thickness from the subsurface and 50 mm in width. See 5.11.3(f) FIGURE 1A and 5.11.3(f) FIGURE 1B for more details.
- The specimens are to be notched in through thickness direction.
- Grain-coarsened HAZ (GCHAZ) is to be targeted for the sampling position of the crack tip.
- The test specimens are to be in as-welded and post-weld heat treated, if applicable.
- Three tests are to be performed at –10°C on each butt weld test assembly.

For grades 70 and above, dehydrogenation of as-welded test pieces may be carried out by a low temperature heat treatment, prior to CTOD testing. Heat treatment conditions of 200°C for 4 hours are recommended, and the exact parameters are to be notified with the CTOD test results.

Alternative CTOD test methodology and acceptance can be agreed with ABS at the time of qualification.

FIGURE 1A
Plate Thickness t ≤ 50 mm *(2018)*

For plate thickness t ≤ 50 mm, CTOD test specimen is to be sampled in full thickness.

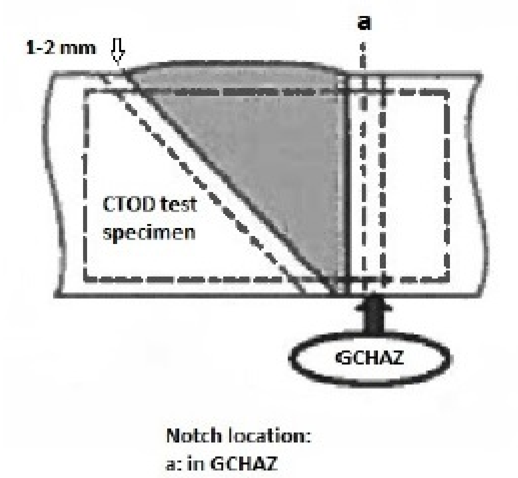
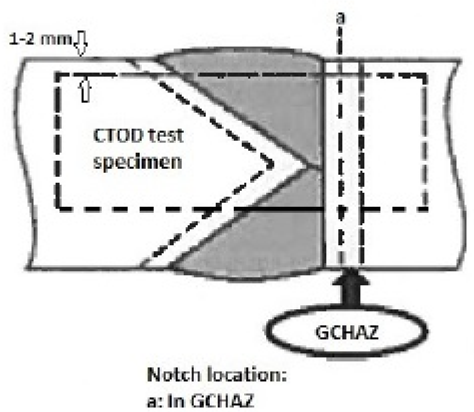


FIGURE 1B
Plate Thickness t > 50 mm *(2018)*

For plate thickness t > 50 mm, subsidiary CTOD test specimen with a thickness of maximum 50 mm in subsurface area is to be sampled.



5.11.3(g) Cold Cracking Test.

Testing in accordance with national and international recognized standards such as ISO 17642, GB/T4675.1 and JIS Z 3158 for Y-groove weld crack test. Minimum preheat temperature is to be determined and the relationship of minimum preheat temperature with thickness is to be derived.

5.11.3(h) Other Tests.

Additional tests may be required in the case of newly developed types of steel, outside the scope of Section 2-A4-3, or when deemed necessary by ABS.

7 Results

All the results are to comply with the requirements of the scheme of initial approval. Before the approval, all test results are evaluated for compliance with the Rules. Depending upon the finding, limitations or testing conditions may be specified in the approval document.

The subject manufacturer is to submit all the test results together with the manufacturing specification containing all the information required under 2-A4-2/3, and manufacturing records relevant to steel making, casting, rolling and heat treatment applicable to the product submitted to the tests.

9 Certification

9.1 Approval

Upon satisfactory completion of the survey, approval will be granted by ABS.

9.3 List of Approved Manufacturers

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

11 Maintenance and Renewal of Approval *(2024)*

The validity of the approval is to be to the maximum of five years, renewable subject to an audit and assessment of the result of satisfactory survey during the preceding period.

The following information is to be submitted to renew the approval,

i) Statistical data for the last 5 years including the chemistry, mechanical properties for the grade or grades approved by ABS.

ii) Any non-conformances during production of ABS grades and the respective corrective and preventive actions.

iii) A written confirmation stating there were no changes to the manufacturing process since last ABS approval.

iv) A copy of the latest certificate of compliance of the quality system with IS0 9001 or 9002 equivalent

The Surveyor's report confirming the above information is to be made available to the ABS Engineering/ Materials department for review and issuance of renewal letter/ certificate.

Where 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 instance, the extension of approval will be backdated to the original renewal date.

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 grades of products during the period are evaluated by ABS and found acceptable for renewal.

13 Withdrawal of the Approval

The approval may be withdrawn before the expiry of the validity period in the following cases:

i) In-service failures traceable to product quality

ii) Non conformity of the product revealed during fabrication and construction

iii) Discovery of failure of the manufacturer's quality system

iv) Changes made by the manufacturer, without prior agreement of ABS, to the extent of invalidating the approval

v) Evidence of major non conformities during testing of the products.

PART 2

APPENDIX 5

Hull Structural Steels Intended for Welding with High Heat Input

CONTENTS

PART 2

APPENDIX 5
Hull Structural Steels Intended for Welding with High Heat Input

SECTION 1
Procedure for the Approval of Manufacturers of Hull Structural Steels Intended for Welding with High Heat Input *(2006)*

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of manufacturers with the intent to meet goals and functional requirements outlined in the cross referenced sections.

1.3 Scope

This Appendix specifies the weldability confirmation procedures of normal and higher strength hull structural steels stipulated in Sections 2-1-2 and 2-1-3 intended for welding with high heat input over 50 kJ/cm (127 kJ/in.).

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

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

1.5 Approval Process *(2024)*

Below activities are involved in the granting of ABS approval.

i) Submission of information (as noted in 2-A5-1/3) for ABS Engineering review.

ii) Qualification tests (as noted in 2-A5-1/5) are to be carried out under ABS Survey witness, along with a plant survey of the works.

iii) Following a review of qualification test results and plant survey checksheet, ABS Engineering will issue the approval letter and certificate.

3 Application for Certification

The manufacturer is to submit to ABS a request for certification of the proposed weldability test program (see 2-A5-1/5.3 below) and technical documents relevant to:

i) Outline of steel plate to be certified

- Grade
- Thickness range
- Deoxidation practice
- Fine grain practice
- Aim range of chemical composition
- Aim 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, steel making, casting, rolling, heat treatment etc.

iii) Welding control points to improve joint properties on strength and toughness.

5 Confirmation Tests

5.1 Range of Certification

Range of certification for steel grades is to be in accordance with the following, unless otherwise agreed by ABS:

i) Approval tests on the lowest and highest toughness levels cover the intermediate toughness level.

ii) Approval tests on normal strength level cover that strength level only.

iii) For high tensile steels, approval tests on one strength level cover strength level immediately below.

iv) Tests may be carried out separately provided the same manufacturing process is applied.

v) Certification and documentation of confirmation tests performed by another Classification Society may be accepted at the discretion of ABS.

5.3 Weldability Test Program

The extent of the test program is specified in 2-A5-1/5.9, but it may be modified according to the contents of certification. In particular, additional test assemblies and/or test items may be required in the case of newly developed types of steel, welding consumable and welding method, or when deemed necessary by ABS. Where the content of tests differs from those specified in 2-A5-1/5.9, the program is to be confirmed by ABS before the tests are carried out.

5.5 Test Plate

The test plate is to be manufactured by a process approved by ABS in accordance with the requirements of Part 2, Appendix 4. For each manufacturing process route, two test plates with different thickness are to be selected. The thicker plate (t) and thinner plate (less than or equal to t/2) are to be proposed by the manufacturer.

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

5.7 Test Assembly

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

Dimensions of the test assembly are to be sufficient to take all the required test specimens specified in 2-A5-1/5.5.

The welding procedures are to be in accordance with the normal practices applied at shipyards for the test plate concerned, and including 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.

5.9 Examinations and Tests for the Test Assembly

The test assembly is to be examined and tested in accordance with 2-A5-1/5.9 TABLE 1, unless otherwise agreed by ABS.

TABLE 1
Tests for Hull Structural Steels with High Heat Input *(2024)*

Type of Test	*Remarks*
Visual examination	• Overall welded surface is to be uniform and free from injurious defects such as cracks, undercuts, and overlaps.
Macroscopic test	• One macroscopic photograph is to be provided representative of transverse section of the welded joint and is to show absence of cracks, lack of penetration, lack of fusion and other injurious defects.
Microscopic test	• Along mid-thickness line across transverse section of the weld, one micrograph with ×100 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.
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.
Transverse tensile test	• Two transverse (cross weld) tensile specimens are to be taken from the test assembly. Test specimens and testing procedures are to comply with the requirements found in Section 2-4-3. • The tensile strength is to be not less than the minimum required value for the grade of base metal.
Bend test	• Two transverse (cross weld) test specimens are to be taken from the test assembly and bent on a mandrel with diameter of quadruple specimen thickness. Bending angle is to be at least 120 degrees. Test specimens are to comply with the requirements found in 2-4-3. • For plate thicknesses up to 20 mm (0.8 in.), one face-bend and one root-bend specimen 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. Upon testing, the test specimens are not to display any crack or other open defect in any direction greater than 3 mm (0.12 in.).

Type of Test	*Remarks*
Impact test	• Charpy V-notch impact specimens (three specimens for one set) are to be taken within 2 mm (0.08 in.) below the plate surface on face side of the weld with the notch perpendicular to the plate surface. • One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and 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 that prescribed for the testing of the steel grade in question. • For steel plate with a thickness greater than 50 mm (2.0 in.) or one side welding for plate thicknesses greater than 20 mm (0.8 in.), one additional set of specimens 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 comply with the requirements of 2-1-2/15.9 TABLE 4 or 2-1-3/7.3 TABLE 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 ABS.
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 ABS. See 2-A5-1/5.3.

7 Results

The manufacturer is to submit to ABS the complete test report including all the results and required information relevant to the confirmation tests specified in 2-A5-1/5.

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

9 Certification

ABS will issue a certificate where the test report is found to be satisfactory. The following information is to be included on the certificate:

i) Manufacturer

ii) Grade designation with notation of heat input (refer to 2-A5-1/11)

iii) Deoxidation practice

iv) Fine grain practice

v) Condition of supply

vi) Plate thickness tested

vii) Welding process

viii) Welding consumable (manufacturer, brand, grade).

ix) Actual heat input applied.

11 Grade Designation

Upon issuance of the certificate, the notation indicating the value of heat input applied in the confirmation test may be added to the grade designation of the test plate, e.g. “E36-W300” [in the case of heat input 300 kJ/cm (762 kJ/in.) applied]. The value of this notation is to be not less than 50 and every 10 added.

PART 2

APPENDIX 6

Nondestructive Examination of Marine Steel Castings (2014)

CONTENTS

PART 2

APPENDIX 6

Nondestructive Examination of Marine Steel Castings (2014)

SECTION 1

General

Note:

The requirements in this Appendix are adopted from the IACS Recommendation No. 69. "Guidelines for Non-destructive Examination of Marine Steel Castings" with some modifications in order to be consistent with existing ABS publications. It becomes effective as of 1 January 2014.

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for inspection to verify conformance to the goals and functional requirements outlined in the cross referenced sections.

1.2 *(2024)*

This Appendix contains general guidance for the nondestructive examination methods, the extent of examination and the minimum recommended quality levels to comply with national or international standards for marine steel castings, unless otherwise approved or specified.

1.3

This Appendix contains guidelines on "Surface Inspections" (2-A6-2) by visual examination, magnetic particle testing and liquid penetrant testing and "Volumetric Inspection" (2-A6-3) by ultrasonic testing and radiographic testing.

1.5

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

1.7

Castings are to be examined in the final delivery condition. For specific requirements, see 2-A6-2/9 and 2-A6-3/7.

1.9

Where intermediate inspections have been performed the manufacturer is to furnish the documentation of the results upon request by the ABS Surveyor.

1.11 *(2024)*

Where a casting is supplied in semi-finished condition, the manufacturer is to take into account the quality level of the final finished machined components. Refer to 2-A6-2/11.3.3 for quality level.

1.13 *(2024)*

Where advanced ultrasonic testing methods are applied (e.g., PAUT or TOFD), reference is to be made to the ABS *Guide for Nondestructive Inspection* for a general approach in adopting and applying these advanced methods. Acceptance levels regarding accept/reject criteria are specified in the applicable section in this Appendix.

3 Qualification of NDT Personnel *(2024)*

Refer to Subsection 1/5 of the ABS *Guide for Nondestructive Inspection*.

PART 2

APPENDIX 6

Nondestructive Examination of Marine Steel Castings (2014)

SECTION 2

Surface Inspection

1 General

1.1 Objective *(2024)*

This section includes requirements for inspection to verify conformance to goals and functional requirements outlined in the cross referenced sections.

1.2

Surface inspections in this Appendix are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.

1.3 *(2024)*

The written procedures, instruments of magnetic particle inspection and liquid penetrant inspection are to comply with a recognized national or international standard.

1.5 *(2024)*

For NDT personnel qualification and certification, refer to 2-A6-1/5.

3 Casting Condition *(2024)*

3.1 Heat Treatment *(2024)*

i) Nondestructive testing for final casting certification is to be made after the final heat treatment of the casting.

ii) Where intermediate inspections have been performed, the manufacturer is to provide documentation of the results upon the request of ABS Surveyor.

3.3 Surface Condition *(2024)*

i) Castings are to be examined in the final delivery condition.

ii) The casting surface is to be free from any material such as scale, dirt, grease or paint that might affect the effectiveness of the inspection.

iii) A thin coating of contrast paint is permissible when using magnetic particle techniques. For surface inspection methods, the surface quality is to be a minimum value of Ra ≤6.3 μm.

5 Extent of Inspection *(2024)*

5.1 Zones to be Examined *(2024)*

i) Zones to be examined in castings are identified in 2-A6-A1.

ii) Inspection is to be made in accordance with an inspection plan approved by ABS. The plan is to specify the extent of the inspection, the inspection procedure, the quality level or, if applicable, the quality level for different locations of the castings.

iii) In addition to the areas identified in 2-A6-A1, surface inspections are to be carried out in the following locations:

- At all accessible fillets and changes of section
- In way of chaplets
- At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging
- In way of fabrication weld preparation, for a band width of 30 mm (1.2 in.)
- In way of weld repairs

7 Visual Inspection *(2024)*

Steel castings nominated for NDT are to be subjected to a 100% visual examination of all accessible surfaces by the manufacturer and results made available to ABS Surveyor. Viewing conditions at the inspected surfaces are to be in accordance with a nationally or internationally recognized standard. Unless otherwise agreed upon by ABS, the visual and surface inspections are to be carried out in the presence of the Surveyor.

9 Surface Inspection

9.1 *(2024)*

Magnetic particle inspection is preferable to penetrant inspection except in the following cases:

- Austenitic stainless steels
- Interpretation of open visual or magnetic particle indications
- At the instruction of the Surveyor, where interpretation of open visual or magnetic particle inspection is required by dye penetrant testing.

9.3

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].

9.5

Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor.

9.7 *(2024)*

For magnetic particle testing, attention is to be paid to the contact between the casting and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods are not permitted on finished machined items. Note that the use of solid copper at the prod tips is to be avoided due to the risk of copper contaminating the casting. The pole of the magnets are to have close contact with the component.

9.9

When indications are detected as a result of the surface inspection, the acceptance or rejection is to be decided in accordance with 2-A6-2/11.

11 Acceptance Criteria and Rectification of Defects

11.1 Visual Inspection *(2024)*

i) All castings are to be free of cracks, crack-like indications, hot tears, cold shuts, laps, seams, folds or other detrimental indications.

ii) Thickness of the remains of sprues, heads or burrs is to be within the casting dimensional tolerance.

iii) Additional magnetic particle, liquid penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor.

11.3 Surface Inspection *(2024)*

11.3.1 *(2024)*

The following definitions relevant to indications apply:

i) *Linear Indication.* An indication with a largest dimension three or more times its smallest dimension (i.e., $L \geq 3W$).

ii) *Nonlinear Indication.* An indication with a circular or elliptical shape with the largest dimension less than three times its smallest dimension (i.e., $L < 3W$).

iii) *Aligned Indication.* Three or more indications in a line, separated by 2 mm (0.08 in.) or less edge-to-edge, which result in a unique indication, defined as follows:

a) Non-linear indications form an alignment when the distance between indications is less than 2 mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.

b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication

iv) *Open Indication.* An indication visible after removal of the magnetic particles or that can be detected by the use of dye penetrant.

v) *Non-open Indication.* An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of dye penetrant.

vi) *Relevant Indication.* An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm (0.06 in.) are to be considered relevant.

11.3.2

For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm (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 is to be taken in the most unfavorable location relative to the indication being evaluated.

11.3.3 *(2024)*

The following quality levels 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 nominated for surface inspection. See 2-A6-A1.

The required quality level is to be shown on the manufacturer's inspection plan.

The allowable number and size of indications in the reference band length and/or area is given in 2-A6-2/13.1 TABLE 1. Cracks and hot tears are not acceptable.

11.5 Rectification of Defects *(2024)*

Indications that exceed the requirements of 2-A6-2/13.1 TABLE 1 are to be classed as defects and are to be repaired or rejected as appropriate.

11.5.1 *(2024)*

i) Shallow indications may be removed by grinding, or by chipping and grinding.

ii) All grooves are to have a bottom radius of approximately three times the groove depth and be smoothly blended to the adjacent surface.

iii) Cosmetic repairs do not require ABS approval. Cosmetic repairs are to be recorded on a weld repair sketch.

iv) These repairs may be carried out after final furnace heat treatment but are to be local stress relief heat treated.

v) Thermal methods of metal removal are only allowed before the final heat treatment. After final heat treatment, only grinding or chipping and grinding is allowed.

vi) Cosmetic repairs are to be recorded on a weld repair sketch

11.5.2 *(2024)*

Repairs by welding are defined as follows:

Major repairs:

i) Where the depth is greater than 25% of the wall thickness or 25 mm (1 in.), whichever is the less, or

ii) Where the weld area (length x width) exceeds 1250 cm^2 (194 in^2) (*Note:* where a distance between two welds is less than their average width, they are considered as one weld), or

iii) Where the total weld area on a casting exceeds 2% of the casting surface.

Minor repairs:

i) Where the total weld area (length x width) exceeds 5 cm^2 (0.8 in^2).

a) Major repairs are to be ABS approved before the repair is carried out. The repair is to be carried out before final furnace heat treatment.

b) In general, minor repairs do not require ABS prior approval before the repair is carried out. However, minor repairs in critical areas do require ABS prior approval. All weld repairs are to be recorded on a weld repair sketch as a part of the manufacturing procedure documents. These repairs are to be carried out before final furnace heat treatment.

c) Complete removal of the defect is to be verified by magnetic particle inspection or penetrant inspection, as appropriate.

d) Castings which are repaired are to be examined by the same method as at initial inspection as well as by additional methods as required by ABS Surveyor.

e) Repairs are to be recorded on a weld repair sketch.

13 Record

13.1 General *(2024)*

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

i) Date of testing

ii) Names and qualification level of inspection personnel

iii) Testing method

- For liquid penetrant testing: the penetrant system used,
- For magnetic particle testing: method of magnetizing, test media and magnetic field strength and magnetic flux indicators
- Viewing conditions, (as appropriate to the penetrant or magnetic technique and media used)
- Inspection procedure number
- Details of any test restrictions

iv) Type of Casting

v) Product number and identification

vi) Grade of steel

vii) Heat treatment

viii) Stage of inspection

ix) Locations for inspection

x) Surface condition

xi) Test standards used, including reference to the appropriate tables for acceptance purposes

xii) Testing condition

xiii) Results, including documentation regarding the repair and inspection history (as appropriate)

xiv) Statement of acceptance/non acceptance

xv) Locations of reportable indications

xvi) Details of weld repair including sketch

TABLE 1
Allowable Number and Size of Indications in a Reference Band Length/Area *(2024)*

Quality Level	*Max. Number of Indications*	*Type of Indication*	*Max. Number for Each Type Indication*	*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 (0.2)
		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 < 2 mm (0.08 in.).

PART 2

APPENDIX 6

Nondestructive Examination of Marine Steel Castings (2014)

SECTION 3

Volumetric Inspection

1 General

1.1 Objective *(2024)*

This Appendix includes requirements for inspection with the intent to verify conformance to goals and functional requirements outlined in the cross referenced sections.

1.3 *(2024)*

i) Volumetric inspection in this Appendix is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique with an approved inspection plan.

ii) In some cases, due to the shape, nature and complexity of casting, or defect type or orientation, there may be a need for radiographic inspection. In such cases, radiographic inspection is to be carried out based on prior agreement with ABS with an approved inspection plan/procedure.

1.5 *(2024)*

The written procedures and instruments of ultrasonic and radiographic inspection are to comply with a recognized national or international standards.

1.7 *(2024)*

For NDT personnel qualification and certification, refer to 2-A6-1/5.

3 Products

3.1 *(2024)*

Volumetric inspection by ultrasonic or radiographic applies to the hull steel castings indicated in Annex 2-A6-A1.

5 Extent of Volumetric Inspection *(2024)*

5.1 *(2024)*

Volumetric inspection is to be carried out according to the inspection plan approved by ABS. The inspection plan is to specify the extent of the examination, the examination procedure, the quality level or, if necessary, levels for different locations of the castings.

5.3 Zones to be Examined *(2024)*

i) In addition to the areas identified in Annex 2-A6-A1, ultrasonic inspections are to be carried out in the following locations:

- In way of all accessible fillets and changes of section
- In way of fabrication weld preparation for a distance of 50 mm (2 in.) from the edge
- At all locations to be subject to subsequent machining (including bolt holes)
- In way of weld repairs where the original defect was detected by ultrasonic testing
- In way of riser positions

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

7 Surface Condition *(2024)*

i) The ultrasonic inspection is to be carried out after the castings have been ground, machined, or shot blasted to a suitable condition, with a minimum value surface quality of Ra ≤ 12.5 μm after the final heat treatment.

ii) The surfaces of castings to be examined are to be such that adequate coupling can be established between the probe and the casting and that excessive wear of the probe can be avoided.

8 Ultrasonic Inspection *(2024)*

i) Ultrasonic scans are to be made using a 0º probe of 1 - 4 MHz frequency, and angle probes. Whenever possible, scanning is to be performed from both surfaces of the casting and from surfaces perpendicular to each other.

ii) The backwall echo obtained on parallel sections is to be used to monitor variations in probe coupling and material attenuation. Any reduction in the amplitude of the back wall echo due to material properties should be corrected. Attenuation in excess of 30 dB/m could be indicative of an unsatisfactory annealing heat treatment and may render the effectiveness of the inspection as unsuitable. Cases of excessive attenuation are to be investigated, and suitable mitigation measures carried out for effective ultrasonic inspection to continue, where possible.

iii) Machined surfaces, especially those in the vicinity of riser locations and in the bores of stern boss castings, are to be subjected to a near surface (approximately 25 mm (1 in.)) scan using a twin crystal 0º probe.

Commentary:

i Additional scans on machined surfaces are of particular importance where bolt holes are to be drilled or where surplus material such as "padding" has been removed by machining, thus moving the scanning surface closer to possible areas of shrinkage.

ii Additionally, it is good practice to examine the machined bores of castings using circumferential scans with 70º probes so that axial radial planar flaws such as hot tears can be detected. Fillet radii is to be examined using 45º, 60º, or 70º probes scanning from the surfaces/direction likely to give the best reflection, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area.

End of Commentary

iv) In the examinations of those zones nominated for ultrasonic examination the reference sensitivity for the 0° probe is to be established against a 6 mm (0.24 in.) reflector.

Commentary:

Sensitivity can be calibrated either against 6 mm (0.24 in.) diameter flat bottomed hole(s) in a reference block (or series of blocks) corresponding to the thickness of the casting provided that a transfer correction is made, using the DGS (distance-gain-size) method.

End of Commentary

v) The reference sensitivity of angle probes is to be established against an appropriate 6 mm (0.24 in.) reflector (e.g., reference reflectors angled perpendicular to the sound beam) for the DGS method.

Commentary:
The DGS diagrams issued by a probe manufacturer identify the difference in dB between the amplitude of a back wall echo and that expected from a 6 mm (0.24 in.) diameter disk reflector. By adding this difference to the sensitivity level initially set by adjusting a back wall echo to a reference height (e.g., 80%), the amended reference level will be representative of a 6 mm (0.24 in.) diameter disk reflector. Similar calculations can be used for evaluation purposes to establish the difference in dB between a back wall reflector and disk reflectors of other diameters such as 12 or 15 mm (0.47 or 0.59 in.).

End of Commentary

vi) Having made any necessary corrections for differences in attenuation or surface condition between the reference block and the casting, any indications received from the nominated zones in the casting that exceed the 6 mm (0.24 in.) reference level are to be marked for evaluation against the criteria given in 2-A6-3/11. Evaluation is to include additional scans with angle probes so that the full extent of the discontinuity can be plotted.

9 Acceptance Criteria

9.1 Ultrasonic Inspection *(2024)*

Acceptance criteria are identified in 2-A6-3/11 TABLE 1 as UT1 and UT2.

i) Level UT1:

- Fabrication weld preparation for a distance of 50 mm (2 in.)
- 50 mm (2 in.) depth from the final machined surface including bolt holes
- Fillet radii for a depth of 50 mm (2 in.) and within distance of 50 mm (2 in.) from the radius end
- Castings subject to cyclic bending stresses (e.g., rudder horn, rudder castings and rudder stocks) - the outer one third of thickness in the zones nominated for volumetric inspection by Annex 2-A6-A1.
- Discontinuities within the examined zones interpreted to be cracks or hot tears.

ii) Level UT2:

- Other locations nominated for ultrasonic testing in Annex 2-A6-A1 or on the inspection plan
- Positions outside locations nominated for level UT1 inspection where feeders and gates have been removed
- Castings subject to cyclic bending stresses - at the central one third of thickness in the zones of nominated for volumetric inspection by Annex 2-A6-A1

iii) The required quality levels are to be shown on the manufacturer's drawings.

iv) Ultrasonic acceptance criteria for other casting areas not nominated in Annex 2-A6-A1 is to be subject to special consideration based on the anticipated stress levels and the type, size and position of the discontinuity.

11 Record *(2024)*

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

i) Date of testing

ii) Names, signature and qualification level of inspection personnel

iii) Inspection method

iv) Type of casting

v) Product number for identification

vi) Grade of steel

vii) Heat treatment

viii) Stage of inspection

ix) Locations for inspection

x) Surface condition

xi) Test standards used

xii) Testing condition - Flaw detector, probe type, size, angle and frequency (and any adaptions to probes for curved surfaces), calibration and reference blocks, sensitivity method (including reflector size, transfer correction), maximum scanning rate (mm/s), and couplant.

xiii) Results, including documentation regarding the repair and inspection history, location of reported indications, details of weld repairs including sketches (where applicable)

xiv) Statement of acceptance/non acceptance

TABLE 1
Acceptance Criteria for Steel Castings *(2024)*

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 Indications that exceed the requirements of 2-A6-3/11 TABLE 1, are to be classed as defects, and are to be repaired or rejected as appropriate to ABS agreement.

2 DGS: distance – gain size.

PART 2

APPENDIX 6

Nondestructive Examination of Marine Steel Castings (2014)

ANNEX 1

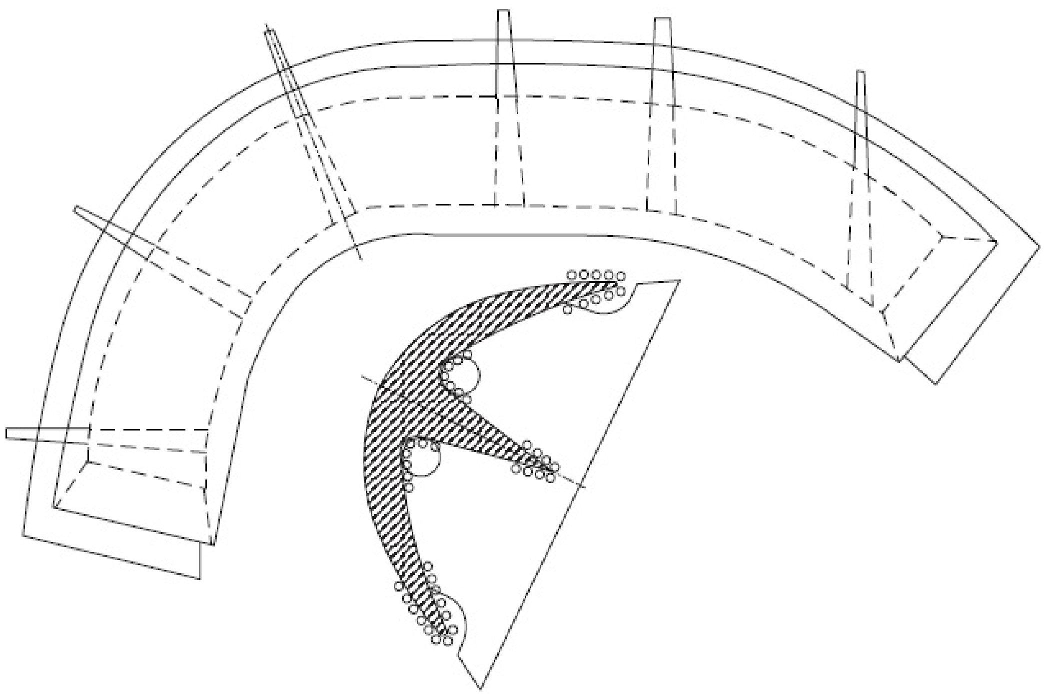
General Location for the Type of Nondestructive Examinations of Typical Hull Steel Castings

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for inspection to verify conformance to goals and functional requirements outlined in the cross-referenced sections.

FIGURE 1
Stern Frame



Notes:

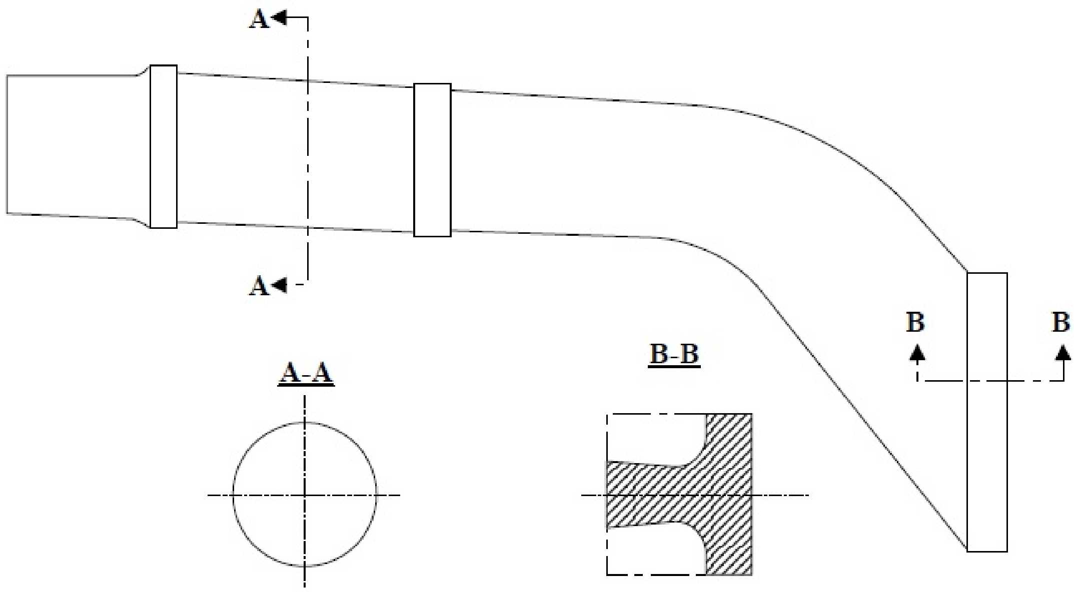
Location of nondestructive examination:

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 2-A6-2 and 2-A6-3.

FIGURE 2
Rudder stock



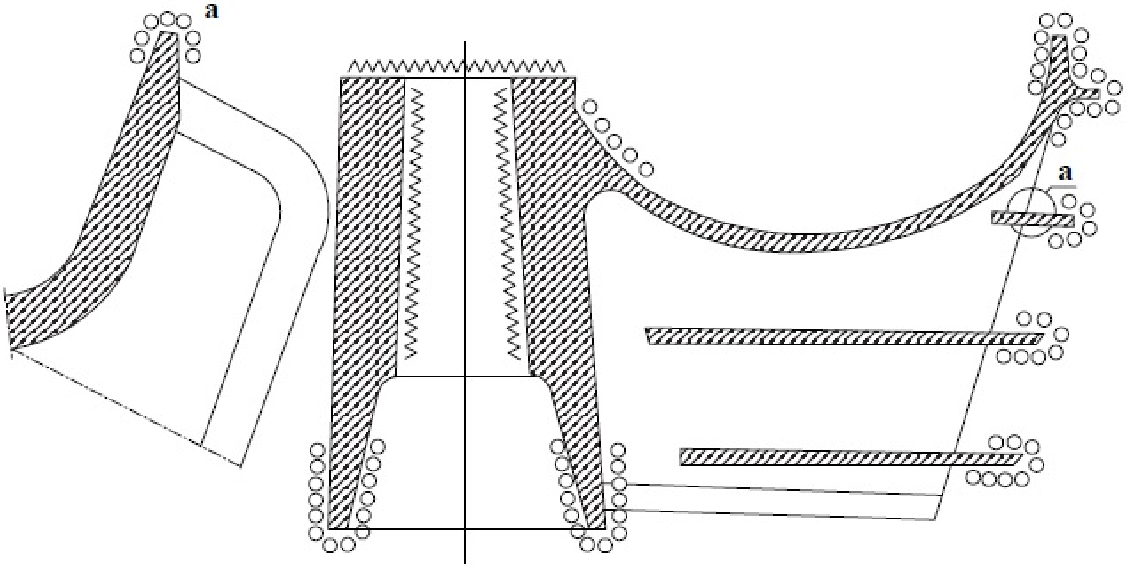
Notes:

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 2-A6-2 and 2-A6-3.

FIGURE 3
Stern Boss *(2011)*



Notes:

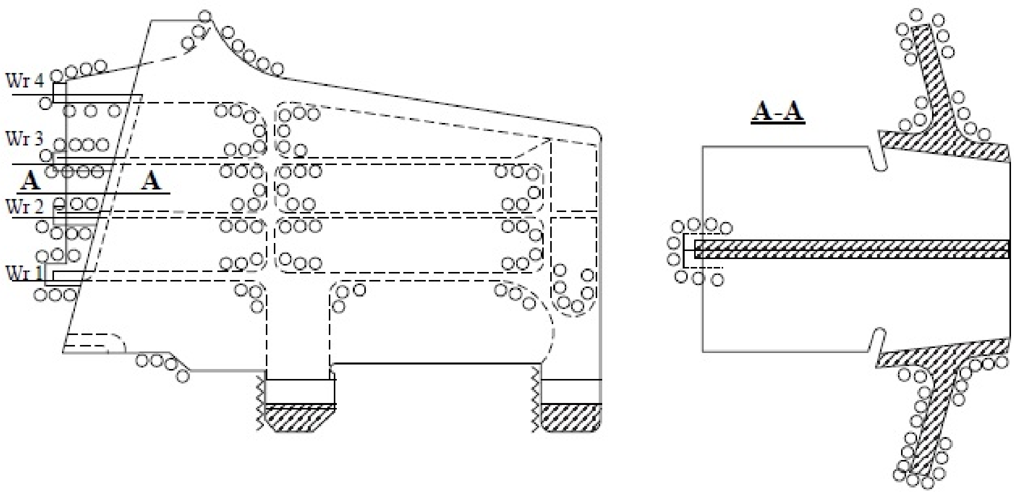
Location of nondestructive examination:

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 2-A6-2 and 2-A6-3.

5 *(2011)* Radiography testing is permitted in lieu of Ultrasonic testing.

FIGURE 4
Rudder Hangings *(2011)*



Notes:

Location of nondestructive examination:

1 All surfaces: Visual examination

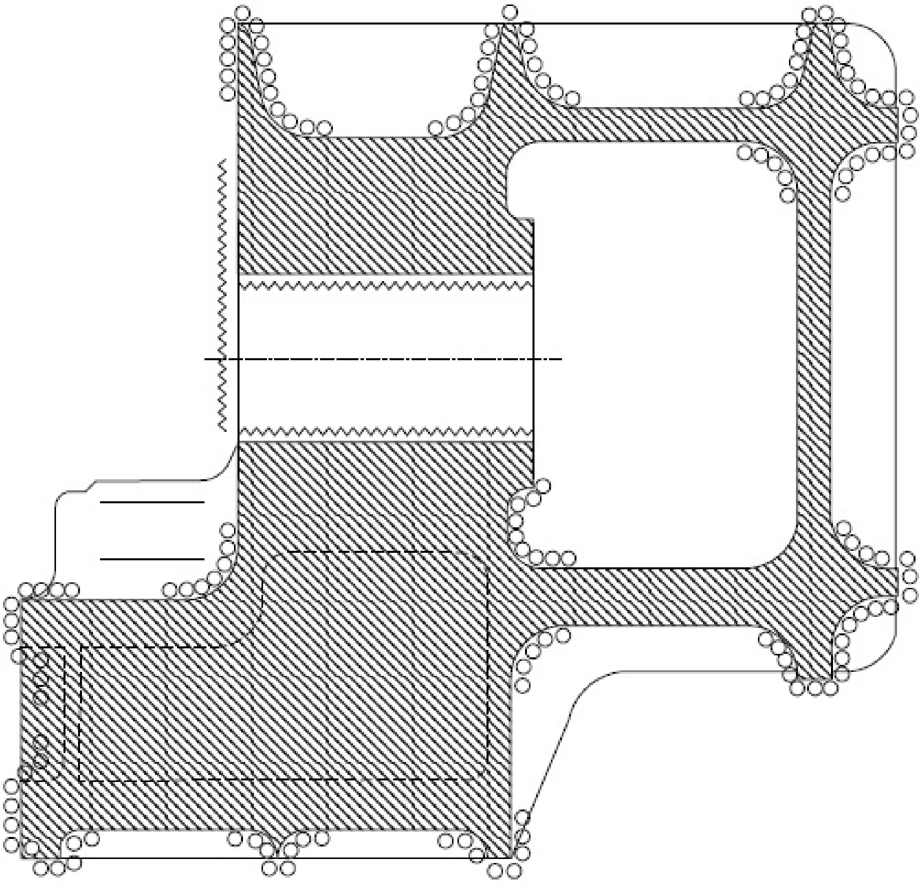
2 Location indicated with (OOO): Magnetic particle testing and Ultrasonic testing

3 Location indicated with (^^^^): Ultrasonic testing

4 The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3.

5 *(2011)* Radiography testing is permitted in lieu of Ultrasonic testing.

FIGURE 5
Rudder (Upper Part) *(2011)*



Notes:

Location of nondestructive examination:

1 All surfaces: Visual examination

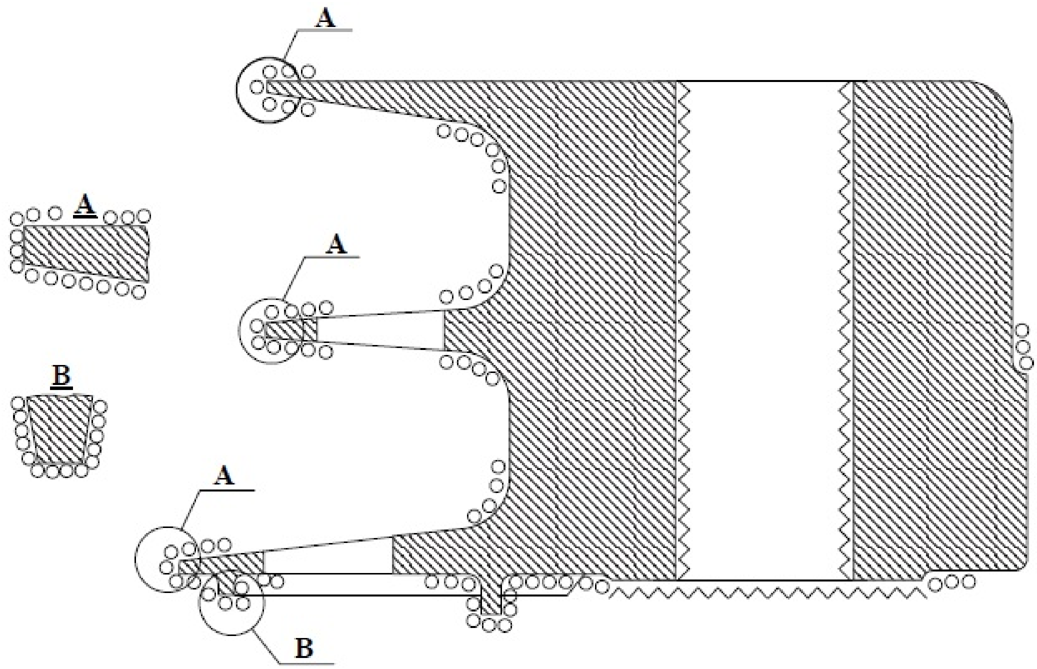
2 Location indicated with (OOO): Magnetic particle testing and Ultrasonic testing

3 Location indicated with (^^^^): Ultrasonic testing

4 The detailed extents of examinations and quality levels are given in 2-A6-2 and 2-A6-3.

5 *(2011)* Radiography testing is permitted in lieu of Ultrasonic testing.

FIGURE 6
Rudder (Lower Part) *(2011)*



Notes:

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 2-A6-2 and 2-A6-3.

5 *(2011)* Radiography testing is permitted in lieu of Ultrasonic testing.

PART 2

APPENDIX 7

Nondestructive Examination of Hull and Machinery Steel Forgings (2014)

CONTENTS

PART 2

APPENDIX 7
Nondestructive Examination of Hull and Machinery Steel Forgings (2014)

SECTION 1
General

Note:

Requirements in the Appendix are based on IACS Recommendation No. 68. "Guidelines for Non-destructive Examination of Hull and Machinery Steel Forgings" with modifications in order to be consistent with existing ABS publications.

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for inspection, with the intent to verify conformance to the goals and functional requirements outlined in the cross referenced sections.

1.2 *(2024)*

This Appendix complements the ABS requirements for "Hull and machinery steel forgings" and "Parts of internal combustion engines for which non-destructive inspection are required", and contains general guidance for the nondestructive examination methods, the extent of examination and the minimum recommended quality levels to be complied with unless otherwise approved or specified.

1.3 *(2024)*

This Appendix contains guidelines on "Surface Inspections" (2-A7-2) by visual examination, magnetic particle inspection and liquid penetrant inspection; "Volumetric Inspection" (2-A7-3) by ultrasonic testing.

1.5

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

1.7

Forgings are to be examined in the final delivery condition. For specific requirements, see 2-A7-2/9.3 and 2-A7-3/7.3.

1.9

Where intermediate inspections have been performed, the manufacturer is to furnish a documentation of the results upon the request of the Surveyor.

1.11

Where a forging is supplied in semi-finished condition, the manufacturer is to take into account the quality level of final finished machined components.

1.13 *(2024)*

Where advanced ultrasonic inspection methods are applied (e.g., PAUT or TOFD), refer to the ABS *Guide for Nondestructive Inspection* for general approach in adopting and application of these advanced methods. Acceptance levels regarding accept/reject criteria are specified in the applicable section of this Appendix.

3 Qualification of NDT Personnel *(2024)*

Refer to Subsection 1/5 of the ABS *Guide for Nondestructive Inspection*.

PART 2

APPENDIX 7

Nondestructive Examination of Hull and Machinery Steel Forgings (2014)

SECTION 2

Surface Inspection

1 General

1.1 Objective *(2024)*

This section includes requirements for inspection, with the intent to verify conformance to the goals and functional requirements outlined in the cross referenced sections.

1.2 *(2024)*

Surface inspections in this Appendix are to be carried out by visual examination and magnetic particle or liquid penetrant inspection.

1.3 *(2024)*

The written procedures, instruments of magnetic particle inspection and liquid penetrant inspection are to comply with a recognized national or international standard.

1.5 *(2024)*

NDT personnel engaged in surface inspection are to comply to the requirements as stated in Subsection 1/5 of the ABS *Guide for Nondestructive Inspection*.

3 Products

3.1 *(2024)*

i) The steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rods, piston rods, gearing, forging stock machined into simple shapes, etc., are to be subjected to a 100% visual examination of all accessible surfaces by manufacturer and made available to the Surveyor. For mass produced forgings, the extent of examination is to be established at the discretion of the attending Surveyor.

ii) Austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings acceptance criteria details are included in the appropriate sections for surface and volumetric inspections. However, other acceptance criteria and national or international standards may be applied upon agreement with ABS.

iii) Where alternative standards are proposed for acceptance criteria, the quality level is to provide reasonable equivalence to the allowable criteria stated in the appropriate tables within this

Appendix. The quality levels are to normally be the highest or most stringent to provide reasonable equivalence with this Appendix.

3.3 *(2024)*

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

i) All crankshafts

ii) Propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm (4 in.)

iii) Cylinder heads, 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.), which are subjected to dynamic stresses such as cylinder cover bolts, coupling bolts for crankshafts, tie rods, crankpin bolts, main bearing bolts, propeller blade fastening bolts

5 Zones for Surface Inspections *(2024)*

Magnetic particle, or where permitted, liquid penetrant inspection, is to be carried out in the zones I, II, and III (as applicable), as indicated in 2-A7-2/13.1 FIGURE 1 to 2-A7-2/13 FIGURE 4.

7 Surface Condition

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

9 Surface Inspection

9.1 *(2024)*

Where indicated by 2-A7-2/13.1 FIGURE 1 to 2-A7-2/13 FIGURE 4, magnetic particle inspections are to be carried out with the following exceptions, when liquid penetrant testing is permitted:

- Austenitic and ferrite-austenitic stainless steels
- Interpretation of open visual or magnetic particle indications
- At the instruction of the Surveyor, where a particular need for penetrant inspection has been identified.

9.3 *(2024)*

Unless otherwise specified in the order or specification, the magnetic particle inspection is to be performed 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].

9.5

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

9.7 *(2024)*

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

9.9

When indications are detected as a result of the surface inspection, the acceptance or rejection is to be decided in accordance with 2-A7-2/11.

11 Acceptance Criteria and Rectification of Defects

11.1 Visual Inspection *(2024)*

i) All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other detrimental indications.

ii) Additional magnetic particle and liquid penetrant inspection may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor.

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

11.3 Surface Inspection *(2024)*

11.3.1 *(2024)*

The following definitions relevant to indications apply:

- *Linear indication.* An indication with a largest dimension three or more times its smallest dimension (i.e., $L \geq 3W$).
- *Nonlinear indication.* An indication with a largest dimension less than three times its smallest dimension (i.e., $L < 3W$).
- *Aligned indication.* Three or more indications in a line, separated by 2 mm (0.08 in.) or less edge-to-edge, which result in a unique indication, defined as follows:

  a) Non-linear indications form an alignment when the distance between indications is less than 2 mm (0.08 in.) and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.

  b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

- *Open indication.* An indication visible after removal of the magnetic particles or that can be detected by the use of dye penetrant.
- *Non-open indication.* An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of dye penetrant.
- *Relevant indication.* An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm (0.06 in.) are to be considered relevant.

11.3.2

For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2 (35 in^2). The area is to be taken in the most unfavorable location relative to the indication being evaluated.

11.3.3 *(2024)*

The allowable number and size of indications in the reference area is given in 2-A7-2/11.3.3 TABLE 1 for crankshaft forgings and in 2-A7-2/11.3.3 TABLE 2 for other forgings (including austenitic stainless steel and ferrite-austenitic stainless-steel forging), respectively. Cracks are not acceptable. Irrespective of the results of nondestructive examination, the Surveyor may reject the forging if the total number of indications is excessive.

TABLE 1
Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm^2(35 in^2) *(2010)*

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)		Linear	0	---
	3	Nonlinear	3	3.2 (0.125)
		Aligned	0	---
III (Journal Surfaces)		Linear	0	---
	3	Nonlinear	3	5.0 (0.2)
		Aligned	0	---

TABLE 2
Steel Forgings Excluding Crankshaft Forgings - Allowable Number and Size of Indications in a Reference Area of 225 cm^2(35 in^2) *(2010)*

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 (0.2)
		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.

11.5 Rectification of Defects

11.5.1 *(2024)*

Indications that exceed the requirements of 2-A7-2/11.3.3 TABLE 1 and 2-A7-2/11.3.3 TABLE 2 are to be classed as defects and are to be repaired or rejected as appropriate.

11.5.1(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 are to be smoothly blended to the surface area with a finish equal to the adjacent surface.

11.5.1(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.

11.5.1(c)

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

11.5.1(d)

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

11.5.1(e) (2024)

Repair welding is not permitted for crankshafts. Repair welding of other forgings is subjected to ABS technical assessment and prior approval on a case-by-case basis.

11.5.2 Zone I in Crankshaft Forgings

Neither indications nor repair are permitted in this zone.

11.5.3 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.

11.5.4 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.

11.5.5 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.

11.5.6 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 (0.4 in.), whichever is smaller. The total ground area is to be less than 2% of the forging surface area.

13 Record

13.1 General *(2024)*

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

i) Date of testing

ii) Names, signature, and qualification level of inspection personnel

iii) Testing method and testing details

- For liquid penetrant testing: the penetrant system used
- For magnetic particle testing: method of magnetizing, test media and magnetic field strength and magnetic flux indicators

- Viewing conditions, (as appropriate to the penetrant or magnetic technique and media used)
- Inspection procedure number
- Details of any test restrictions

iv) Type of Forging

v) Product number and identification

vi) Grade of steel

vii) Heat treatment

viii) Stage of inspection

ix) Position (zone) of inspection

x) Surface condition

xi) Test standards used, including reference to the appropriate tables for acceptance purposes

xii) Testing condition

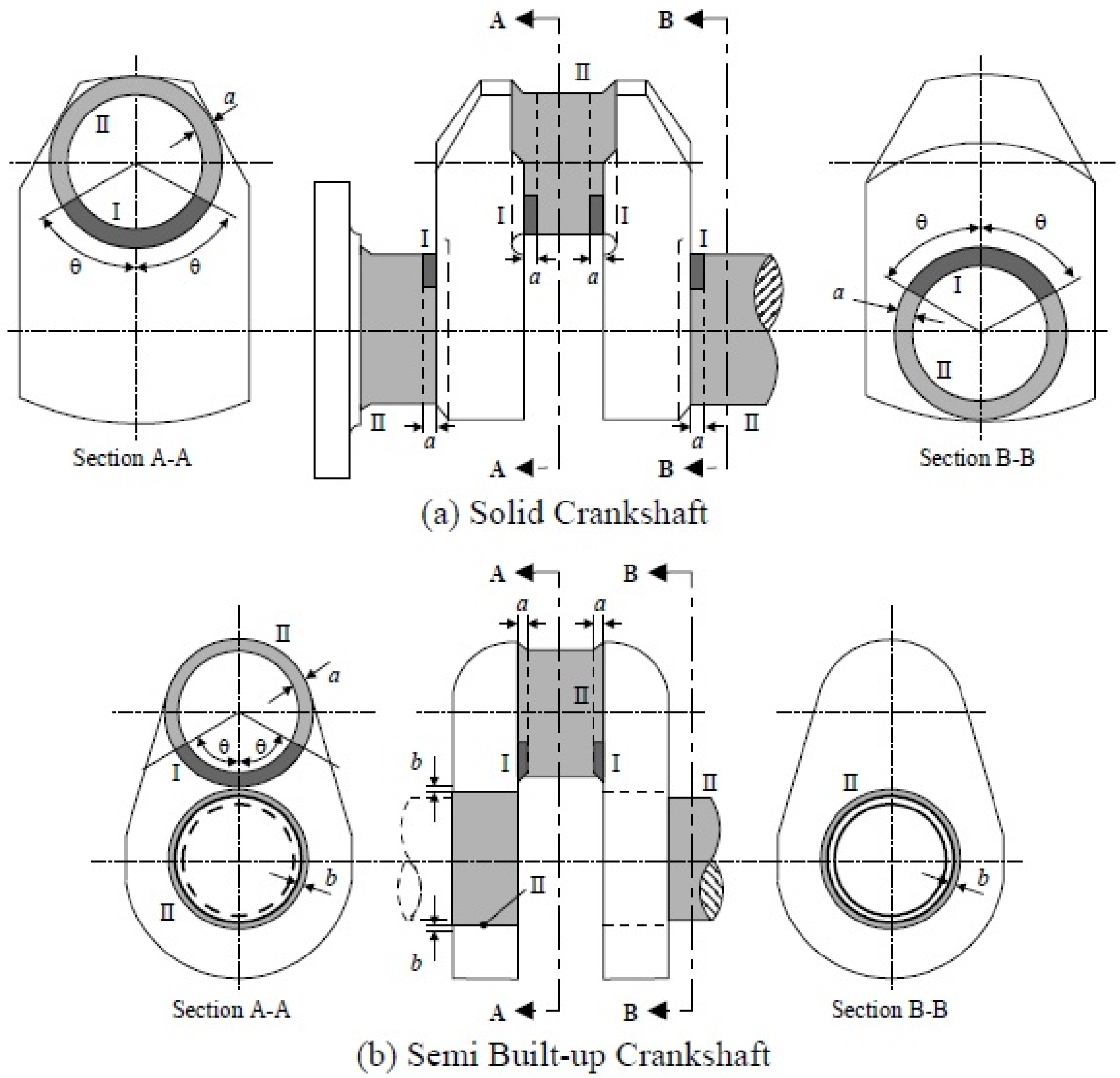
xiii) Results, including documentation regarding the repair and inspection history (as appropriate)

xiv) Statement of acceptance/non acceptance

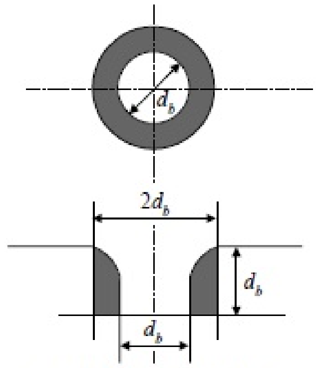
xv) Locations of reportable indications

xvi) Details of weld repair including sketch

FIGURE 1
Zones for Magnetic Particle/Liquid Penetrant Inspection on Crankshafts *(2024)*

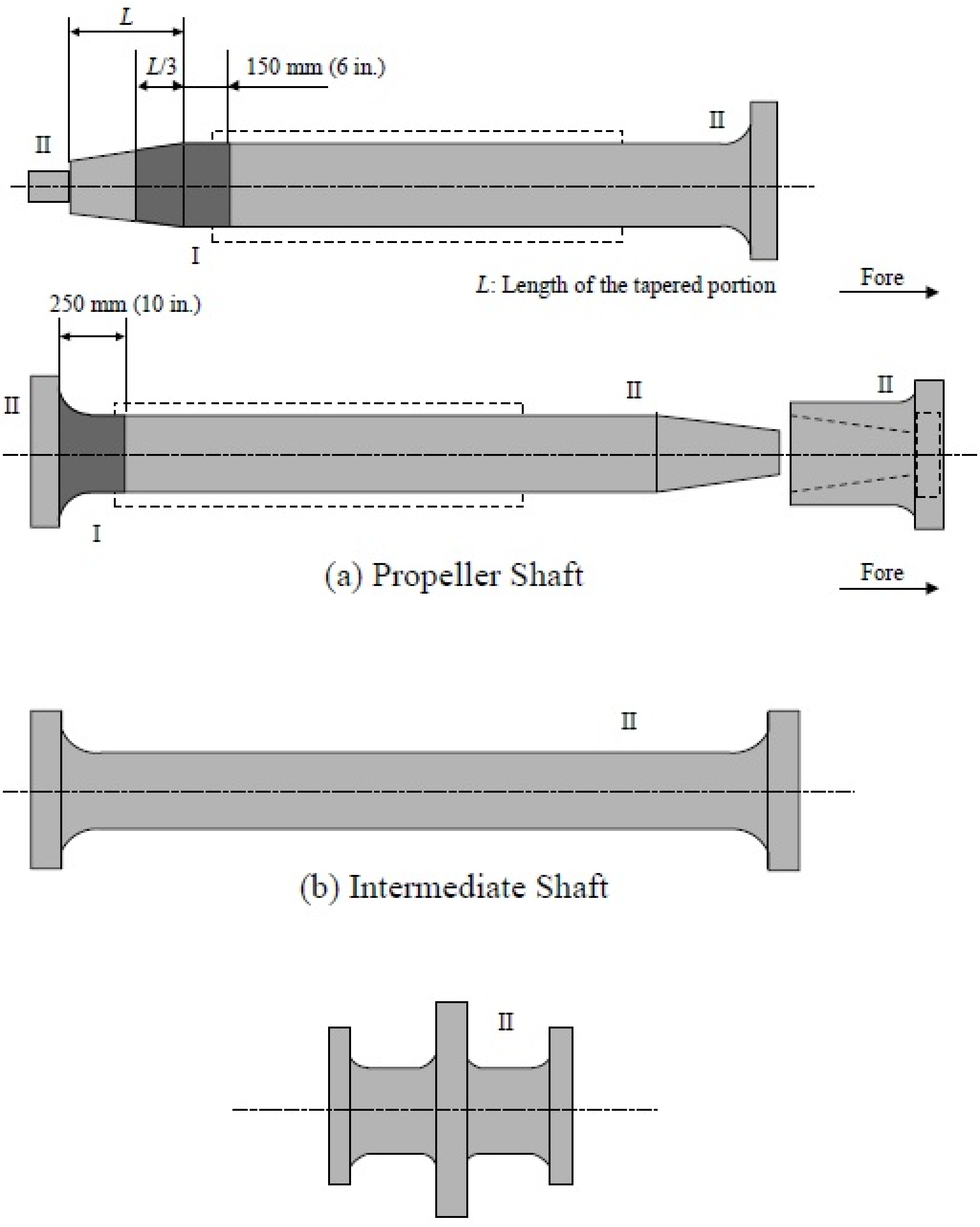


Notes

<table>
<tr><td>1</td><td colspan="2">Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I. (See the figure in the right.)</td></tr>
<tr><td>2</td><td>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</td><td>Identification of the Zones (Similar in 2-A7-2/13.1 FIGURE 1 through 2-A7-2/13 FIGURE 4):
: Zone I
: Zone II
: Zone III</td></tr>
</table>

FIGURE 2
Zones for Magnetic Particle/Liquid Penetrant Inspection on Shafts *(2024)*



(a) Propeller Shaft

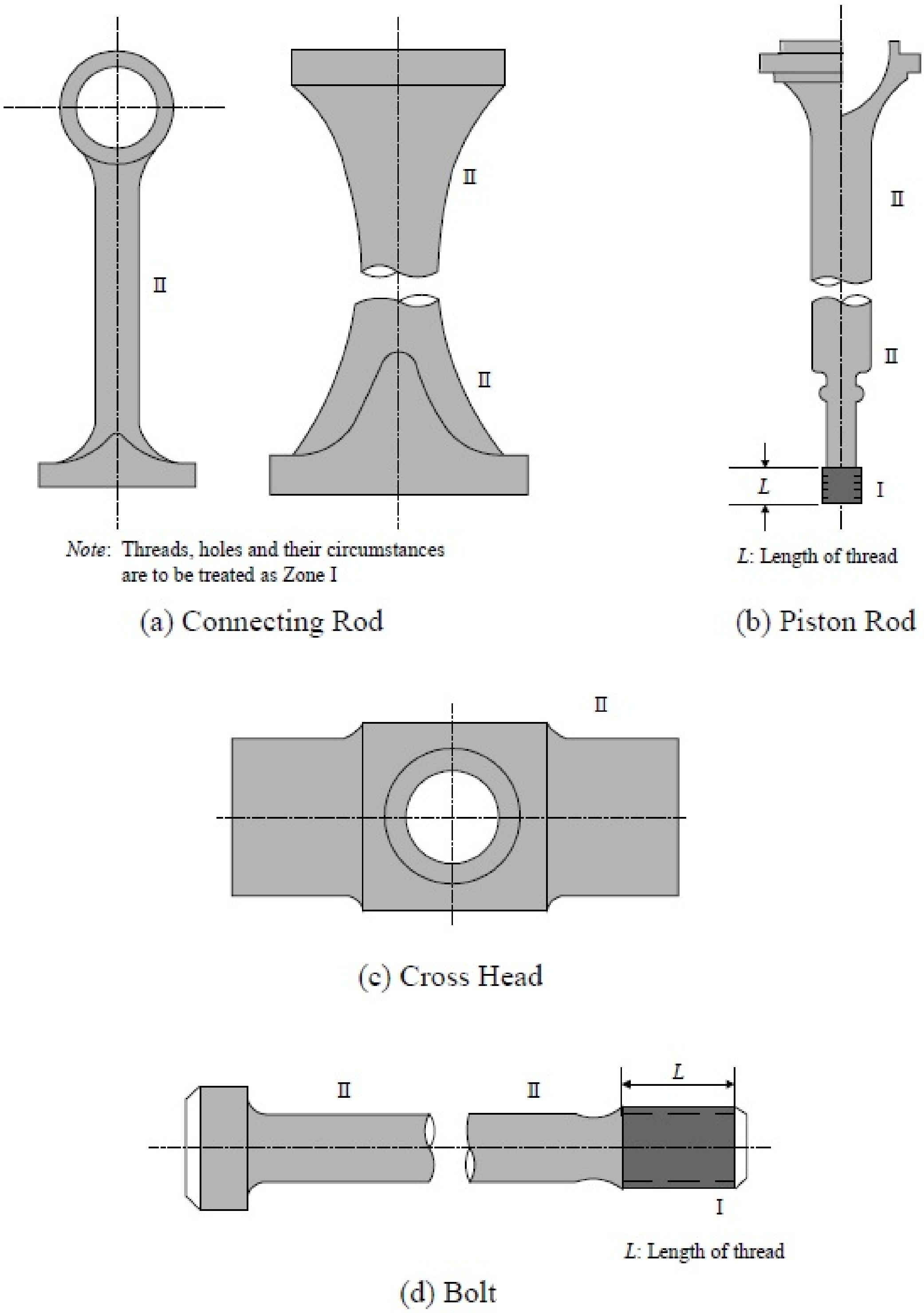
(b) Intermediate Shaft

(c) Thrust Shaft

Note:

For propeller shafts, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and keyways are to be considered as Zone I.

FIGURE 3
Zones for Magnetic Particle/Liquid Penetrant Inspection on Machinery Components *(2024)*



(a) Connecting Rod

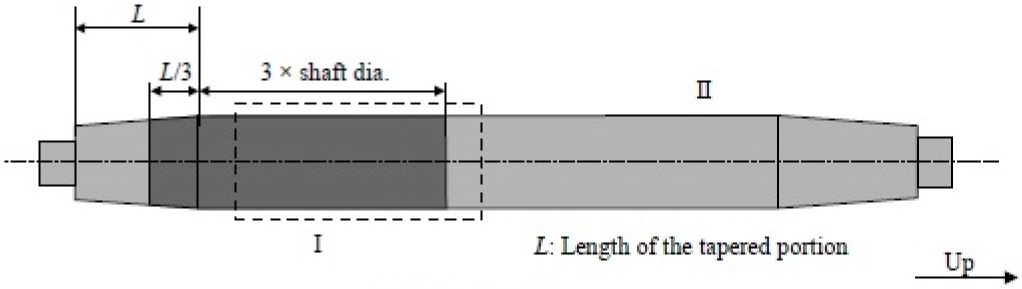
(b) Piston Rod

(c) Cross Head

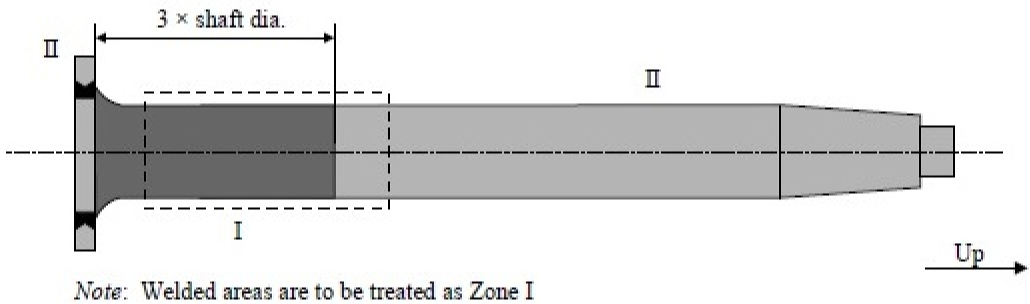
(d) Bolt

.

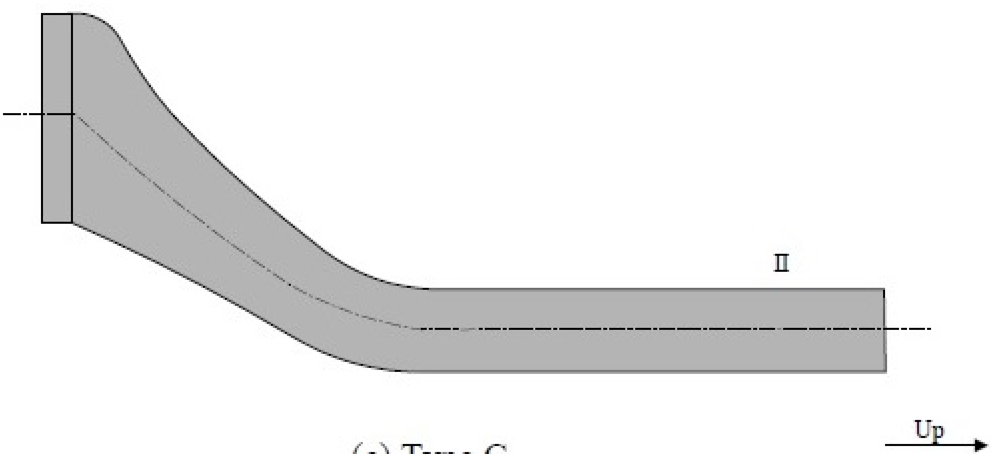
FIGURE 4
Zones for Magnetic Particle/Liquid Penetrant Inspection on Rudder Stocks
(2024)



(a) Type A



(b) Type B



(c) Type C

PART 2

APPENDIX 7

Nondestructive Examination of Hull and Machinery Steel Forgings (2014)

SECTION 3

Volumetric Inspection

1 General

1.1 Objective *(2024)*

This section includes requirements for inspection, with the intent to verify conformance to goals and functional requirements outlined in the cross referenced sections.

1.2

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

1.3 *(2024)*

i) The inspection procedures, apparatus, and conditions of ultrasonic inspection are to comply with the recognized national or international standards.

ii) DGS (distance-gain size) method is to be used for setting the test sensitivity and testing evaluation. The applied methodology is to use 2 to 4 MHz straight beam probes and/or angle beam probes. For near surface testing (up to a depth of 25 mm (1 in.)) twin crystal 0º probe is to be used, plus a single crystal 0º probe for the remaining volume inspection.

iii) Fillet radii are to be examined using 45°, 60° or 70° probes to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area.

iv) Advanced UT methods (such as PAUT or TOFD) are to meet the general requirements of the ABS *Guide for Nondestructive Inspection* or other recognized national or international standards.

1.5 *(2024)*

NDT personnel engaged in ultrasonic inspection are to comply to the requirements as stated in Subsection 1/5 of the ABS *Guide for Nondestructive Inspection*.

3 Products

3.1 *(2024)*

Volumetric inspections by ultrasonic testing apply to the following steel forgings:

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 Appendix 2-A7-4.

iii) Intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm (8 in.)

iv) Connecting rods, cylinder heads, piston rods, crossheads, coupling bolts, and studs are to be examined in accordance with 4-2-1/15 TABLE 3.

3.3 *(2024)*

Ultrasonic acceptance criteria detailed in 2-A7-3/11 TABLE 1 and 2-A7-3/11 TABLE 2 are intended for C, C-Mn, and alloy steel forgings, and do not apply to austenitic stainless steel or ferritic-austenitic (duplex) stainless steel forgings. Examples of standards for acceptance criteria for stainless steel or duplex stainless steel forgings are provided below, and quality levels are to be agreed upon with ABS. Other national or international standards may be used, as agreed with ABS.

i) ASTM A745 / A745M – 20

ii) EN 10228-4:2016

5 Zones for Volumetric Inspection *(2024)*

Ultrasonic inspection is to be carried out in the zones I to III as indicated in 2-A7-3/11 FIGURE 1 to 2-A7-3/11 FIGURE 4. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

7 Surface Condition

7.1

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

7.3 *(2024)*

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

9 Acceptance Criteria

Acceptance criteria of volumetric inspection by ultrasonic testing are shown in 2-A7-3/11 TABLE 1 and 2-A7-3/11 TABLE 2.

11 Record *(2024)*

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

i) Date of testing

ii) Names and qualification level of inspection personnel

iii) Testing method including procedure number, and details of the following items:

  a) Equipment used (instrument, probes and any adaptions to probes for curved surfaces, calibration and refence blocks)

  b) Technique(s) used to set test sensitivity (including sensitivity method, specific reference blocks, reflector size, transfer correction) *c)* Maximum scanning rate (mm/s)

d) Details of any testing restrictions

iv) Kind of product

v) Product number and identification

vi) Grade of steel

vii) Heat treatment

viii) Stage of testing

ix) Position (zone) of testing

x) Surface condition

xi) Test standards used, including reference to the appropriate tables for acceptance purposes

xii) Testing condition

xiii) Results, including documentation regarding the repair and testing history (as appropriate)

xiv) Statement of acceptance/non acceptance

TABLE 1
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	$d \leq 0.5$ mm (0.02 in.)	NA	NA
	II	$d \leq 2.0$ mm (0.08 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
	III	$d \leq 4.0$ mm (0.16 in.)	≤ 15 mm (0.6 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 larger indication. This also applies to the distance in axial direction as well as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

TABLE 2
Acceptance Criteria for Shafts and Machinery Components *(2024)*

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: $d \leq 2$ mm (0.08 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
		inner: $d \leq 4$ mm (0.16 in.)	≤ 15 mm (0.6 in.)	≥ 20 mm (0.8 in.)
	III	outer: $d \leq 3$ mm (0.12 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
		inner: $d \leq 6$ mm (0.24 in.)	≤ 15 mm (0.6 in.)	≥ 20 mm (0.8 in.)
Connecting Rod, Piston Rod, Crosshead	II	$d \leq 2$ mm (0.08 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)
	III	$d \leq 4$ mm (0.16 in.)	≤ 10 mm (0.4 in.)	≥ 20 mm (0.8 in.)

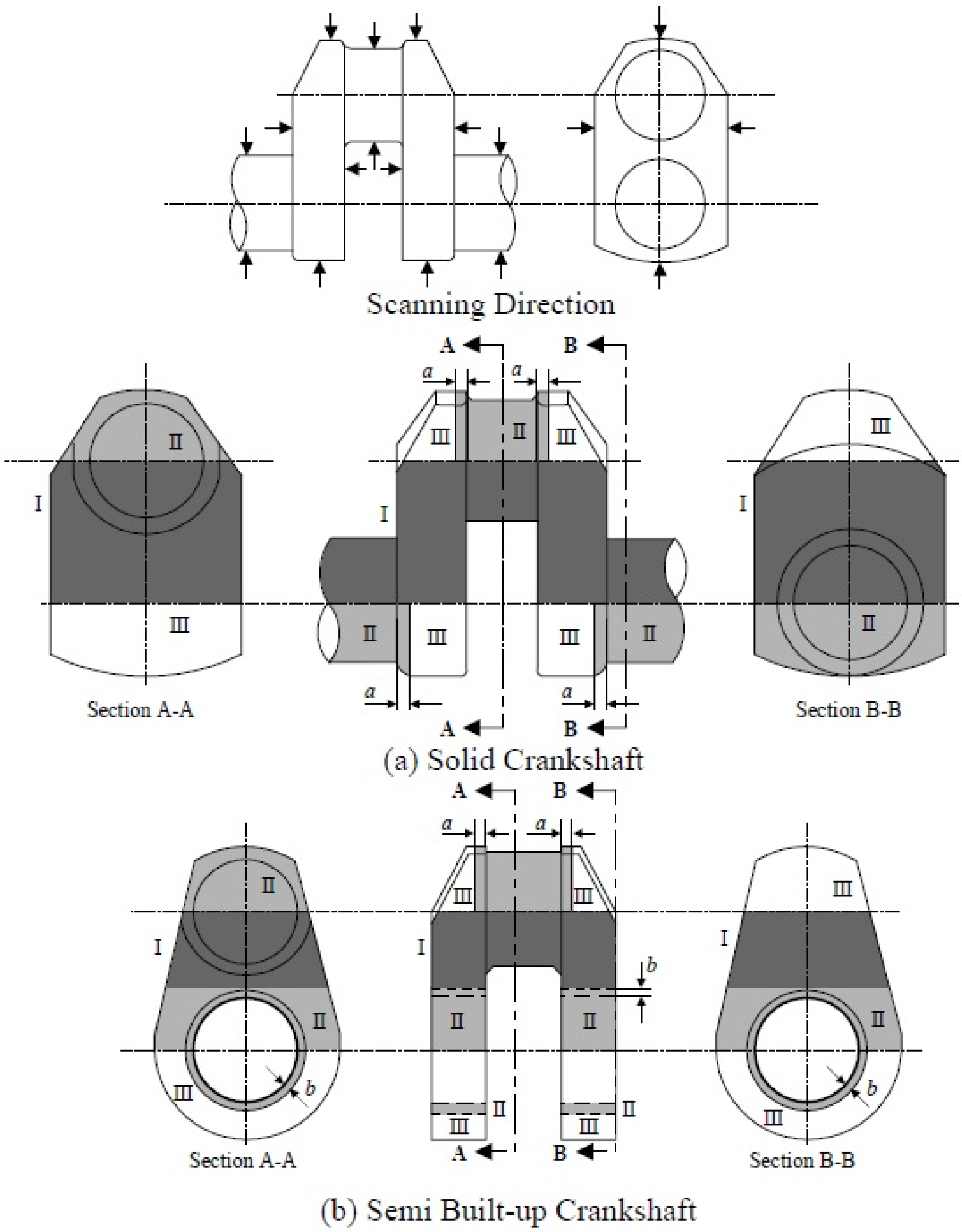
Notes:

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 larger indication. This also applies to the distance in axial directions as well as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

FIGURE 1
Zones for Ultrasonic Inspection on Crankshafts *(2024)*



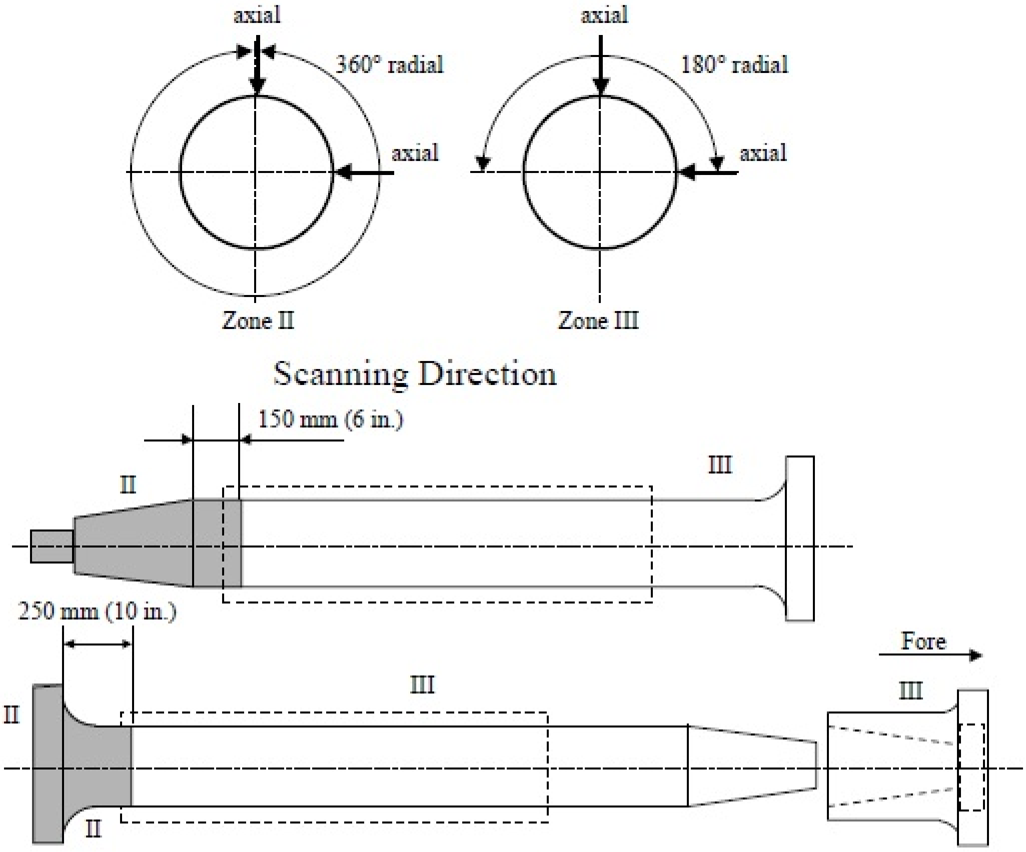
Notes

1. In the above figures, "□ " 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.

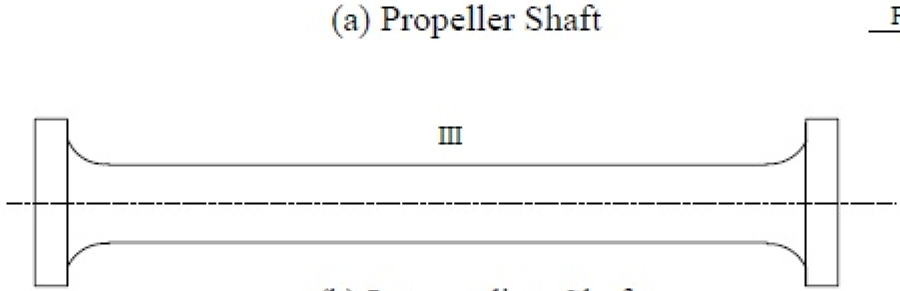
2. Core areas of crank pins and/or journals within a radius of 0.25d between the webs are to be coordinated to Zone II.

3. Identification of the Zones (Similar in 2-A7-3/11 FIGURE 1 through 2-A7-3/11 FIGURE 4):
   : Zone I
   : Zone II
   : Zone III

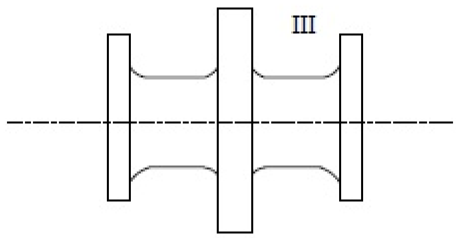
FIGURE 2
Zones for Ultrasonic Testing on Shafts



(a) Propeller Shaft



(b) Intermediate Shaft



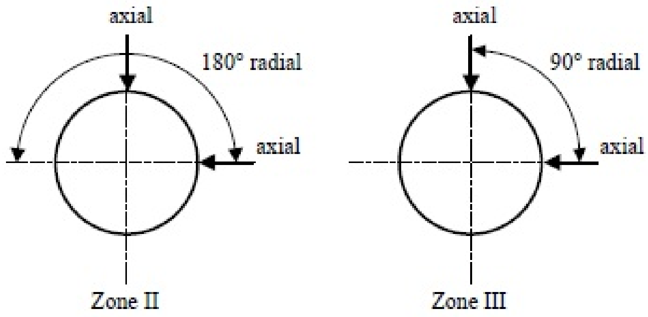
(c) Thrust Shaft

Notes:

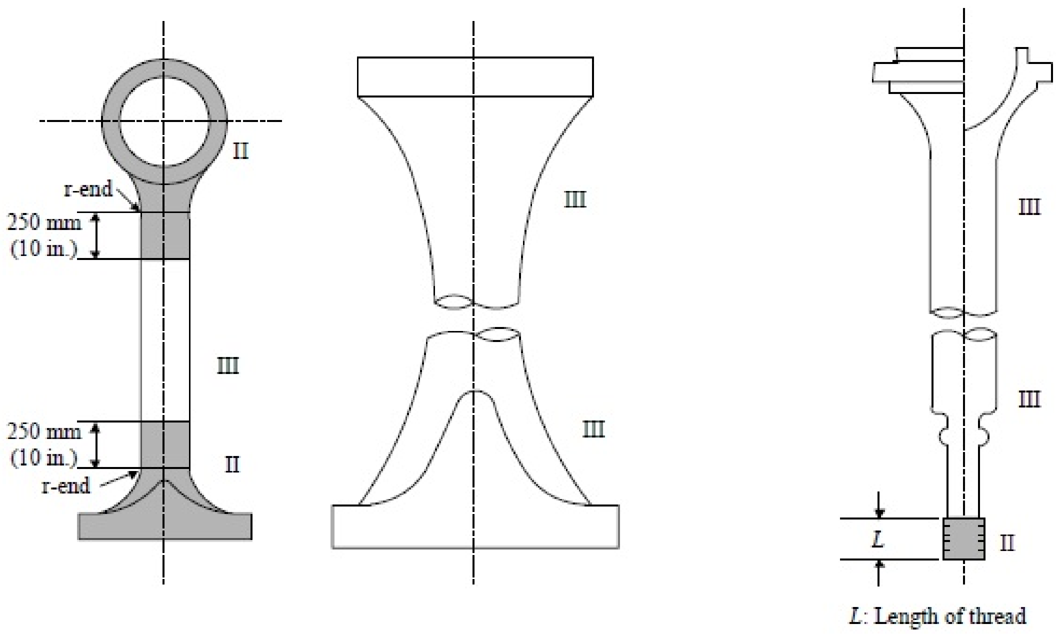
1 For hollow shafts, 360° radial scanning applies to Zone III.

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

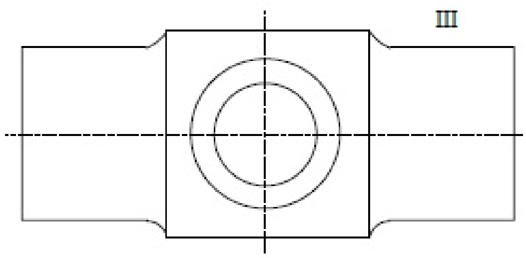
FIGURE 3
Zones for Ultrasonic Inspection on Machinery Components *(2024)*



Scanning Direction

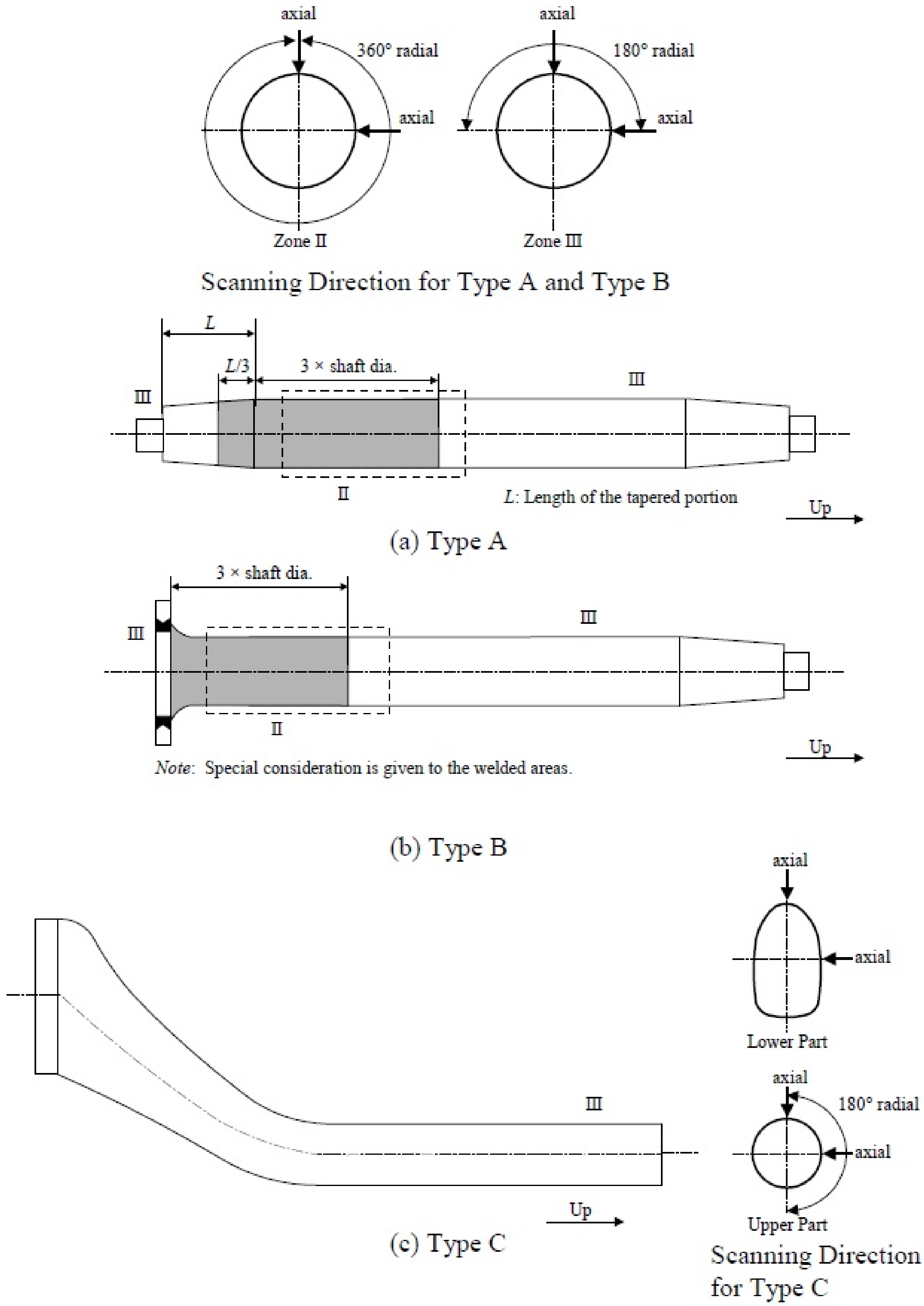


(a) Connecting Rod (b) Piston Rod



(c) Cross Head

FIGURE 4
Zones for Ultrasonic Testing on Rudder Stocks



PART 2

APPENDIX 7
Nondestructive Examination of Hull and Machinery Steel Forgings (2014)

SECTION 4
Ultrasonic Examination of Carbon Steel Forgings for Tail Shafts *(2024)*

1 General

1.1 Objective

This section includes requirements for inspection to verify conformance to the goals and functional requirements outlined in the cross referenced sections.

3 Scope

i) Ultrasonic examination on new carbon steel forgings for solid shafts with a finished diameter 455 mm (18 in.) and over; and hollow shafts 455 mm (18 in.) and over which have an outside to inside diameter ratio of 2 to 1 or greater.

ii) Procedure and acceptance criteria for hollow shafts 455 mm (18 in.) and over with an outside to inside diameter ratio smaller than 2 to 1 will be subjected to ABS technical assessment and approval.

iii) Ultrasonic examination for tail shafts greater than or equal to 200 mm (8 in.) and less than 455 mm (18 in.) in diameter are to be carried out in accordance with Appendix 2-A7-3.

iv) Surface inspection by Magnetic Particle, Dye Penetrant or equivalent methods as per Appendix 2-A7-2.

5 Referenced Standards

Refer to ASTM A 388 latest edition or other equivalent recognized national standard.

7 Personnel Requirements

Refer to Subsection 1/5 of the ABS *Guide for Nondestructive Inspection*.

9 Preparation of Forging for UT Examination

i) The surface roughness of the exterior finish is to be not exceed 6 μm (250 μin).

ii) The surface of forging to be examined is to be free of extraneous material such as loose scale, paint, dirt and other contaminants.

iii) The ends of the forging are to be machined perpendicular to the axis of the forging for longitudinal scans through the shaft axis.

11 UT Examination

i) Ultrasonic examination is to be performed after final heat treatment for mechanical properties (excluding of stress relief treatments) but prior to drilling holes, cutting keyways, tapers, grooves, or machining sections to contour. The criteria found in 2-A7-4/17.3 TABLE 1, referring to shaft finished dimensions, are to be taken into account.

ii) When the configuration of the forging required for the heat treatment for mechanical properties prohibits a subsequent complete examination of the forging, examination prior to heat treatment for mechanical properties is permissible. In such cases, the forging is to be ultrasonically inspected after heat treatment to the maximum extent possible.

iii) The ultrasonic examination is to be conducted using straight beam scanning. Unless specifically indicated in the section, the general procedures of Section 8 of ASTM A 388 or other equivalent standard apply.

iv) If possible, all sections of forgings are to be scanned in two perpendicular directions.

v) Scan disk forgings using a straight beam technique from at least one flat face and radially from the circumference are to be employed, whenever practicable.

vi) Cylindrical sections and hollow forgings are to be scanned radially using a straight-beam technique. When practicable, forgings in the axial direction are to be examined. In addition, hollow forgings are to be examined by angle-beam technique from the outside diameter surface

13 Procedure

The manufacturer's specific ultrasonic procedures, written in accordance with recognized international standard with acceptance criteria, is to be submitted to ABS Materials Department for review and approval.

13.1 Apparatus and Technique

Instruments, calibration, couplants, search units, reference block and DGS scales are to be in accordance with Section 6 ASTM A 388 or equivalent standard.

13.3 Coverage

i) There is to be complete coverage of the forging volume and index of the search unit with at least 15 % overlap with each pass.

ii) For manual scanning, the scanning rate is not exceed 150 mm/s (6 in./s).

iii) For automated scanning, scanning speed or instrument repetition rate is to be adjusted, or both, to enable detection of the smallest discontinuities referenced in the specification and to allow the recording or signaling device to function. The scanning speed is not to exceed the speed at which an acceptable calibration was made.

iv) Coverage along the length of the shaft is to be in accordance with 2-A7-4/17.3 FIGURE 1. Each end of the shaft (end views A-A, B-B, C-C, D'-D') is to be subjected to complete coverage. The scanning paths are to be equivalent to those detailed in 2-A7-4/17.3 FIGURE 2 and 2-A7-4/17.3 FIGURE 3.

13.5 Radial Scanning

i) The instrument sensitivity is to be established by the back-reflection technique. With the attenuator set at an appropriate level, the instrument controls are to be adjusted to obtain a back-reflection reference level of approximately 80% of the full-screen height from the opposite surface of the forging in an area free of indications. The forging is to be scanned at the maximum amplification setting of the attenuator which does not produce excessive noise. The evaluation of discontinuities is to be carried out with the gain control setting at the 80% reference level. Appropriate resetting of the 80% back-reflection reference level is required for significant changes in section thickness or diameter.

ii) The entry and reflecting surface are to be parallel to each other. When entry and back surfaces are not parallel, the instrument setting is to be re-calibrated for the maximum diameter of the section, unless otherwise approved. Recalibration is to be in accordance with Section 9 of ASTM A 388 or equivalent standard.

iii) The instrument is to be equipped with an Automatic Distance Amplitude Correction (DAC). An instrument which does not automatically compensate for changes in signal amplitude with signal path length may be used provided one of the following calibration methods is used:

a) Re-calibrate the instrument using the back reflection technique as per ASTM A 388 or equivalent standard, appropriate to each thickness being inspected.

b) Graphically calibrate the instrument by relating amplitude values of back reflection with changes in signal path length or increases of decibels with distance.

c) Calibration methods of other recognized specifications is to be submitted to class for review and agreed.

13.7 Longitudinal Scanning Through Shaft Axis

i) A longitudinal scan through each end of the shaft axis is to be conducted using a 1 MHz transducer.

ii) The forging is to be scanned at the maximum amplification setting of the attenuator which does not produce excessive noise.

iii) Any indication is to be further investigated to determine that it does not exceed the criteria of 2-A7-4/17.3 TABLE 1 in any orientation. Radial scanning using a straight beam technique or appropriate shear wave techniques are to be conducted to account for these indications.

15 Recording

i) The indications described in 2-A7-4/15.1 are to be recorded with the gain control setting at the 80% reference level.

ii) For instruments not equipped with an automatic DAC feature, the indications are to be suitably corrected in accordance with 2-A7-4/13.5.iii.a, 2-A7-4/13.5.iii.b or 2-A7-4/13.5.iii.c.

iii) When discontinuities are indicated, the search unit is to be positioned to maximize the signal amplitude. The search unit is then to be moved parallel to the discontinuity and away from the position of maximum signal amplitude until the indication drops toward the base line. Using the center of the search unit as an index, the extremity points of the discontinuities are defined as the points where the signal amplitude either remains below the criteria as per 2-A7-4/17.3 TABLE 1 for a distance equal to one-half the major dimension of the transducer or drops to one-half the maximum signal amplitude, whichever occurs first.

iv) For radial scanning an appropriate correction is to be made to the arc length measurement of an indication on the circumference so that it will represent the equivalent arc length of the indication at a given depth (i.e., at mid-radius the actual length of indication is one-half the length measured at the surface).

15.1 Recordable Indication

i) Individual indications ≥ 20% of screen height from an adjacent area free from indications.

ii) Indications ≥ 15% of screen height provided that they are traveling, planar or clusters as defined in 2-A7-4/13.3.

iii) A reduction in back-reflection to a level of 50% screen height or less except where the observed loss of back-reflection is attributable to non-parallel entry and back surfaces or other geometric considerations.

15.3 Definitions

The following definitions are illustrated in 2-A7-4/17.3 FIGURE 4.

15.3.1 Traveling Indication

A *Traveling Indication* is an indication whose leading edge moves a distance equivalent to 25.4 mm (1 in.) or more of metal depth with movement of the search unit over the surface of the forging.

15.3.2 Planar Indication

A *Planar Indication* is an indication in the same plane which has a major axis greater than 25.4 mm (1 in.). Multiple planar indications on the same plane which are within any 1290 mm^2 (2 in^2) area are to be considered as a single planar indication of a size equivalent to the length or area which encompasses all indications.

15.3.3 Cluster

A *Cluster* is defined as five (5) or more indications located in a volume representing a 51 mm (2 in.) cube in the forging.

17 Reports

17.1 Content

i) Reports are to be in accordance with Section 10 of ASTM A388 or equivalent standard

ii) For recordable indications, see 2-A7-4/15.1 above.

iii) The paths of the longitudinal scans through the shaft axis (see 2-A7-4/17.3 FIGURE 3, Detail E) are to be indicated on the required sketch which shows the locations of recordable indications.

17.3 Reporting of Indications Beyond Acceptance Levels

i) Indications beyond the acceptance quality level of 2-A7-4/17.3 TABLE 1 are to be submitted to the ABS Materials Department for special consideration.

ii) The submission is to include an interpretation of the nature, location and distribution of the discontinuities indicated; the results of supplementary ultrasonic examination using shear wave techniques may be used to support the interpretation.

iii) The examination of sections where complete radial coverage is not required, is intended to verify the core soundness of the shaft and the criteria in column B are applicable.

iv) When any recordable indication from the outer half radius exceeds a criterion of column A, the shaft is to be subjected to complete coverage.

TABLE 1
Acceptance Quality Levels (1, 2, 3, 4) (Radial Scanning) for Tail Shaft Forgings

Recordable Indication (5)	*A* *Outer Half Radius Finished Diameter*	*B* *Inner Half Radius Finished Diameter*
Traveling (2-A7-4/13.3.i) (Greater than 15%)	25.4 mm (1 in.)	51 mm (2 in.)
Planar (2-A7-4/13.3.ii) (Greater than 15%)	150 mm (6 in.) or 1290 mm^2 (2 $in.^2$)	300 mm (12 in.) or 2580 mm^2 (4 $in.^2$)

Recordable Indication [(5)]	*A* *Outer Half Radius Finished Diameter*	*B* *Inner Half Radius Finished Diameter*
Cluster (2-A7-4/13.3.iii) (Greater than 15%)	1 cluster	2 clusters separated by 51 mm (2 in.) or less
Loss of Back Reflection (2-A7-4/15.1.iii)	See Note 2	51 mm (2 in.) Max. in any dimension traversed

Notes:

1 Columns A and B represent the maximum allowable discontinuity length, area or volume.

2 In all cases, an indication must be reported to account for a reduction in back-reflection where screen height level is below 50% (see 2-A7-4/15.1.iii) of this Appendix for non-parallel surfaces. No reportable indication related to this reduction in back-reflection is permitted within the outer half radius unless it is established that the reduction is not associated with the indication.

3 When ultrasonic examination is conducted prior to finish machining, appropriate allowance is to be made for the fact that 2-A7-4/17.3 TABLE 1 applies to finished dimensions (see 2-A7-4/11.i).

4 All dimensions represent values corrected in accordance with 2-A7-4/13.7 and 2-A7-4/15.

5 Individual indications recorded as per 2-A7-4/15.1 are to be subjected to appropriate supplementary ultrasonic examination using shear wave techniques to verify that the criteria of 2-A7-4/17.3 TABLE 1 are not exceeded.

FIGURE 1
Extent of Ultrasonic Examination

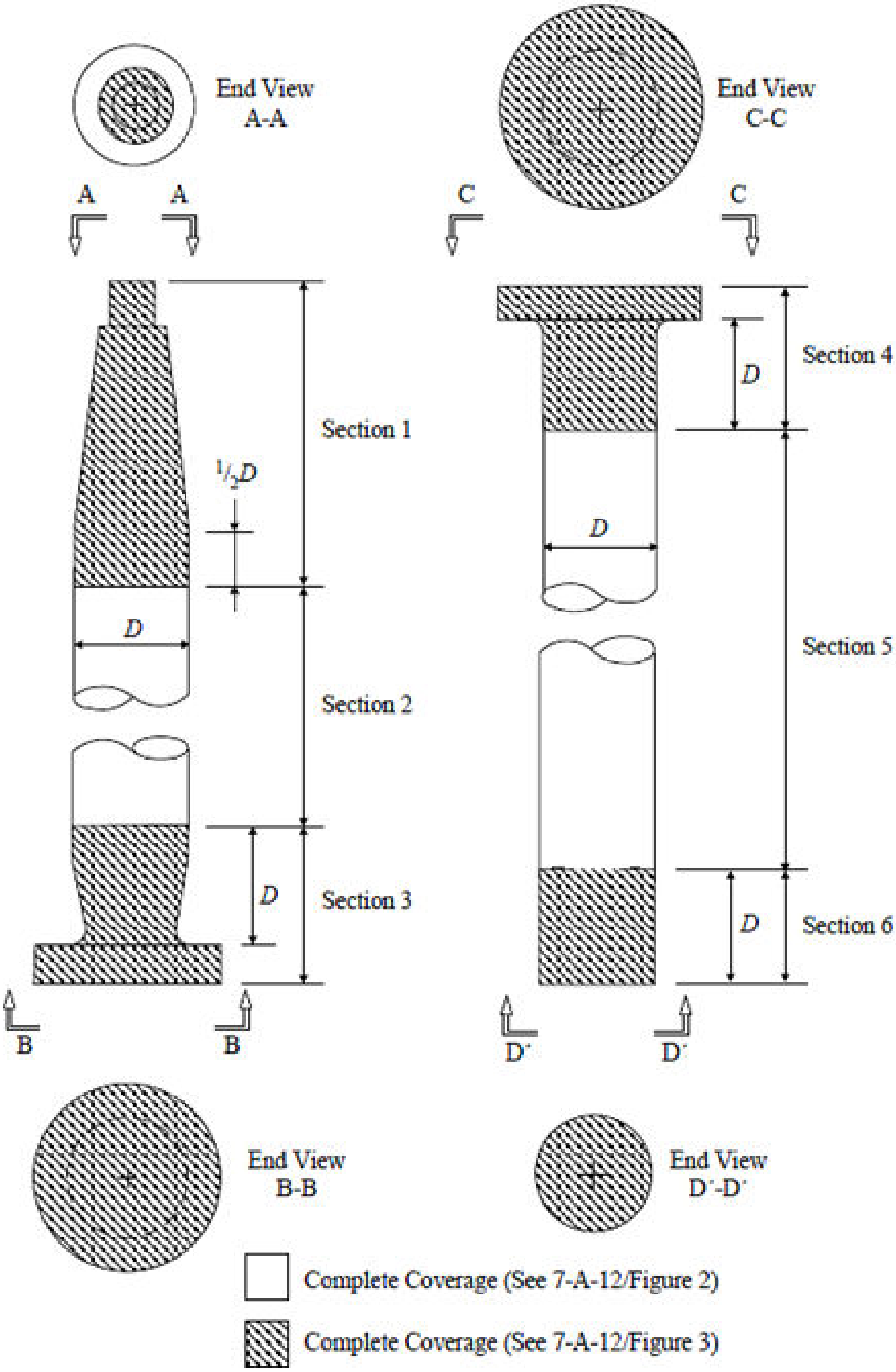


FIGURE 2
Coverage for Sections 2 and 5 of 2-A7-4/Figure 1

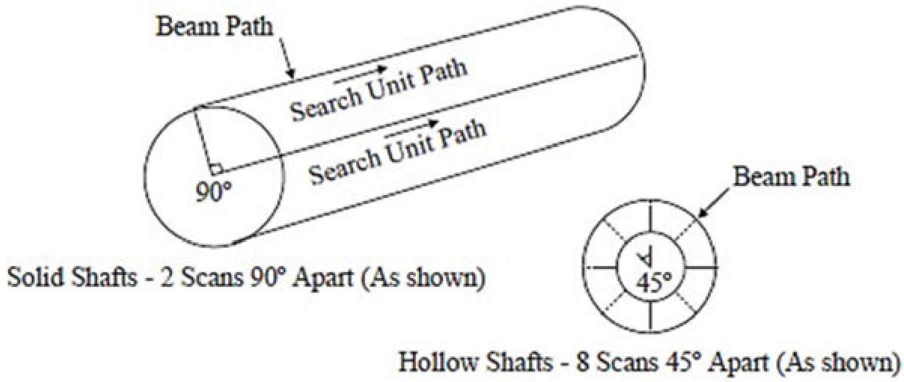
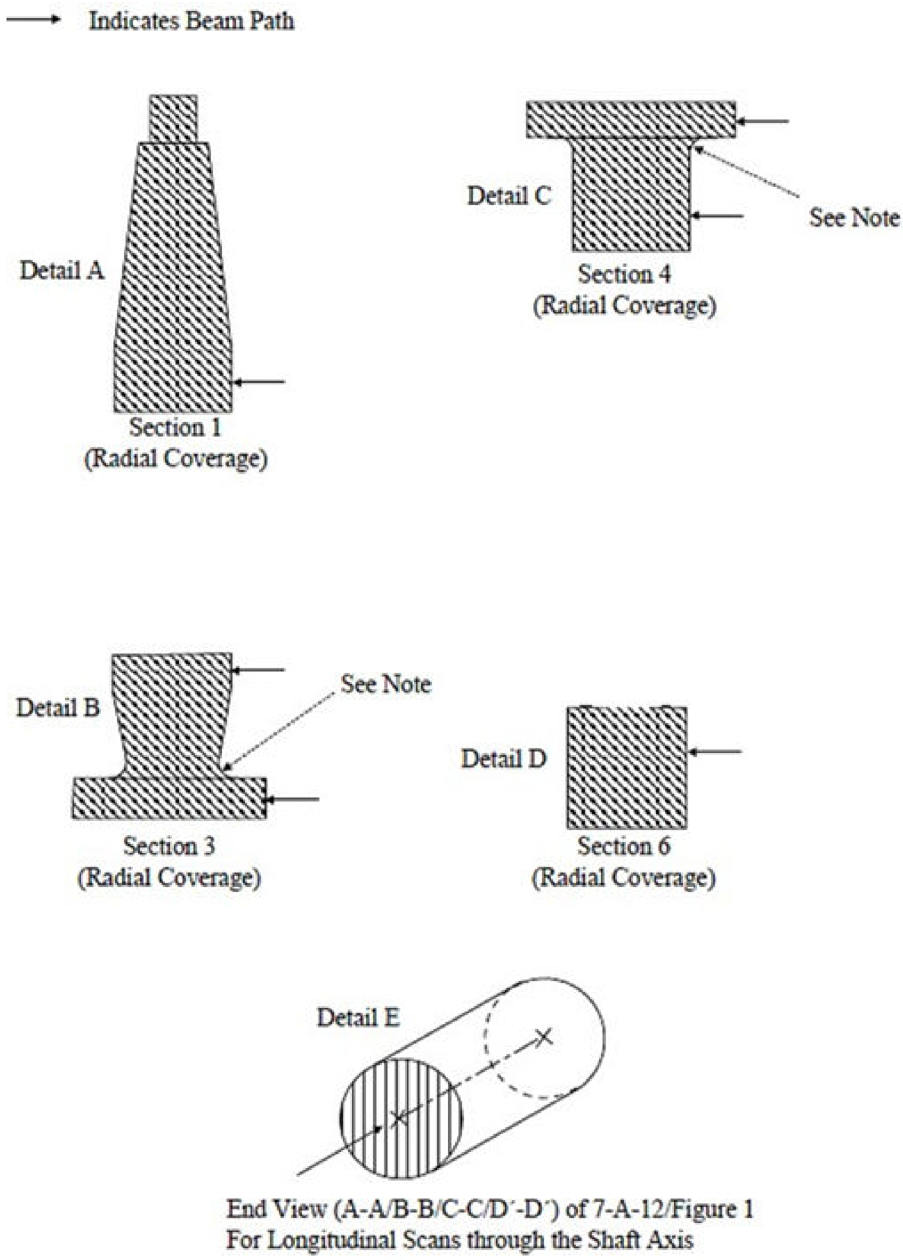
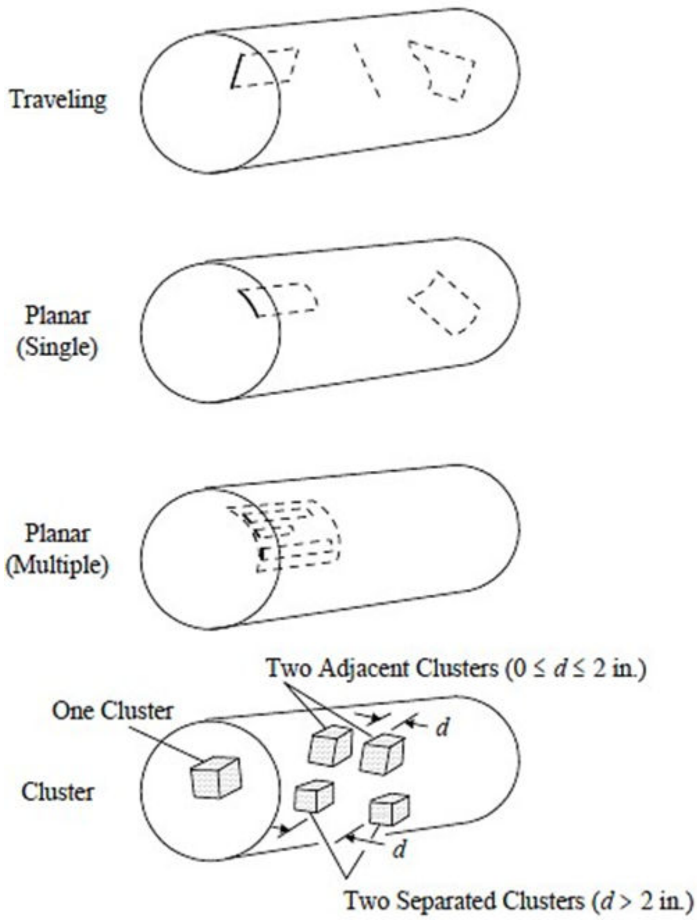


FIGURE 3
Coverage for Sections 1, 3, 4, and 6 of 2-A7-4/Figure 1



Note Coverage may be omitted if curvature is excessive for flat transducer

FIGURE 4
Typical Discontinuities



PART 2

APPENDIX 8

Steel with Enhanced Corrosion Resistance Properties

CONTENTS

PART 2

APPENDIX 8
Steel with Enhanced Corrosion Resistance Properties

SECTION 1
Additional Approval Procedure for Steel with Enhanced Corrosion Resistance Properties *(2014)*

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of manufacturers to meet the goals and functional requirements outlined in the cross-referenced sections.

1.2

Approval is to be carried out in accordance with the requirements of the Appendices in the ABS *Rules for Materials and Welding (Part 2)* together with the additional requirements for corrosion testing specified in this Appendix.

1.3

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

3 Application for Approval

3.1 *(2024)*

In addition to the requirements provided in the Appendices in the ABS *Rules for Materials and Welding (Part 2)*, the manufacturer is to submit to ABS a request for approval, which is to include the following:

i) Corrosion test plan and details of equipment and test environments.

ii) Technical data related to product assessment criteria for confirming corrosion resistance

iii) The technical background explaining how the variation in added and controlled elements improves corrosion resistance.

iv) 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 2-A8-1/5.3.3 TABLE 1.

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

5 Approval of Test Plan

5.1

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

5.3 *(2024)*

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

5.3.1

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

5.3.2

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.

5.3.3

Additional tests may be required by ABS when reviewing the test program against 2-A8-1/5.3.2.

TABLE 1
Designations for Steels with Enhanced Corrosion Resistance Properties *(2014)*

Type of Steel	*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

5.5

In addition to 2-A8-1/5.3 above, ABS may require additional tests in the following cases:

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

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

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

iv) When the ABS surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition, and ABS determines that additional testing is necessary in order to confirm the validity of the test result data; and *v)* When ABS determines 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 Carrying out the Approval Test

7.1

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

9 Attendance of the ABS Surveyor for Test

9.1

The ABS Surveyor is to be present, as a rule, when the test samples for the approval test are being identified and for approval tests, see also 2-A8-1/5.1.

11 Test Results

11.1 *(2024)*

After completion of the approval test, the manufacturer is to produce the report of the approval test and submit it to ABS. Test report is to include the information as listed in the Appendix of IMO Resolution MSC.289 (87) "Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks".

13 Assessment Criteria for Results of Corrosion Resistance Tests of Welded Joint

13.1

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

15 Approval *(2024)*

15.1

ABS will give approval for steel with enhanced corrosion resistance properties where approval tests are considered by the society to have given satisfactory results based on the data submitted in accordance with the provisions of this Appendix.

15.3

The certificate is to contain the following information.

i) Manufacturer's name

ii) Period of validity of the certificate

iii) Grades and thickness of the steel approved

iv) Welding methods and welding consumables approved

PART 2

APPENDIX 9

Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

CONTENTS

PART 2

APPENDIX 9

Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

SECTION 1

General Requirements

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Welded fabrication is to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/ specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface & internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, the materials are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D Chapter 2.

1.2 Scope

1.2.1 *(2022)*

Refer to 2-4-1/1.7 "Welding Procedures". This Appendix covers weld procedure qualification of steels used in marine and offshore hull structures.

1.2.2 *(2022)*

For weld procedure qualification of stainless steels, refer to the ABS *Requirements for Materials and Welding of Stainless Steels*.

1.2.3 *(2023)*

Refer to Section 2-4-5 for aluminum weld procedure qualification.

3 General

3.1

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

3.3 *(2024)*

Welding procedure qualification tests are to reflect fabrication conditions with respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any post-weld heat treatment. It is the manufacturer’s responsibility to establish and document whether a procedure is suitable for the particular application.

3.5 *(2024)*

For welding procedure approval, 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. All limits and ranges of the applicable welding essential variables are to be stated in the weld procedure specification.

3.7 *(2024)*

The approved WPS is to 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. In addition, the manufacturer qualifying the weld procedure retains complete responsibility for all production welding performed based on the weld procedure.

3.9 *(2024)*

For plug and slot welding, a procedure qualification test is to be carried out in accordance with AWS D1.1 Figure 6.26 or other recognized standards as agreed with ABS. Alternatively, a butt weld qualification may also qualify plug and slot welds.

3.11 *(2022)*

Stud welding procedure qualificaiton is to be carried out in accordance with AWS D1.1 Chapter 5 or other recognized standards, as agreed with ABS.

3.13 *(2022)*

This qualification scheme does not cover welding of process piping, structural tubulars or TKY joints. Weld procedures for process piping are to be qualified in accordance with ASME IX or other welding codes or standards agreed with ABS. For qualification of weld procedures intended for structural tubulars or TKY joints, refer to AWS D1.1 or other welding codes as agreed with ABS.

3.15 *(2022)*

A butt weld procedure qualification is required for welding full penetration T-butt joint.

3.17 *(2022)*

Butt weld qualification will permit welding of partial penetration welds. Alternatives for weld procedure qualification for partial penetration welds can be specifically agreed with ABS.

3.18 *(2024)*

For qualification of procedures for welding with high heat input, the base material is to be qualified for the maximum heat input in accordance with Part 2, Appendix 5.

3.19 *(2024)*

Qualification of weld procedures for materials or welding process/techniques not covered by this section are to be qualified in accordance with a recognized standard as agreed with ABS (for example, arc welding of titanium alloys may be qualified to ISO 15614-5).

5 Welding Procedure Specification – pWPS and WPS

5.1 Preliminary Welding Procedure Specification (pWPS) and Welding Procedure Specification (WPS)

5.1.1 pWPS *(2024)*

The shipyard or manufacturer is to submit a pWPS 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 shipyard or manufacturer as deemed necessary. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

5.1.2 WPS *(2024)*

During qualification, all welding parameters are to be recorded for each pass in the Weld Procedure Qualification Record (WPQR). Upon completion of the WPQT and satisfactory review of WPQR, 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 2-A9-1/9.

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.

7 Welding Procedure Qualification Test – WPQT

7.1 General

7.1.1

Preparation and welding of test pieces are to be carried out in accordance with the pWPS and under the general condition of production welding which it represents.

7.1.2

Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

7.1.3

If tack welds and/or start and stop points are a condition of the welding process they are to be fused into the joint and are to be included in the test assemblies.

7.1.4 *(2024)*

For qualifications of procedures for welding with high heat input (over 50 kJ/cm or 35 kJ/cm for strength levels 420 N/mm^2 and above in QT condition), the heat input level is not to exceed the maximum used by the plate manufacturer for the plate approval (during qualification tests) as indicated by the plate manufacturer's approval certificate or the plate material certificate.

7.1.5 *(2024)*

For steel strength levels 890 N/mm^2 and 960 N/mm^2, the weld metal strength and/or toughness may be lower than that specified for the base metal provided that the application has design approval for the undermatching weld metal and the consumables are a lower grade approved in accordance with Part 2, Appendix 2. In such cases, the weld metal strength and/or toughness is to be not less than that specified in the approved design.

7.1.6 *(2024)*

For fully mechanized or automated welding processes, when the test coupon for WPS approval is not welded in a comparable environment as the production conditions, or the manufacturer has no or limited experience with the process and equipment, the first fabrication weld is to be subjected to nondestructive testing as part of the welding procedure test.

7.1.7 *(2023)*

Welds performed with shop primer are to be qualified in accordance to recognized standards such as AWS D3.9, ISO 17652-2 or equivalent, in addition to the weld procedure qualification tests. Type of primer, manufacturer, brand name, and thickness of the shop primer applied onto the test plate during qualification is to be recorded, and these are to be considered as essential variables for the qualified welding procedure.

7.3 Butt Welds

7.3.1 Assembly of Test Pieces

The test assembly is to be in accordance with 2-A9-1/7.3.1 FIGURE 1 with the following minimum dimensions:

- *Manual or Semi-automatic Welding:*

  Thickness = t

  Width = $2a$, where $a = 3 \times t$. Minimum width to be no less than 150 mm

  Length $b = 6 \times t$. Minimum length to be no less than 350 mm

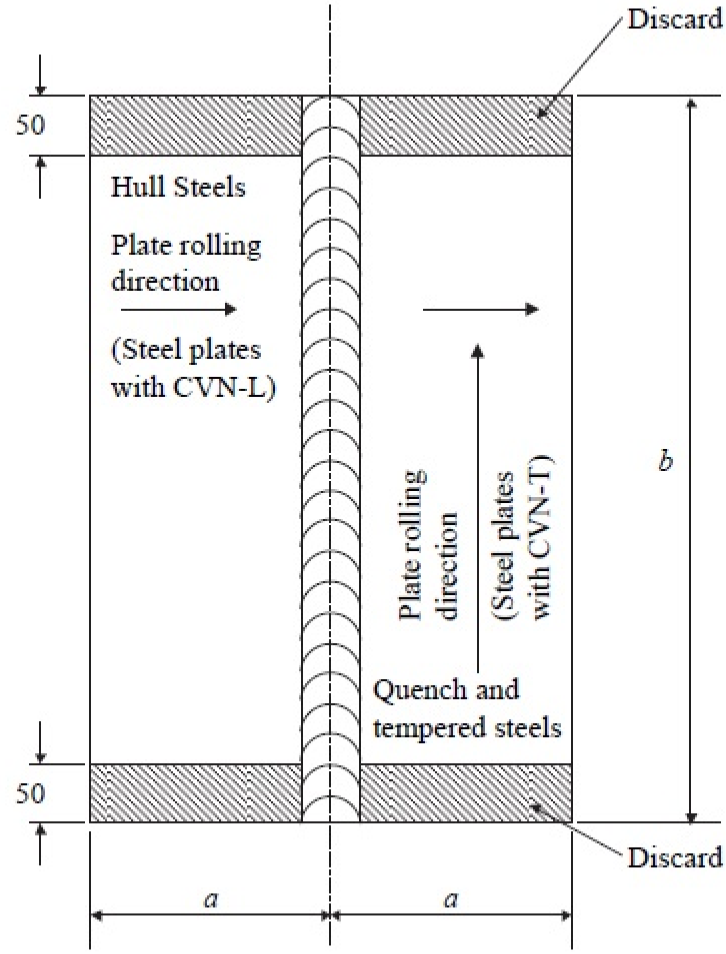
- *Automatic Welding:*

  Thickness = t

  Width = $2a$, where $a = 4 \times t$. Minimum width to be no less than 200 mm

  Length b. Minimum length to be no less than 1000 mm

FIGURE 1
Test Assembly for Butt Weld *(1 July 2014)*

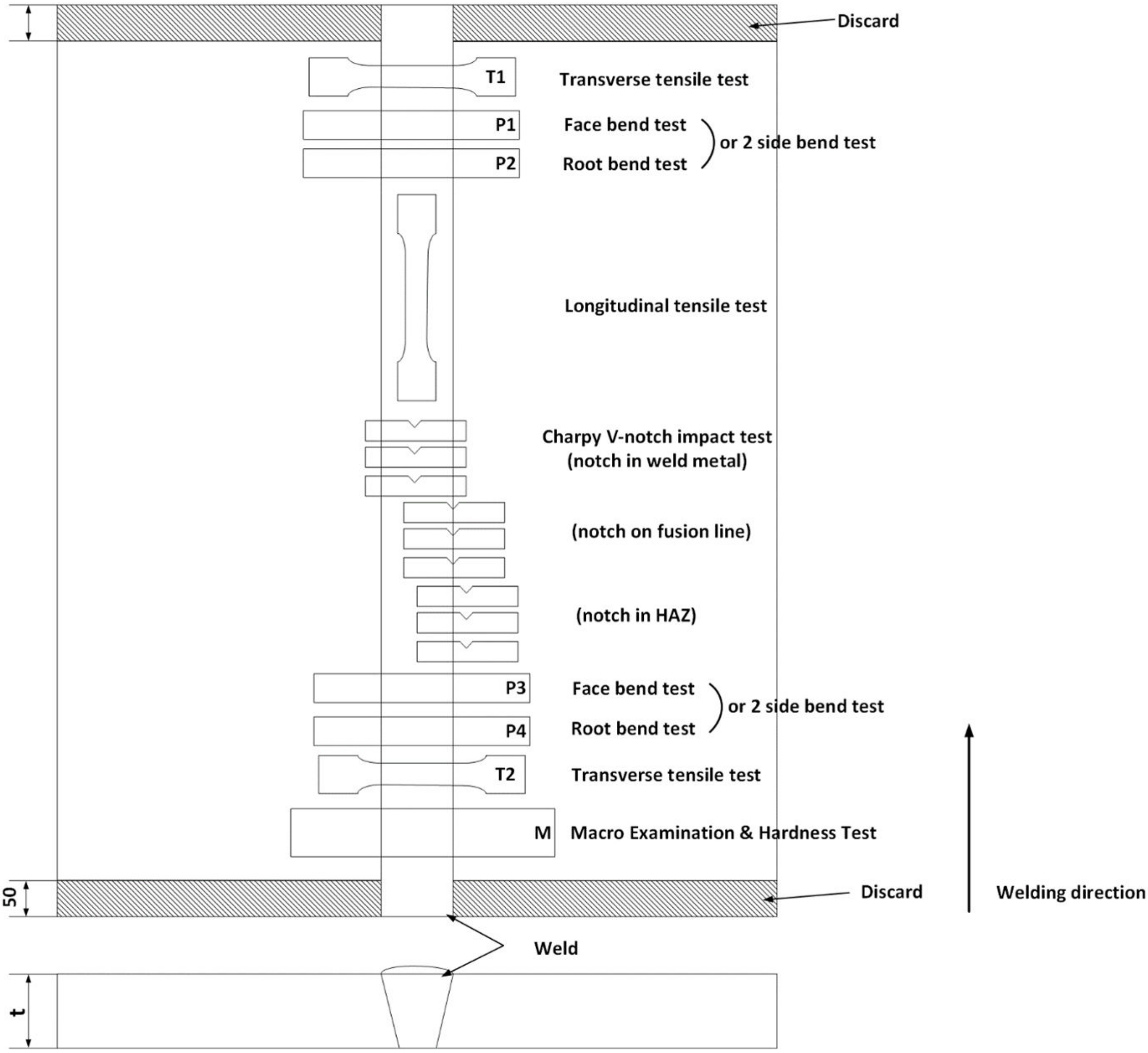


7.3.2 Examinations and Tests

Test assemblies are to be examined nondestructively and destructively in accordance with the following requirements and 2-A9-1/7.3.2 FIGURE 2:

• Visual testing	100%
• Surface crack detection	100% (dye penetrant testing or magnetic particle testing)
• Radiographic or Ultrasonic testing	100%
• Transverse tensile test	two specimens as per 2-A9-1/7.3.2(b)
• Longitudinal tensile test	as per 2-A9-1/7.3.2(c)
• Transverse bend test	four specimens as per 2-A9-1/7.3.2(d)
• Charpy V-notch impact test	as per 2-A9-1/7.3.2(e)
• Macro examination	one specimen as per 2-A9-1/7.3.2(f)
• Hardness test	required as per 2-A9-1/7.3.2(g)

FIGURE 2
Test Sampling *(2024)*



7.3.2(a) Nondestructive Testing. (2024)

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 415 N/mm^2 and greater but less than 690 N/mm^2 the nondestructive testing is to be delayed for a minimum of 48 hours, unless post weld heat treatment has been carried out. For steels with a specified minimum yield strength of 690 N/mm^2 to 960 N/mm^2, the nondestructive testing is to be delayed for a minimum of 72 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, Level B, except for undercut excess weld metal and excess penetration for which the Level C applies.

7.3.2(b) Transverse Tensile Test. (2024)

The testing is to be carried out in accordance with 2-4-3/11.5.4 FIGURE 3. The tensile strength recorded for each specimen is not to be less than the minimum required for the base metal. When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength. If a lower strength consumable is proposed the details are to be submitted to ABS for consideration.

For steel strength levels 890 N/mm^2 – 960 N/mm^2, where an undermatching consumable is used, the transverse tensile strength is to be not less than minimum specified weld metal tensile strength required by the approved design.

7.3.2(c) Longitudinal Tensile Test. (2024)

Longitudinal tensile test of deposited weld metal taken lengthways from the weld is required for cases where the welding consumable is not ABS approved.

Testing is to be carried out in accordance with 2-A2-1/33 FIGURE 1. The tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the 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.

For steel strength levels 890 N/mm^2 – 960 N/mm^2, where an undermatching consumable is used, the longitudinal tensile strength is to be not less than minimum specified weld metal tensile strength required by the approved design.

7.3.2(d) Bend Test. (2024)

Transverse bend tests for butt joints are to be in accordance with 2-4-3/11.5.4 FIGURE 5 and 2-4-3/11.5.4 FIGURE 6. The mandrel diameter to thickness ratio (i.e., D/t) is to be in accordance with 2-4-3/11.5.4 FIGURE 7.

The bending angle is to be 180°. After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.

For butt joints in heterogeneous steel plates or with undermatching weld metal approved for strength levels 890 N/mm^2 and 960 N/mm^2, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

7.3.2(e) Impact Test (2024)

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 2-1-1/11.11.

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. Requirements for sampling and positions in the butt-welded joint as indicated in 2-A9-A1/1.1 FIGURE 1 and 2-A9-A1/1.1 FIGURE 2, and the V-notch is to be cut perpendicular to the surface of the weld. Test temperature and absorbed energy are to be in accordance with 2-A9-1/7.3.2(e).i TABLE 1.

When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.

Where base material thickness is less than 6 mm, an impact test is not required unless specifically required by ABS or client.

The testing of sub-size specimens is to be in accordance with Section 2-1-2 and 2-1-1/16 FIGURE 3.

TABLE 1
Impact Test Requirements for Butt Joints ($t \leq 50$ mm)(1, 2) *(1 July 2014)*

<table>
<tr><th rowspan="3">Grade of Steel</th><th rowspan="3">Testing Temperature (C°)</th><th colspan="3">Value of Minimum Average Absorbed Energy (J)</th></tr>
<tr><th colspan="2">For Manually or Semi-automatically Welded Joints</th><th rowspan="2">For Automatically Welded Joints</th></tr>
<tr><th>Downhand, 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>
</table>

Notes:

1 For thickness above 50 mm impact test requirements reference is to be made to ABS Rules 2-4-3/11.5 TABLE 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.

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 2-A9-A1/1.1 FIGURE 1 and 2-A9-A1/1.1 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.

For steel strength levels 890 N/mm^2 – 960 N/mm^2, where an undermatching consumable is used, the longitudinal tensile strength is to be not less than minimum specified weld metal tensile strength required by the approved design.

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.

7.3.2(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 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.

7.3.2(g) Hardness Tests. (2024)

Hardness tests are required for steels with specified minimum yield strength of $R_{eH} \geq 355$ 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 2-A9-A2/1.1 FIGURE 1 and 2-A9-A2/1.1 FIGURE 2.

In addition, two indentations are required in the grain coarsened heat affected zone, one above and one below the hardness survey row.

For each row of indentations there is to be a minimum of three 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-A9-A2.

The results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm^2: 350 HV10
- Steel with a specified minimum yield strength 420 N/mm^2 < $R_{eH} \leq 690$ N/mm^2: 420 HV10
- Steel with a specified minimum yield strength 690 N/mm^2 < $R_{eH} \leq 960$ N/mm^2: 450 HV10

7.5 Fillet Welds

7.5.1 Assembly of Test Pieces

The test assembly is to be in accordance with 2-A9-1/7.5.1 FIGURE 3 with the minimum dimensions:

- *Manual and Semi-automatic Welding:*

  Thickness = t

  Width $a = 3 \times t$. Minimum width is to be no less than 150 mm

  Length $b = 6 \times t$, Minimum length is to be no less than 350 mm

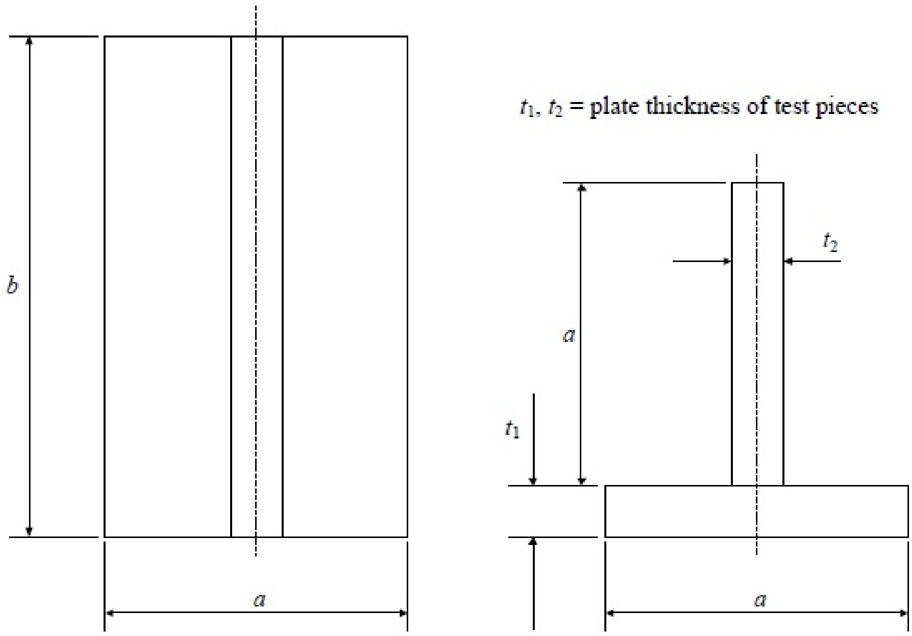
- *Automatic Welding:*

  Thickness = t

  Width $a = 3 \times t$, Minimum width is to be no less than 150 mm

  Length b = Minimum length is to be no less than 1000 mm

FIGURE 3
Test Assembly for Fillet Weld *(1 July 2014)*



7.5.2 Welding of Test Pieces

The test assembly is welded on one side only. For single run manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination.

7.5.3 Examinations and Tests

Test assemblies are to be examined nondestructively and destructively in accordance with the following:

• Visual testing	100%
• Surface crack detection	100% (dye penetrant testing or magnetic particle testing)
• Macro examination	two specimen as per 2-A9-1/7.5.3(b)
• Hardness test	required as per 2-A9-1/7.5.3(c)
• Fracture test	required as per 2-A9-1/7.5.3(d)

7.5.3(a) Nondestructive Testing. (2024)

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 415 N/mm^2 and greater but less than 690 N/mm^2, nondestructive testing is to be delayed for a minimum of 48 hours, unless post weld heat treatment has been carried out. For steels with a specified minimum yield strength of 690 N/mm^2 to 960 N/mm^2, nondestructive testing is to be delayed for a minimum of 72 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, 2014 Level B, except for undercut excess convexity and excess throat thickness for which the Level C applies.

7.5.3(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 of 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.

7.5.3(c) Hardness Test. (2024)

Hardness test is required for steels with specified minimum yield strength of $R_{eH} \geq 355$ 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 2-A9-A2/1.1 FIGURE 3, 2-A9-A2/1.1 FIGURE 4A and 2-A9-A2/1.1 FIGURE 4B.

For each row of indentations there is to be a minimum of three individual indentations in the weld metal, heat affected zone (both sides), and base metal (both sides). In addition, two indentations are required in the grain coarsened heat affected zone, one above and one below the hardness survey row.

A typical example is shown in Annex 2-A9-A2.

Results from the hardness test are not to exceed the following:

- Steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm^2 : 350 HV10
- Steel with a specified minimum yield strength 420 N/mm^2 $< R_{eH} \leq 890$ N/mm^2 : 420 HV10
- Steel with a specified minimum yield strength 890 N/mm^2 $< R_{eH} \leq 960$ N/mm^2: 450 HV10

For steel with a specified minimum yield strength $R_{eH} \leq 420$ N/mm^2, a higher value up to 380 HV10 may be accepted for single pass fillet welds subject to ABS technical assessment and approval.

7.5.3(d) Fracture Test. (2024)

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, Level B.

7.7 Re-testing

7.7.1

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.

7.7.2

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.

7.7.3

If a tensile test specimen fails to meet the requirements, re-testing is to be in accordance with 2-1-2/9.11.

7.7.4

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.

7.7.5

Re-testing of Charpy impact specimens is to be carried out in accordance with the requirements of 2-1-2/11.7.

7.7.6

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.

7.9 Welding Procedure Qualification Record (WPQR) *(2024)*

7.9.1 *(2024)*

Welding conditions for test assemblies and test results are to be recorded in the welding procedure qualification record, sometimes referred to as the PQR or WPQR.

7.9.2 *(2024)*

A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure test. The relevant items listed for the WPS are to be included.

7.9.3 *(2024)*

A statement that the test piece was made according to the particular welding procedure specification is to be signed by the Surveyor witnessing the test and is to include the ABS stamp.

9 Range of Approval

9.1 General *(2024)*

All the conditions governing the range of approval stated below are to be met independently of each other.

Changes outside of the ranges specified are to require a new welding procedure test.

A qualification performed with high heat input welding is applicable to steels approved in accordance with Part 2, Appendix 5.

Welding procedure qualification with shop primer will qualify those without but not vice versa.

9.3 Base Metal

9.3.1 Ordinary Strength Hull Structural Steel

For each grade tested, welding procedures are considered applicable to that grade and the lower toughness designations (grades).

9.3.2 Higher Strength Hull Structural Steel

9.3.2(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.

9.3.2(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.

9.3.2(c)

For applying the above 2-A9-1/9.3.2(a) and 2-A9-1/9.3.2(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 electrogas welding, the welding procedure is applicable to that toughness grade tested and one strength level below.

9.3.2(d)

Where steels used for construction are supplied with different delivery conditions from those tested ABS may require additional tests.

9.3.2(e) (2024)

For welding with high heat input (above 50 kJ/cm), the qualification applies to steels approved for the same or higher heat input level used for qualification. Refer to 2-A9-1/9.13.

9.3.3 High Strength Quenched and Tempered Steels

9.3.3(a) (2024)

For each strength level tested, welding procedures are considered applicable to that strength level and the lower toughness designations (grades) in that strength level as that tested except for the high heat input process (above 50 kJ/cm or 35 kJ/cm for QT condition), welding procedures are considered applicable to the same and one lower toughness grades as that tested.

9.3.3(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).

9.3.3(c)

The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

9.3.3(d) (2024)

For welding with high heat input (above 50 kJ/cm or 35 kJ/cm for QT condition), the qualification applies to steels approved for the same or higher heat input level to that used for qualification. Refer to 2-A9-1/9.13.

9.3.3(e) (2024)

For steel strength levels 890 N/mm^2 to 960 N/mm^2, each steel grade is to be qualified separately.

9.3.4 Weldable C and C-Mn Hull Steel Forgings

9.3.4(a)

Welding procedures are considered applicable to that strength level and strength levels lower than that tested.

9.3.4(b)

The approval of quenched and tempered hull steel forgings does not qualify other delivery conditions and vice versa.

9.3.5 Weldable C and C-Mn Hull Steel Castings

9.3.5(a)

Welding procedures are considered applicable to that strength level and strength levels lower than that tested.

9.3.5(b) (2020)

The approval of quenched and tempered hull steel castings does not qualify other delivery conditions and vice versa.

9.5 Thickness

9.5.1 *(2024)*

For butt weld and T-joint welds, the base material thickness t used in a WPQT is valid for the thickness range given in 2-A9-1/9.5.1 TABLE 2.

TABLE 2
Approval Range of Thickness for Butt and T-Joint Welds *(2024)*

Thickness of Test Piece $t^{(1)}$ (mm)	*Range of Approval$^{(2, 3, 4, 5, 6, 7)}$*	
	Butt and T-joint Welds with Single Run or Single Run from Both Sides	*Butt and T-Joint Welds with Multi-run and Fillet Welds$^{(2)}$*
$3 < t \leq 12$	$0.5 \times t$(3 min) to $1.1 \times t$	3 mm to $2 \times t$
$12 < t \leq 40$	$0.5 \times t$ to $1.1 \times t$	$0.5 \times t$ to $2 \times t$
$40 < t \leq 100$	$0.7 \times t$ to $1.1 \times t$	$0.5 \times t$ to $2 \times t$
$t > 100$		50 mm to $2 \times t$

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 high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be $1.0 \times t$.
3. For unequal plate thickness, the lesser thickness is the ruling dimension.
4. Thicknesses above 150 mm are subject to ABS technical assessment and approval.
5. For T-joint butt welds, the approval range is to be applied individually to both base metals.
6. For vertical-down welding, the test piece thickness “t” is always taken as the upper limit of the range of application.
7. Further restrictions may be applied where a fracture mechanics test (CTOD) are applied.

9.5.2 *(2024)*

For fillet welds, the base material thickness, t, and nominal throat thickness a used in a WPQT is valid for the thickness range given in 2-A9-1/9.5.2 TABLE 3.

TABLE 3
Approval Range of Thickness for Fillet Welds *(2024)*

Thickness of Test Piece t[1] *(mm)*	*Range of Approval*[2, 3, 4, 5]		
	Material Thickness	*Throat Thickness (a)*	
		Single Run	*Multi-run*
$3 < t \leq 30$	3 (min) to $2 \times t$	0.75 x a to 1.5 x a	No restriction
$t \geq 30$	≥ 5		

Notes:

1 For fillet welds, the range of approval is to be applied individually to both base metals.

2 For high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be $1.0 \times t$.

3 For vertical-down welding, the test piece thickness "*t*" is always taken as the upper limit of the range of application.

4 Where a fillet weld is qualified by means of a butt weld test, the throat thickness (a) range is to be based on the thickness of the deposited metal.

9.5.3

For vertical-down welding, the test piece thickness "*t*" is always taken as the upper limit of the range of application.

9.5.4

For unequal plate thickness of butt welds the lesser thickness is the ruling dimension.

9.5.5

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 in 2-A9-1/7.3.2(g) and 2-A9-1/7.5.3(c).

9.7 Welding Position

9.7.1 *(2024)*

Approval for a test made in any position is restricted to that position (see Annex2-A9-A3). 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. This excludes welding in the vertical downwards position, which requires separate qualification testing.

9.7.2 *(2024)*

It is permissible that a test assembly welded in the PC position will qualify both PA and PC positions provided that the heat input is in accordance with 2-A9-1/9.13

9.9 Welding Process

9.9.1

The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run process to a single run process.

9.9.2 *(2024)*

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. It is not permitted to use a single process from a multi-process weld WPS in production.

9.9.3 *(2024)*

Separate approval is required for each degree of mechanization of the welding process (e.g., manual, partly mechanized, fully mechanized, or automatic welding).

9.9.4 *(2024)*

For gas shielded welding processes, the qualification is restricted to the nominal composition of the shielding gas used in the qualification test.

9.11 Welding Consumable *(2024)*

A re-qualification test is to be carried out if any one or more of below conditions are met.

i) Any change in consumable classifications: mechanical properties, type of covering core or flux (e.g., basic, rutile), nominal chemical composition and increase in hydrogen content.

ii) ABS is to be notified if there is a change of filler consumable brand name (different manufacturer of record). In such cases, ABS may require additional qualification tests such as CVN tests or confirmation that a satisfactory weld can be produced without defects using the essential variables from the existing weld procedure.

iii) This section does not cover allowable limits for changes of mixture or composition, flow rate, filling time, and filling volume for shielding and purging gases. Refer to applicable recognized standards for structural welding for range of approval and requalificaiton requirements.

iv) A substitute consumable with a different trade name to that approved in the ABS listing may be applied, provided an affidavit of complaince is submitted by the consumable manufacturer.

v) No change in welding consumable trade name is permitted for high heat input welding procedure qualifications over 50 kJ/cm. Refer to 2-A9-1/7.1.4.

Notes:

For welding procedure qualifications with heat input not exceeding 50 kJ/cm (or 35 kJ/cm for strength levels 420 N/mm^2 and above in the QT condition), a change in welding brand name to another approved welding brand name having the same approval grade mark, the same or lower hydrogen content, and all suffixes specified is permitted. The following welding process and consumable grade-specific requirements and exclusions also apply:

i For SMAW and FCAW, a change of welding consumable trade name for consumables approved to grade 3Y and above, the manufacturer is to weld an additional test piece with the maximum heat input qualified. The impact test specimens taken from the weld metal are to be tested and are to meet the requirements of 2-A9-A2/1.1 TABLE 1 Impact test requirements for butt joints ($t \leq 50$ mm).

ii For SAW, a change in combinations (wire and flux) approved to grade 2Y and below is permitted provided that the proposed combination is approved, that the welding flux of the combination is of the same type (e.g., agglomerated, fused, neutral, active, alloyed, etc.) and has the same nominal composition of main flux constituents. It is not permitted to change the wire and flux for consumables graded 3Y and above.

iii For strength levels 890 N/mm^2 and 960 N/mm^2, no change in the trade name of the consumable is permitted.

Commentary:

i For 2-A9-1/9.11.ii, if the fabricator has experience with a manufacturer under the same grade designation but with a different brand name, the consumable may be applied without additional tests provided the batch test results are satisfactory.

ii Brand name means same grade, different manufacturer, different manufacturer of record.

iii Trade name means same grade, same manufacturer, may be different manufacturer of record.

End of Commentary

9.13 Heat Input

9.13.1 *(2024)*

For normal and higher strength steels, the upper limit of heat input approved is 25% greater than that used in welding the test piece or 55 kJ/cm whichever is smaller, except for high heat input processes, (over 50 kJ/cm) in which case the upper limit is 10% greater than that tested.

9.13.2 *(2024)*

The lower limit of heat input approved is 25% lower than that used in welding the test piece. New materials will be subject to ABS technical assessment and approval.

9.13.3 *(2024)*

For high strength steels, the upper limit of heat input approved is 25% greater than that used in welding the test piece or 55 kJ/cm (38.5 kJ/cm for QT condition) whichever is smaller, except for high heat input processes (over 50 kJ/cm or 35 kJ/cm for QT condition) in which case the upper limit is 10% greater than that tested.

9.13.4 *(2024)*

For strength levels 890 N/mm^2 and 960 N/mm^2, the upper and lower limit is 10% to that used in the test.

9.15 Preheating and Interpass Temperature

9.15.1 *(2022)*

The minimum preheating temperature is not to be less than that used in the qualification test. Alternatively, the range of preheat and interpass temperature can be based on AWS D1.1, ASME BPVC.IX or other recognized standards, as agreed with the ABS Materials Department.

9.15.2

The maximum interpass temperature is not to be higher than that used in the qualification test.

9.16 Post-Heating *(2024)*

The temperature and duration of post-heating used in the test for hydrogen release are not to be reduced. Post-heating is not to be omitted but may be added.

9.17 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.

9.17.1 *(2024)*

For welding of TMCP steel, the PWHT is not to be carried out above the lower transformation temperature.

9.17.2 *(2024)*

The temperature used in production is not to deviate by more than 20°C from that used for the qualification.

9.19 Type of Joint

9.19.1

Range of approval depending on type of welded joints for test assembly is to be as specified in 2-A9-1/9.19.3 TABLE 4.

9.19.2 *(2024)*

Butt welds also qualify full and partial penetration welds including T-joint welds and fillet welds.

9.19.3 *(2023)*

A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in 2-A9-1/9.5 above.

TABLE 4
Range of Approval for Type of Welded Joint *(1 July 2014)*

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

In case there is a change from a butt weld without shop primer to a fillet weld with shop primer, an addtional weld procedure qualification will be required (refer to 2-A9-1/7.1.4). Alternatively, available shop primer qualification test data can be submitted to ABS Materials Department for agreement.

9.21 Other Variables *(2024)*

i) A change in the current (AC or DC) or polarity (electrode positive or negative for DC current) would require weld procedure requalification.

ii) A change from semi-automatic to automatic welding processes, or vice versa would require weld procedure requalification.

iii) For mechanized or automatic welding, a change exceeding ±20% in the oscillation variables.

iv) A change in weld position angle different from qualified position in the WPS and WPQR is to be submitted to ABS for technical assessment and approval.

Other variables may also be considered in determining the range of approval.

PART 2

APPENDIX 9

Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

ANNEX 1

Location of Charpy V-Notch Impact Test

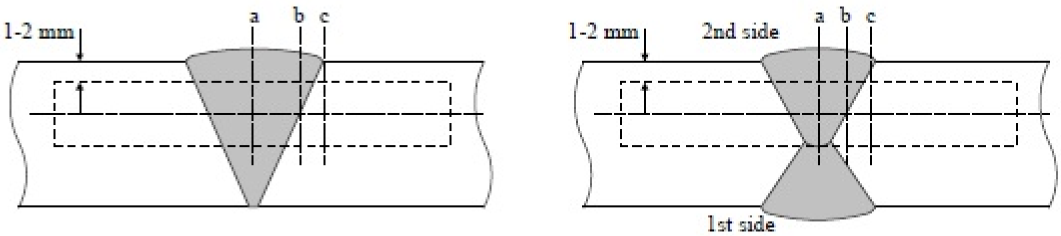
1 General *(2024)*

1.1 Objective *(2024)*

This Annex provides the location of Charpy V-notch impact test during weld procedure qualification to verify conformance to goals and functional requirements outlined in the cross-referenced sections.

FIGURE 1
Locations of V-notch for Butt Weld of Normal Heat Input
(Heat Input ≤ 50 kJ/cm) *(1 July 2014)*

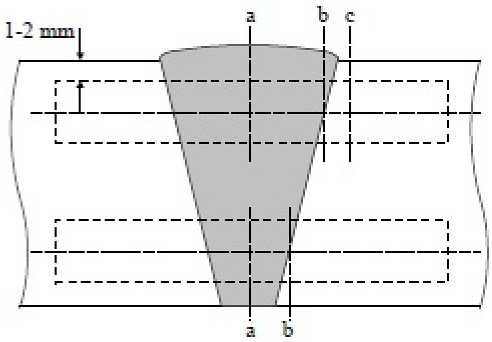
a) t < 50 mm (1)

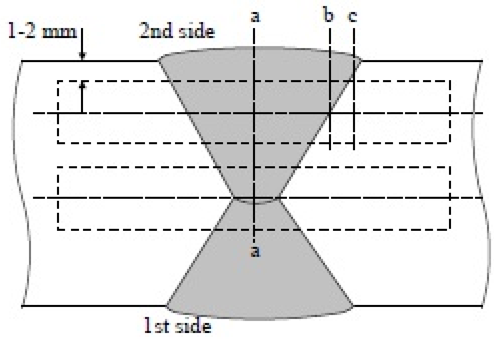


Note:

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:

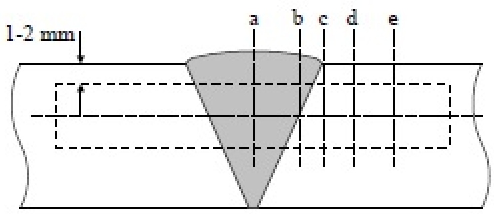
a: center of weld "WM"

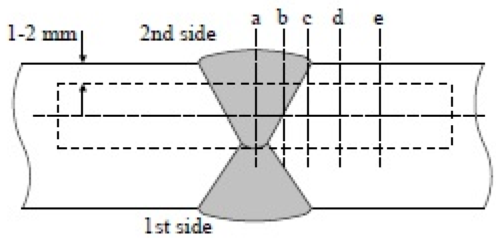
b: on fusion line "FL"

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) *(1 July 2014)*

a) $t \leq 50$ **mm** (1)

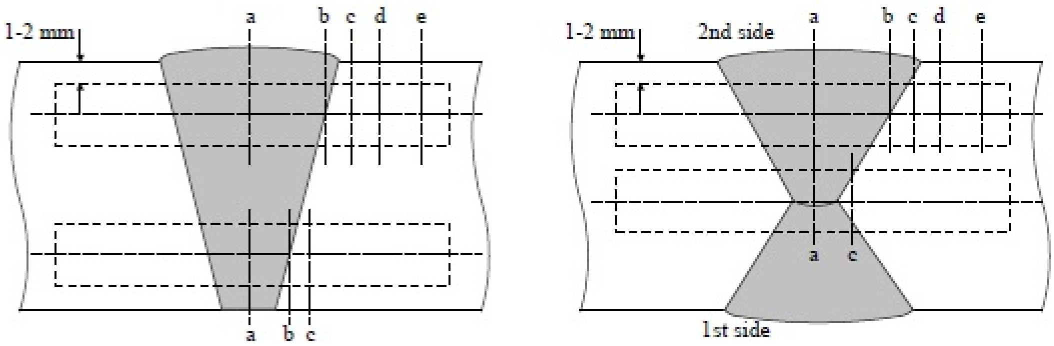




Note:

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

PART 2

APPENDIX 9
Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

ANNEX 2
Hardness Test *(Typical examples of hardness test)*

1 General *(2024)*

1.1 Objective *(2024)*

This Annex provides the location of hardness test during weld procedure qualification to verify conformance to goals and functional requirements outlined in the cross-referenced sections.

FIGURE 1
Examples of Hardness Test with Rows of Indentations (R) in Butt Welds *(1 July 2014)*

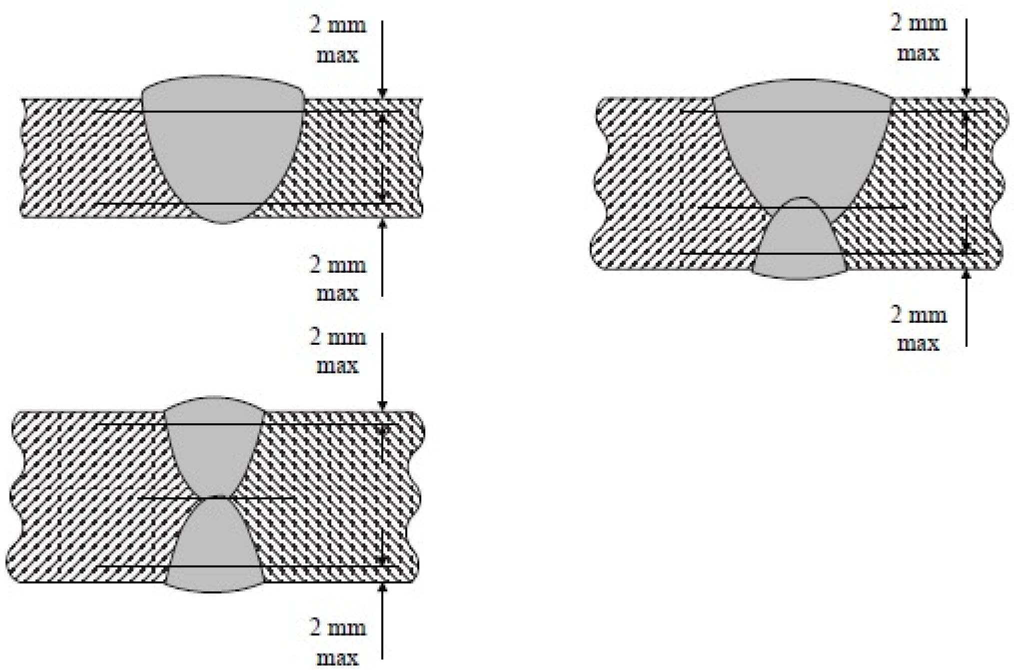


TABLE 1
Recommended Distances ℓ Between Indentations for Hardness Test in the Heat Affected Zone *(1 July 2014)*

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)*

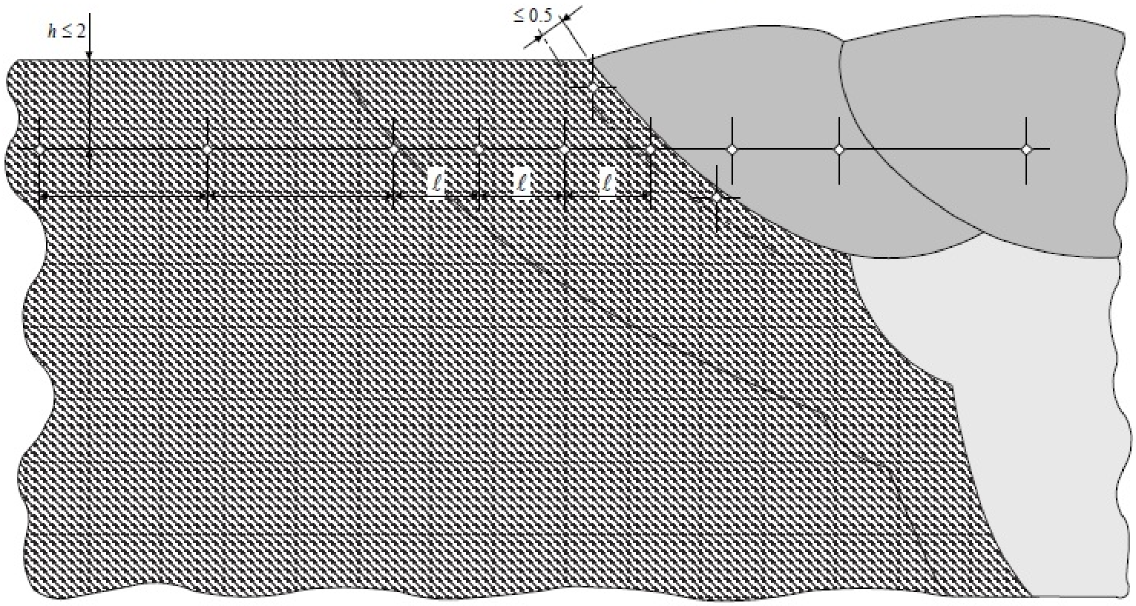
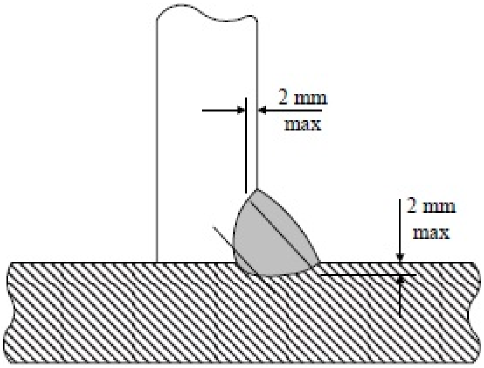
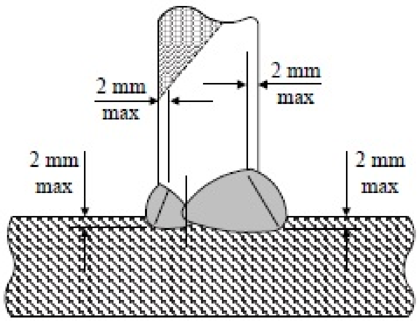


FIGURE 3
Examples of Hardness Test with Row Indentation (R) in Fillet Welds and in T-Joint Welds *(1 July 2014)*

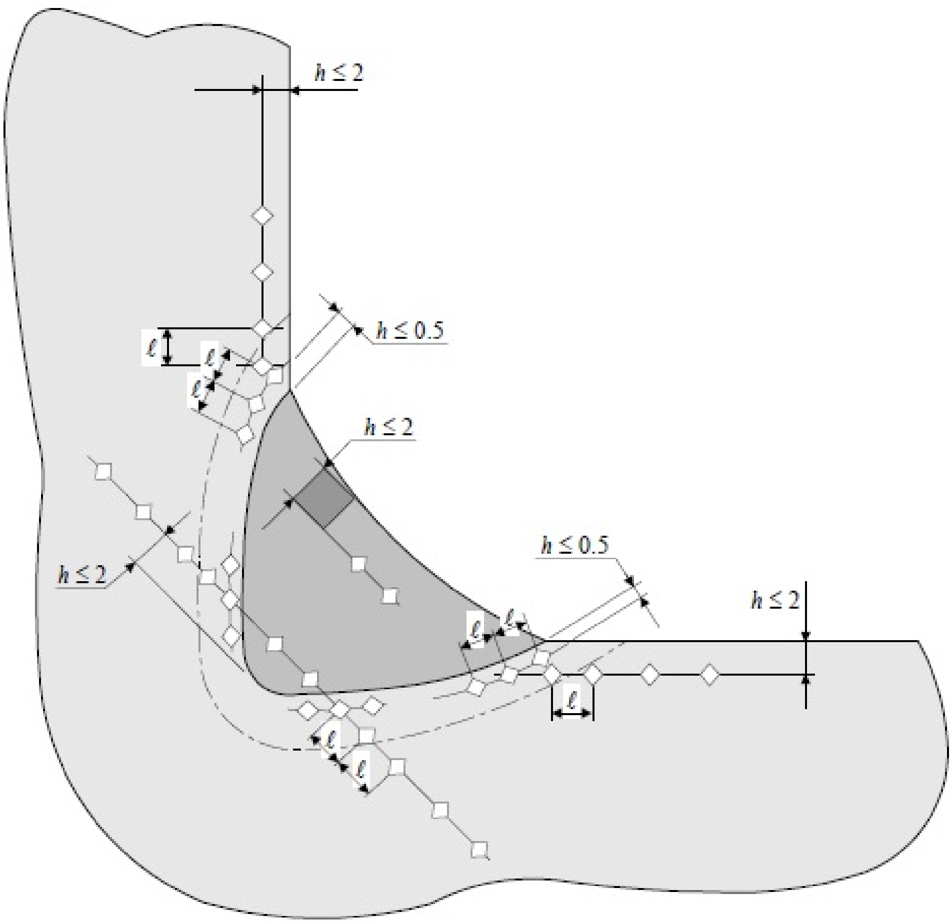


a) Fillet Weld



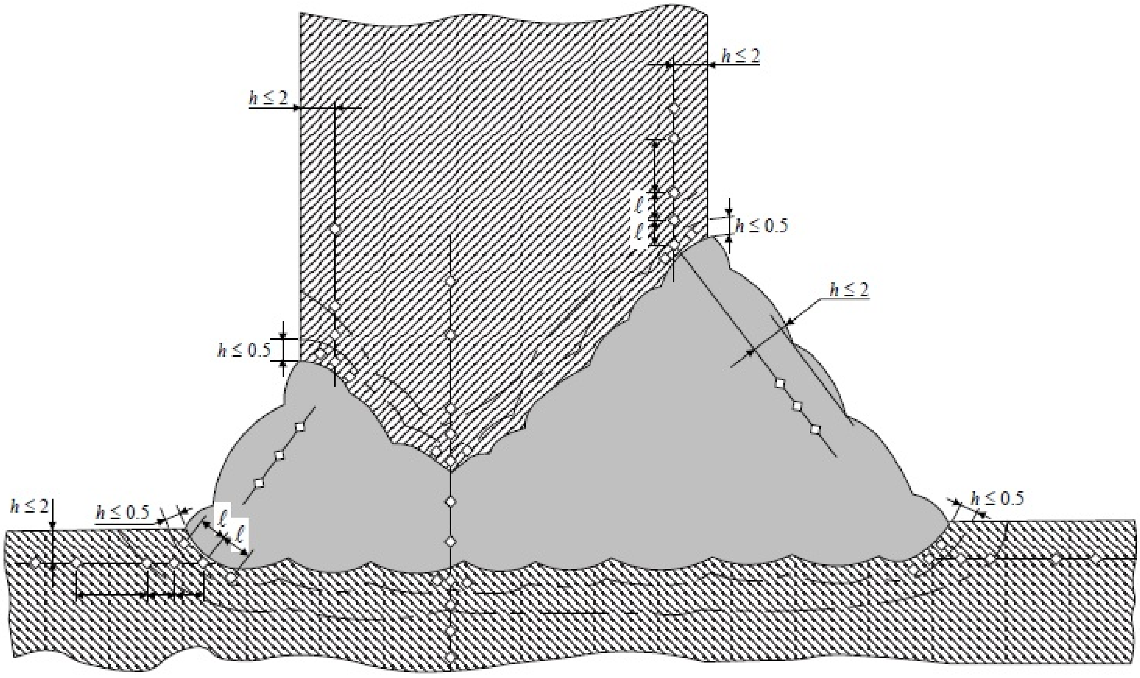
b) T-Joint Weld

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) *(1 July 2014)*



Note: Where the measurement at less than 0.5mm of heat affected zone from fusion is impractical, the greater distance than 0.5 mm may be accepted.

PART 2

APPENDIX 9

Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures (1 July 2014)

ANNEX 3

Welding Positions

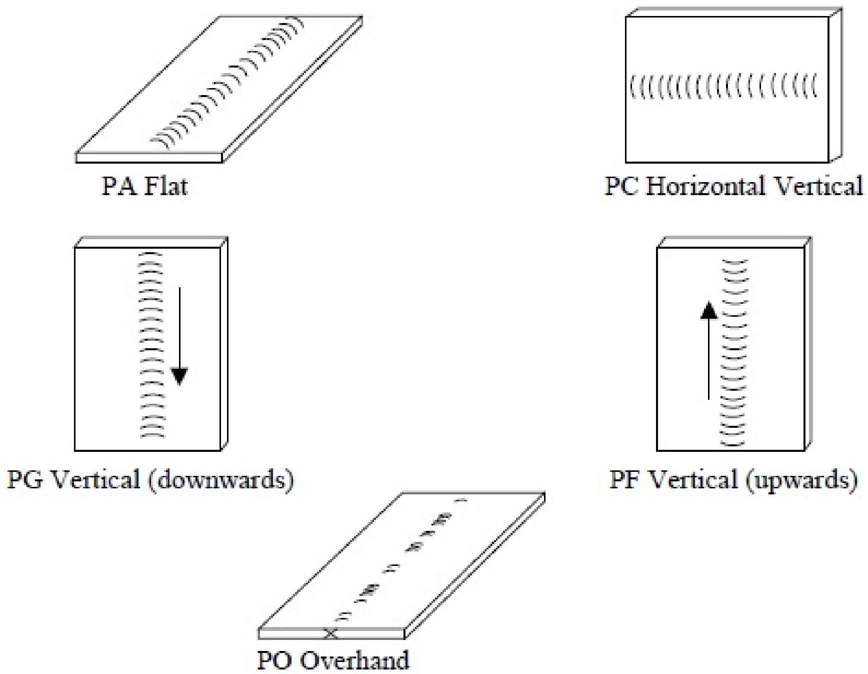
1 General *(2024)*

1.1 Objective

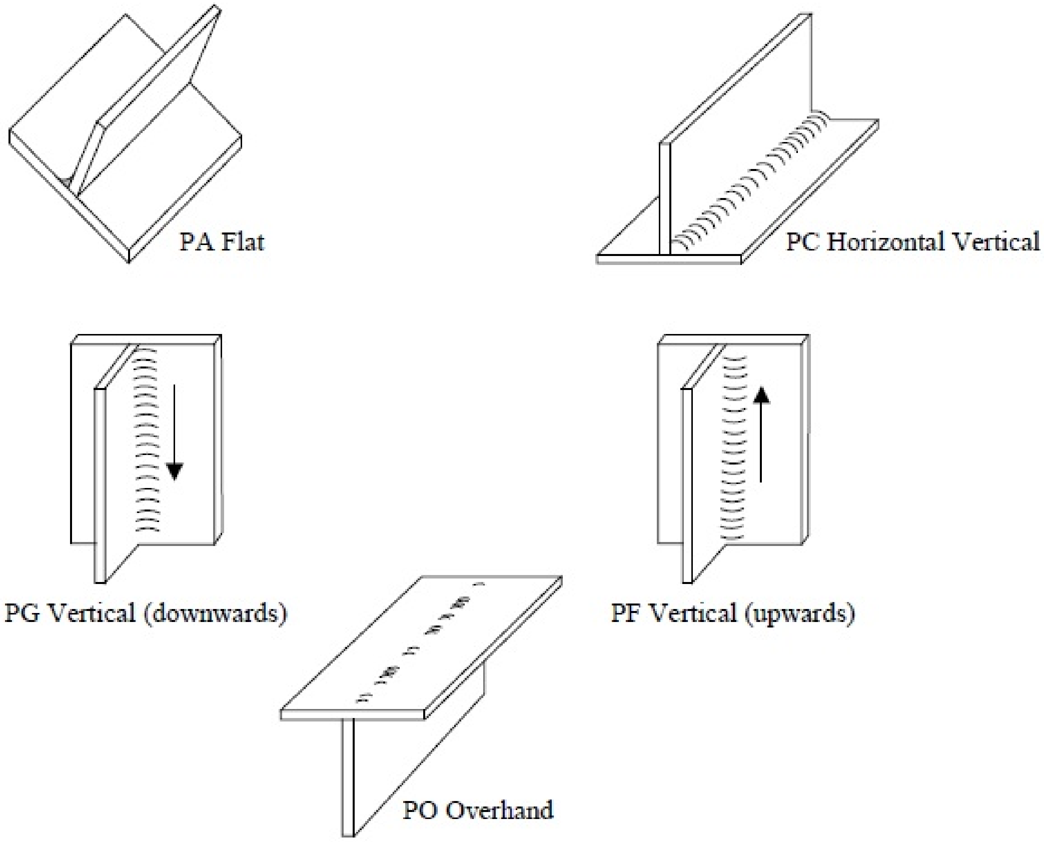
This Annex includes requirements for welding positions during weld procedure qualification test to verify conformance to goals and functional requirements outlined in the cross-referenced sections.

1 Welding Positions According to ISO Standard

a) Butt Welds for Plates

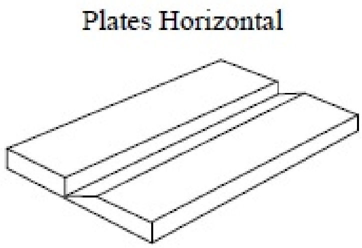


b) Fillet Welds for Plates

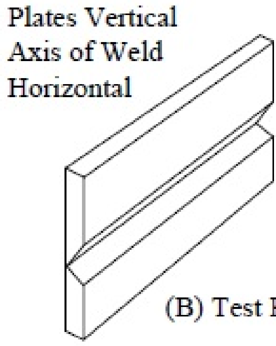


3 Welding Positions According to AWS-Code

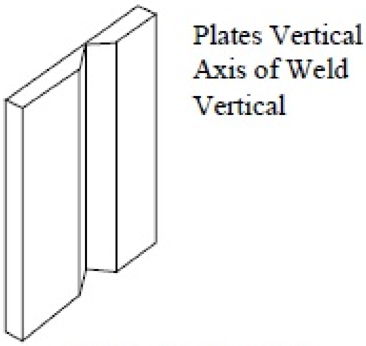
a) Butt Welds for Plates



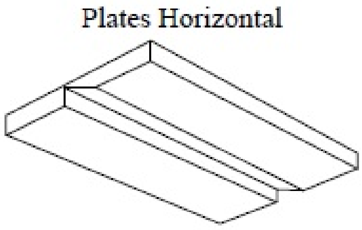
(A) Test Position 1G



(B) Test Position 2G

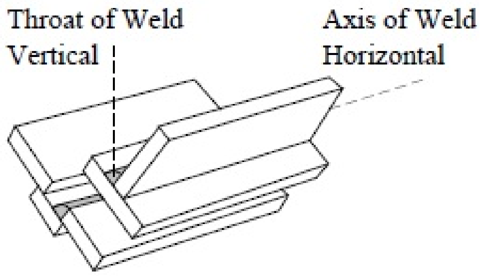


(C) Test Position 3G

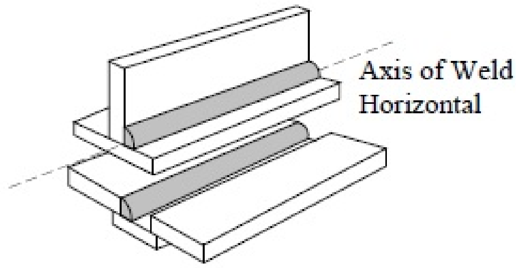


(D) Test Position 4G

b) Fillet Welds for Plates

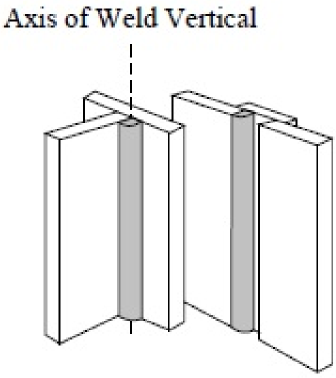


(A) Flat Position 1F

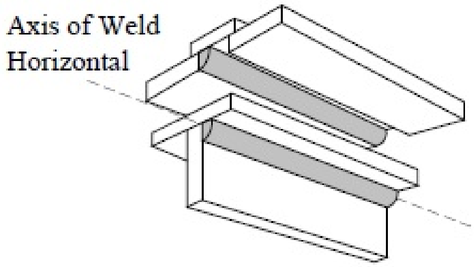


Note: One plate must be horizontal

(B) Horizontal Position 2F



(C) Vertical Position 3F



Note: One plate must be horizontal

(D) Overhead Position 4F

PART 2

APPENDIX 10

Procedure for the Approval of Aluminum Manufacturers

CONTENTS

PART 2

APPENDIX 10

Procedure for the Approval of Aluminum Manufacturers

SECTION 1

Scheme for the Approval of Aluminum Manufacturers

1 General *(2024)*

1.1 Objective *(2024)*

This section includes requirements for approval of manufacturers, with the intent to meet goals and functional requirements outlined in the cross-referenced sections.

1.3 Scope *(2024)*

In accordance with 2-5-1/1.3, this Appendix provides specific requirements for the approval of manufacturers of aluminum plate, sheet, extrusions, castings, and forgings. The manufacturer approval scheme is intended to certify the manufacturer's capability of furnishing satisfactory products under effective process and production and inspection controls in operation.

1.5 Approval Process *(2024)*

Below activities are involved in the granting of ABS approval.

i) Submission of information (as noted in 2-A10-1/3) for ABS Engineering review.

ii) Qualification tests (as noted in 2-A10-1/3.5.2) are to be carried out under ABS Survey witness, along with a plant survey of the works.

iii) Following a satisfactory review of qualification test results and plant survey checksheet, ABS Engineering will issue the approval letter and certificate.

2 Approval of Semi-finished Product Manufacturers *(1 July 2022)*

Manufacturers intending to supply semi-finished products such as ingots, billets or blooms are to be approved by ABS in accordance with 2-5-1/1.2.

i) The manufacturer is to submit to ABS request of approval together with applicable information as noted in 2-A10-1/3.

ii) Tests on the semi-finished products are to include chemical analysis. The analysis is to be completed including micro alloying elements. If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

iii) An inspection by the Surveyor of the plant in operation will be required and recorded in the plant survey report.

3 Approval Application

3.1 Initial Approval *(1 July 2022)*

For consideration to produce ABS-certified aluminum alloy plate and sheet or extrusions, the manufacturer is to apply for approval of the process of manufacture by submitting information and supporting test data to ABS Engineering/Materials Department, or alternatively to the local Surveyor who attends the facility who is to include this information with the survey report.

Request for approval is to be submitted to ABS by the manufacturer together with proposed approval test program (refer to 2-A10-1/3.5) and general information relative to the following items:

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

ii) Organization and quality

- Organizational chart
- Staff employed
- Organization of the quality control department and its staff employed
- 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.

iii) Organization and quality manufacturing facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of semi-finished or finished products
- Equipment for systematic control during fabrication

iv) Details of inspections and quality control facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for nondestructive examinations
- List of quality control procedures

v) Approval already granted by the other Classification Societies and documentation of approval tests performed for reference.

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

3.3 Content of Application

The submittal is to be specific to the Alloy and Temper, product form, maximum thickness, melting practice, casting practice and heat treatment or special rolling or extrusion practice for which approval is sought. At the option of the facility, this submittal may be preceded by a proposed test program to verify that the appropriate testing is scheduled.

3.5 Information and Data Required for Approval

The following summarizes the minimum information and test data required for approval as well additional requirements for special alloys, claimed to exhibit superior properties.

3.5.1 Production and Process Information *(1 July 2022)*

i) Plant tonnage capacity

ii) Product type and grade

iii) Maximum thickness

iv) Melting, refining and pouring practices

- Furnace type and capacity
- Melting practice-including charges of metallics and slag
- Ladle additions
- Refining practice
- Pouring practice
- Reheating furnace equipment and practices
- Special rolling or extrusion practices
- Inspection practices
- Heat treatment equipment and procedure if applicable
- Nondestructive testing procedures

3.5.2 Test Data *(1 July 2022)*

i) Sketch showing locations of test coupons.

ii) Tension Test Specimen

- At least two tension specimens from two different locations of the product or from two samples are to be taken for each qualification testing
- Rectangular full-thickness specimens for thickness of less than 12.5 mm (0.5 inch).
- Round specimens for thicknesses of 12.5 mm (0.5 inch) and greater. For material thickness of 12.5 mm (0.5 inch) and up to 40 mm (1.5 inch), tensile specimens to be from mid-thickness or of full-section. For thickness over 40 mm (1.5 inch), two specimens are to be taken from ½ and ¼ thickness.

iii) Tension Test Specimen Orientation

- Nonheat-treatable Sheet/Plate - longitudinal
- Heat-treatable Sheet/Plate - long-transverse
- Heat-treatable Extrusion/Section - longitudinal
- Forging - longitudinal (specimen axis parallel to grain flow direction)

iv) Tension Test Data

- Yield Point (or Strength)
- Ultimate Tensile Strength
- Elongation

v) Chemical Analysis

- Ladle and Product

  Fe, Si, Cu, Mn, Mg, Cr, Zn, Ti

  Plus any other intentionally added element

vi) Metallographic Examination

- Photomicrographs – at surface, 1/4 thickness and mid-thickness locations
- Microstructure – longitudinal at 100× and 500×, unetched and etched
- Photomacrograph – etched

  Transverse from center width of slabs

  Transverse from center width of plates

  Full transverse section of shapes and bars

Rolled plate/sheet and extruded sections are to be tested for at least two heats for each selected type of product, material grade and temper condition. One heat is to represent the minimum thickness/dimension for approval. Another heat is to represent the maximum thickness/dimension of the product. For extrusions, the approval testing is to represent all profile types and shapes. The extent of testing for minimum thickness may be reduced to tensile test, photomacrograph examination and micrographic examination at mid-thickness if the test scope is accepted by ABS Materials Department.

Drift expansion test for extruded closed profiles is to be carried out from each end of the extruded product before and after the aging process if applicable, as indicated in 2-5-8/5.3. Additionally, one macro section test is to be verified from each end of the extruded product for Approval of Aluminum Manufacturers.

Unless otherwise agreed, bend tests across the fusion line are required. The detailed procedures and test results are to be submitted to ABS for review.

Corrosion testing for rolled 5xxx alloys in H116 and H321 tempers are to be carried out in accordance with G66 and G67 or equivalent standards satisfying the acceptance criteria as indicated in 2-5-6/3. Surface finish of the test samples is to be representative of the surface finish of the product in the final delivered condition.

The photomicrographs and photomacrographs are considered acceptable if they are representative of metallurgically sound material.

3.7 Superior Properties

In the event that aluminum alloys which are claimed to exhibit superior properties are the subject of the approval, the additional test data for special alloys that are listed below will also be required as part of the test program.

Additional Test Data for Special Aluminum Alloys*

Test Data	*Special Alloy*
Fracture Test	Specific Fracture Criterion
Weldability Test	Superior Weldability
Corrosion Tests – ASTM G 66 and G 67	Superior Corrosion Resistance
Ultrasonic Inspection	Superior Internal Quality

* The alloy and temper designations should be denoted when reporting the data

3.9 ABS Activity in the Approval Process

Topic	*MMPS*	*Attending Surveyor*
Process/Production Information	Technical Review	Verification by Plant Survey
Proposed Test Program*	Technical Review	---
Material Test Data	Technical Review	Witness of Mechanical Testing**

* Optional

** Not necessary during production testing for manufacturing facilities participating in the ABS Quality Assurance Program

4 Approval Tests *(1 July 2022)*

4.1 Extent of the Approval Tests

The extent of the test program is specified in 2-A10-1/3.5.2. The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

A reduction of the indicated number of casts, product thicknesses and types to be tested or complete omission of the approval tests may be considered, taking into account the following items:

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

ii) Types of materials to be approved and availability of long-term historical statistic results of chemical properties and of mechanical properties tested on products

iii) Change of the approval conditions

An increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of aluminum or manufacturing processes.

4.3 Test Results

Before the approval, all test results are to be evaluated in compliance with the Rules. Depending upon the finding, limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All information required, applicable to the products submitted to the tests, is to be collected by the manufacturer and incorporated into a single document including all test results and operation records relevant to materials making, casting, and when applicable, rolling and heat treatment of the tested products.

For closed profiles, the essential parameters are to be identified, such as wall thickness, height, width, number of pockets, number of press welds.

4.5 Certification

Upon satisfactory completion of the survey, approval will be granted by ABS. The following information is to be stated on the approval certificate:

i) Type of products (ingots, slabs, blooms, billets)

ii) Aluminum alloy making and casting processes

iii) Thickness range of the semi-finished or finished products *iv)* Types of aluminum alloy (Grade, Heat Treatment Hardening or Strain Hardening, Tempered Condition etc)

It is also to be indicated that the individual user of the semi-finished products is to be approved for the manufacturing process of the specific grade of aluminum products. The individual user is going to manufacture with those semi-finished products.

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

5 Renewal of Approval *(2024)*

The validity of the approval is to be to the maximum of five years. The renewable of approval is subject to an audit and assessment of the result of satisfactory survey during the preceding period.

The following information is to be submitted for renewal of approval:

i) Statistical data for the last 5 years including the chemistry, mechanical properties for the grade or grades approved by ABS.

ii) Any non-conformances during production of ABS grades and the respective corrective and preventive actions.

iii) A written confirmation stating there were no changes to the manufacturing process since last ABS approval.

iv) A copy of the last certificate of compliance of the quality system with IS0 9001 or 9002 equivalent.

The Surveyor's report confirming the above information is to be made available to the ABS Engineering/ Materials department for review and issuance of renewal letter/certificate.

Where 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 instances, the extension of approval will be backdated to the original renewal date.

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 grades of products during the period are evaluated by ABS and found acceptable for renewal.

7 Withdrawal of the Approval *(1 July 2022)*

The approval may be withdrawn before the expiry of the validity period in the following cases:

i) In-service failures traceable to product quality

ii) Nonconformity of the product revealed during fabrication and construction

iii) Discovery of failure of the manufacturer's quality system

iv) Changes, made by the manufacturer without prior agreement of ABS, impact the approval

v) Evidence of major nonconformities during testing of the products.

PART 2

APPENDIX 11

Qualification for Welders and Welding Operators

CONTENTS

PART 2

APPENDIX 11
Qualification for Welders and Welding Operators

SECTION 1
General *(1 July 2018)*

1 General *(2024)*

1.1 Objective

This Appendix includes guidance on welder's/welding operator's qualification process intending to meet the goals and functional requirements identified in Appendix 2-A11-2.

2

The general guidelines and requirements defined in the ABS *Rules for Materials and Welding (Part 2)* are to be applied. This Appendix covers the qualification for welders and welding operators for structural welding of marine and offshore vessels.

3

These requirements apply to ABS's acceptance of welders and welding operators for welding of steel and non-ferrous metals.

5

This Appendix specifies the requirements for welder and operator qualifications including:

- Ship hull structure and other ship structure
- Offshore hull and other offshore structure

7

The training of welders and welding operators, control of their qualification, and maintenance of their skills are the responsibility of the builders and subcontractors. When requested, these are to be documented and demonstrated to the satisfaction of ABS.

9

The certified welders and welding operators are to be recorded by builders and subcontractors with welders' training, as well as date and documents of qualification tests. The qualification documents are to include the information about the base metal, type of welding consumable, welding process, type of welded joint, material thickness, welding position, and destructive and nondestructive test results. One example is shown in 2-A11-A1.

PART 2

APPENDIX 11
Qualification for Welders and Welding Operators

SECTION 2
Welders Qualification for Hull Structures* *(2019)*

Note: This Appendix specifies an alternative welder qualification process per 2-4-3/11.3.

1 General *(2024)*

1.1 Objective *(2024)*

1.1.1 Goals

Welding and fabrication are to be suitable for their intended application in accordance with the following goals and support the Tier I goals listed elsewhere in the Rules.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 3	The fabrication and welding process is to be capable of producing products that meets the specified quality and property requirements.

The goals in the cross-referenced Rules are also to be met.

Commentary:

i In general, satisfying the MAT 1 goal is the Designer's responsibility, who selects the material grade/specification suitable for the loads, operating conditions, and the environment. An order is issued to the manufacturer to procure the products in accordance with the material specification. In some cases, an experienced manufacturer may assist the designer in selecting the appropriate material.

ii Alternative manufacturing methods can be applied to meet the specified quality and property requirements.

iii Material specifications include requirements for manufacturing process, chemistry, heat treatment, mechanical properties, surface and internal quality requirements and any other relevant details.

iv Refer to Appendix 2-A1-2 for Physical, Chemical, Mechanical Properties that may be considered during material selection and design assessment.

End of Commentary

1.1.2 Functional Requirements

To achieve the above stated goals, welding and fabrication during hull construction are to comply with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
MAT-FR11	Welding is to be performed to a documented procedure which includes relevant variables appropriate for the application.
MAT-FR12	The welding procedure is to be capable of producing weldments that meet the specified weldment properties and specified quality requirements appropriate for the applicaiton.
MAT-FR13	The chemical composition and storage/handling of the filler metal is to be capable of achieving the specified weldment properties.
MAT-FR14	Welding personnel are to be qualified and demonstrate they are capable of producing weldments which meet the specified weldment properties and quality requirements.
MAT-FR15	Relevant welding variables/parameters are to be controlled and monitored during production welding.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Scope *(2024)*

This Section gives requirements for a qualification scheme for welders intended to be engaged in the fusion welding of steels for hull structures as specified in the ABS *Rules for Materials and Welding (Part 2)* as follows:

- Section 2-1-2: Ordinary-Strength Hull Structural Steel
- Section 2-1-3: Higher-Strength Hull Structural Steel
- Section 2-1-5: Hull Steel Castings
- Section 2-1-6: Hull Steel Forgings
- Section 2-1-7: Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks
- Section 2-1-8: Extra High Strength Steels

and other steels, at the discretion of ABS, such as:

- H47 and H36/H40/H47 BCA (Brittle Crack Arrest) Steel.

1.5 *(2024)*

This qualification scheme does not cover welders engaged in oxy-acetylene welding and Friction Stir Welding.

1.7 *(2024)*

This qualification scheme does not cover welding of pipes or structural tubulars. For qualification for welding of pipes, refer to ASME IX or other welding codes as agreed with ABS. for qualification for welding of structural tubulars or TKY joints, refer to AWS D1.1 or other welding codes as agreed with ABS.

1.9 *(2023)*

Refer to Section 4-2 of the ABS *Requirements for Materials and Welding for Stainless Steels* for stainless steel welder qualification.

1.11 *(2023)*

Refer to 2-4-5/15 for aluminum welder qualification.

3 Approval of Welders *(2024)*

3.1

Those welders intended to be engaged in welding of hull structures in shipyards, manufacturers, and subcontractor are to be tested and qualified in accordance with this scheme and issued with a qualification certificate endorsed by ABS.

3.3

This Appendix is applicable to welding of hull structures during new construction, conversion, and the repair of vessels or offshore structures.

3.4 *(2024)*

Welders are to undergo an annual vision test using standard test methods for determining visual acuity. The acceptance standard is to be natural or corrected near distance acuity to the satisfaction of the ABS Surveyor.

3.5 *(2024)*

Welders or welding operators qualified in accordance with recognized national or international welder qualification standards may also be engaged in welding of hull structures at the discretion of ABS, provided that the qualification testing, range of approval, and revalidation requirements are considered to meet the technical intent of this Section. Recognition of welders and welding operators certified to another classification society will be evaluated when necessary. ABS reserves the right to seek verification of such certification by performing testing before production and additional NDT.

3.7

If the production weld has restricted access the ABS Surveyor is to verify the welder has the necessary skill to achieve a satisfactory production weld under the anticipated production conditions.

5 Range of Qualification of Welders

5.1 *(2024)*

A welder is to be qualified in relation to the following welding variables:

i) Base metal

ii) Welding consumables type

iii) Welding process

iv) Type of welded joint

v) Plate thickness

vi) Welding position and progression

5.3 *(2024)*

In case of steels, base metals for qualification of welders or welding operators are divided into two groups, as noted below. Welding of any one metal in a group covers qualification of the welder or welding operator within the group.

ABS Group No	*Minimum Yield Strength, R_{eH}*	
	N/mm²	*ksi*
1	$R_{eH} \leq 460$	$R_{eH} \leq 67$
2	$460 < R_{eH} \leq 690$	$67 < R_{eH} \leq 100$

Steels with a specified minimum yield strength R_{eH} > 690 N/mm² (100 ksi) are subject to ABS technical assessment and approval.

Depending upon the welders experience and level of skill, additional qualification test may be required, at the discretion of the ABS Surveyor, if the welder is only qualified in welding ordinary strength steel and is required to weld higher strength grades.

5.5 *(2024)*

For Shielded/Manual metal arc welding, qualification tests are required using basic, acid or rutile covered electrodes. Basic (B) electrode covers basic (B), acid (A) and rutile (R) electrodes. Acid (A) or rutile (R) electrode covers acid (A) and rutile (R) electrodes. The type of covered electrodes (basic, acid or rutile) included in the range of approval is at the discretion of ABS.

A change in shielding gas blend or deletion of shielding for FCAW requires requalification. Welding with filler material qualifies for welding without filler material, but not vice versa.

5.7

The welding processes for welder's qualification are classified in 2-A11-2/5.7 TABLE 1 as:

- M –Manual welding
- S – Semi-automatic welding/partly mechanized welding
- T – Gas Tungsten arc welding (GTAW) or Tungsten inert gas (TIG) welding

Each testing normally qualifies only for one welding process. A change of welding process requires a new qualification test.

For automatic welding (e.g., SAW), see Section 2-A11-3 for Welding Operators Qualification.

TABLE 1
Welding Processes for Welder's Qualification *(2024)*

Symbol	*Welding Process in Actual Welding Works*		*ISO 4063*
M	Manual welding	Shielded/Manual metal arc welding (metal arc welding with covered electrode)	111
S	Semi-automatic welding/Partly mechanized welding	Gas metal arc welding (GMAW)	131
		Metal active gas (MAG) welding Flux cored arc welding (FCAW)	135, 138 (1) 136 (2)
T	TIG welding	Gas Tungsten arc welding (GTAW)	141

Notes:

ABS may require separate qualification for solid wires, metal-cored wires and flux-cored wires as follows:

1) A change from MAG welding with solid wires (135) to that with metal cored wires (138), or vice versa is permitted.

2) A change from a solid or metal cored wire (135/138) to a flux cored wire (136) or vice versa requires a new welder qualification test.

5.9

The types of welded joint for welder's qualification are to be classified as shown in 2-A11-2/5.9 TABLE 2 in accordance with the qualification test. Welders engaged in full/partial penetration T welds are to be qualified for butt welds for the welding process and the position corresponding to the joints to be welded.

TABLE 2
Types of Welded Joint for Welder's Qualification *(1 July 2018)*

Type of Welded Joint Used in the Test Assembly for the Qualification Test				*Type of Welded Joint Qualified*
Butt weld	Single sided weld	With backing	A	A, C, F
		Without backing	B	A, B, C, D, F
	Double sided weld	With gouging	C	A, C, F
		Without gouging	D	A, C, D, F
Fillet weld	----	----	F	F

5.11 *(2024)*

For fillet welding, welders who passed the qualification tests for multi-layer technique welding can be deemed as qualified for single-layer technique, but not vice versa. A change from fillet to a groove joint requires requalification.

5.13

The qualified plate thickness range arising from the welder qualification test plate thickness is shown in 2-A11-2/5.13 TABLE 3.

TABLE 3
Plate Thicknesses for Welder's Qualification *(1 July 2018)*

Thickness of Test Assembly ***T***		***Qualified Plate Thickness Range*** ***t***	
mm	*in.*	*mm*	in.
$T < 3$	$T < 0.12$	$T \le t \le 2T$	$T \le t \le 2T$
$3 \le T < 12$	$0.12 \le T < 0.47$	$3 \le t \le 2T$	$0.12 \le t \le 2T$
$12 \le T$	$0.47 \le T$	$3 \le t$	$0.12 \le t$

5.15

The welding positions qualified as a result of the actual welding position used in a satisfactory welder's qualification test, are shown in 2-A11-2/5.15 TABLE 4 and 2-A11-2/5.15 TABLE 5. Diagrams showing the definitions of weld position used in 2-A11-2/5.15 TABLE 4 and 2-A11-2/5.15 TABLE 5 are shown in 2-A11-2/7.9 FIGURE 1.

ABS may require a qualification test with fillet welding for welders who are employed to perform fillet welding only.

TABLE 4
Qualified Welding Positions When Testing with Butt Welding 2-A11-2/7.9 FIGURE 1 *(1 July 2018)*

Qualification Test Position with Butt Weld	*Qualified Welding Positions in Actual Welding Works*	
	Butt Welds	*Fillet Welds*
PA-Flat (1G)	1G, PA	1F, 2F, PA, PB
PC-Horizontal (2G)	1G, 2G, PA, PC	1F, 2F, PA, PB, PC
PE-Overhead (4G)	1G, 2G, 4G, PA, PC, PE	1F, 2F, 4F, PA, PB, PC, PD, PE
PF-Vertical upwards (3G)	1G, 3G Up, PA, PF	1F, 2F, 3F Up, PA, PB, PF
PG-Vertical downwards (3G)	3G Down, PG	3F Down, PG

TABLE 5
Qualified Welding Positions when Testing with Fillet Welding 2-A11-2/7.9 FIGURE 1 *(1 July 2018)*

Qualification Test Position with Fillet Weld	*Qualified Welding Positions in Actual Welding Works*
	Fillet Welds
PA-Flat (1F)	1F, PA
PB-Horizontal vertical (2F)	1F, 2F, PA, PB
PC-Horizontal	1F, 2F, PA, PB, PC
PD-Horizontal overhead (4F)	1F, 2F, 4F, PA, PB, PC, PD, PE
PE-Overhead	1F, 2F, 4F, PA, PB, PC, PD, PE
PF-Vertical upwards (3F Up)	1F, 2F, 3F Up, PA, PB, PF
PG-Vertical downwards (3F Down)	3F Down, PG

5.17

A welder qualified for butt or fillet welding can be engaged in tack welding for the welding process and position corresponding to those permitted in his certificate.

Alternatively, welders engaged in tack welding only can be qualified on the test assemblies shown in 2-A11-2/7.9 FIGURE 5 or 2-A11-2/7.9 FIGURE 6.

7 Test Assemblies

7.1

Welding of the test assemblies is to be witnessed by the Surveyor. Test assemblies for butt welds and for fillet welds are to be prepared as shown in 2-A11-2/7.9 FIGURE 2, 2-A11-2/7.9 FIGURE 3 and 2-A11-2/7.9 FIGURE 4 in each qualification test.

7.3

Test assemblies for butt tack welds and for fillet tack welds are to be prepared as shown in 2-A11-2/7.9 FIGURE 5 and 2-A11-2/7.9 FIGURE 6.

7.5

Testing materials and welding consumables are to conform to one of the following requirements or to be of equivalent grade approved by ABS:

7.5.1 Testing Materials

- Section 2-1-2: Ordinary-Strength Hull Structural Steel
- Section 2-1-3: Higher-Strength Hull Structural Steel
- Section 2-1-5: Hull Steel Castings
- Section 2-1-6: Hull Steel Forgings
- Section 2-1-7: Ordinary and Higher Strength Steels with Enhanced Corrosion Resistance Properties for Cargo Oil Tanks
- Section 2-1-8: Extra High Strength Steels

and other steels, at the discretion of ABS, such as:

- H47 and H36/H40/H47 BCA (Brittle Crack Arrest) Steel.

7.5.2 Welding Consumables *(2024)*

- Consumables for hull structural steels specified in Part 2, Appendix 2 and Part 2, Appendix 3, or
- Other consumables, such as for BCA steels, at the discretion of ABS.

Welders qualified using a higher grade welding consumable are allowed to weld with lower grade consumables but not vice versa.

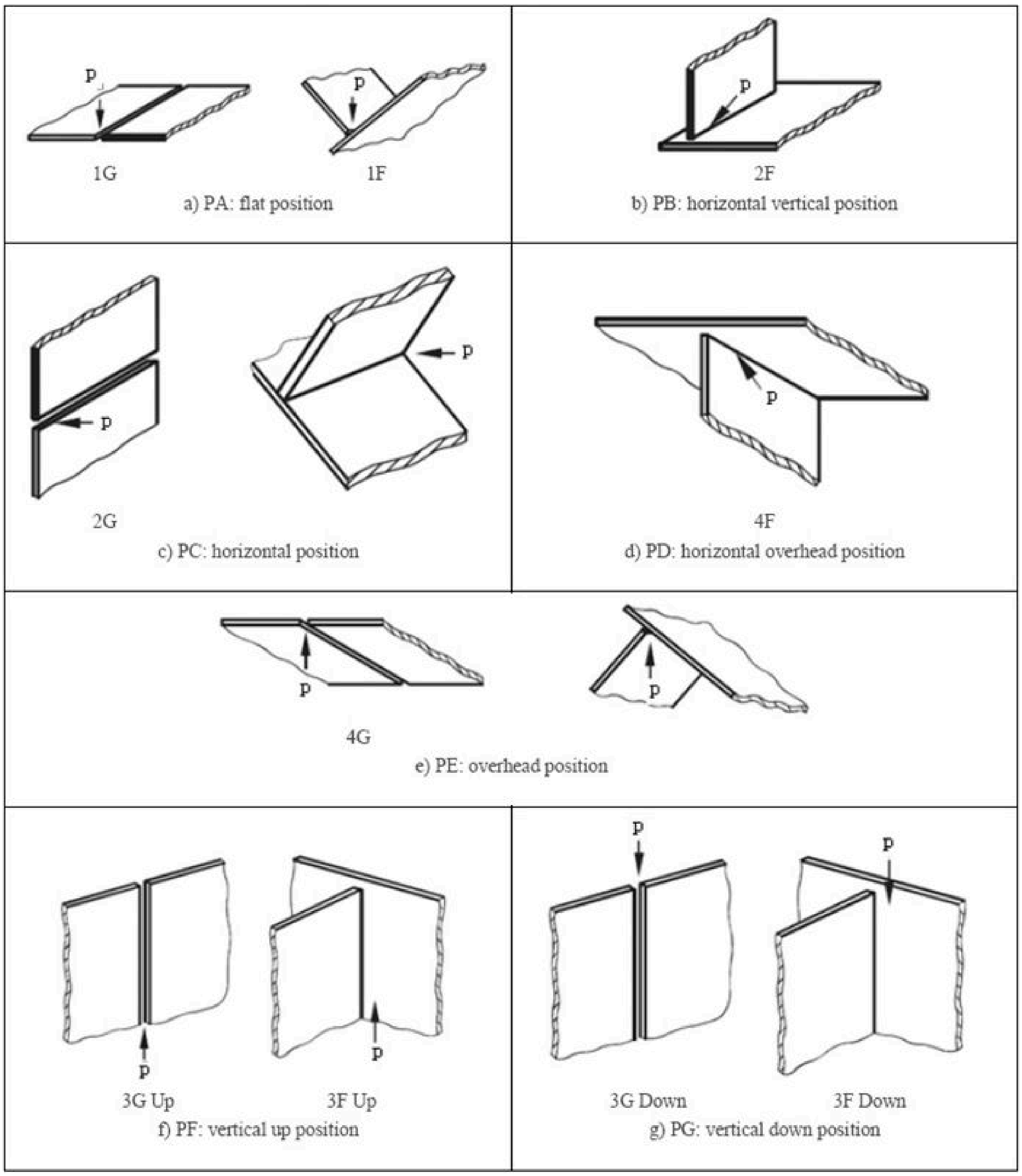
7.7

The welder qualification test assembly is to be welded according to a welding procedure specification (WPS or pWPS).

7.9

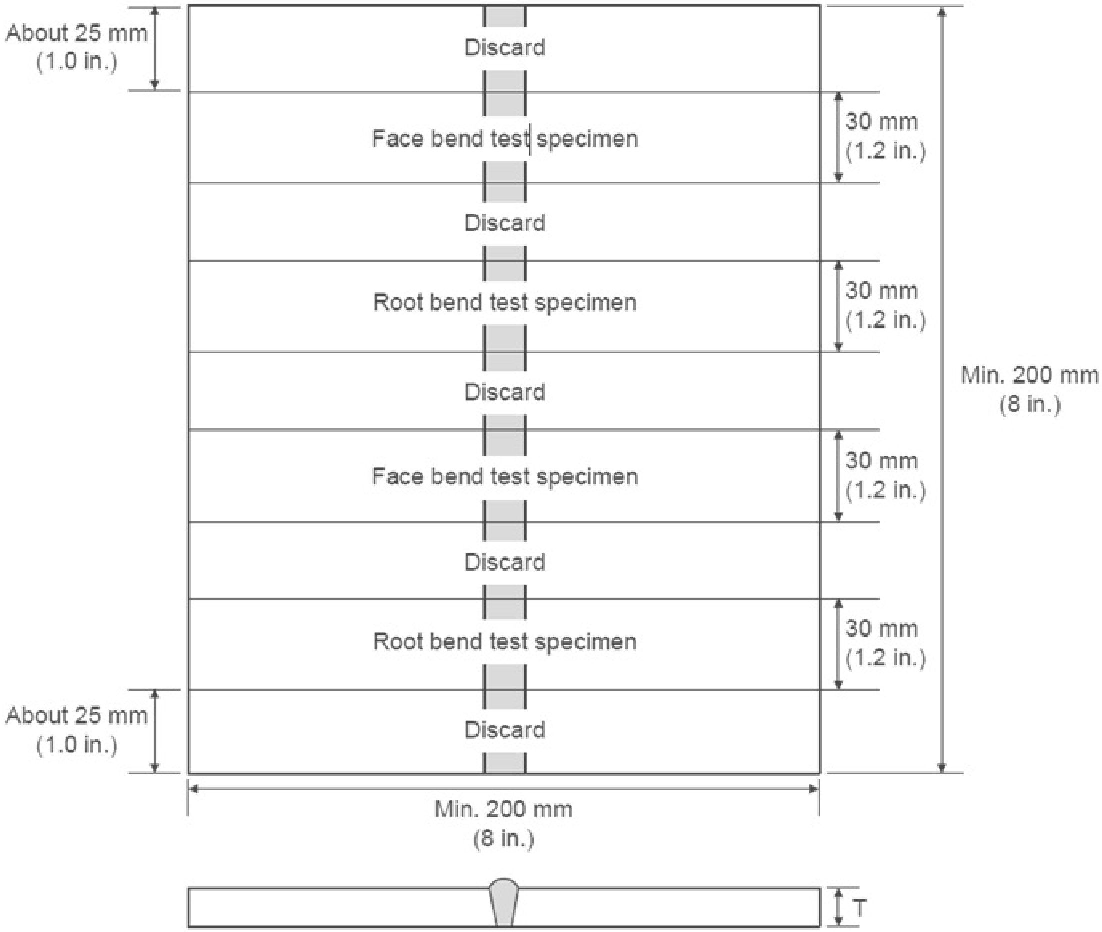
Root run and capping run are each to have a minimum of one stop and restart. The welders are allowed to remove minor imperfections in the stop by grinding before restarting welding.

FIGURE 1
Welding Positions *(1 July 2018)*



Note: *p* is the welding position.

FIGURE 2
Dimensions and Types of Test Assembly for Butt Welds (t < 12 mm (0.5 in.)) *(2024)*

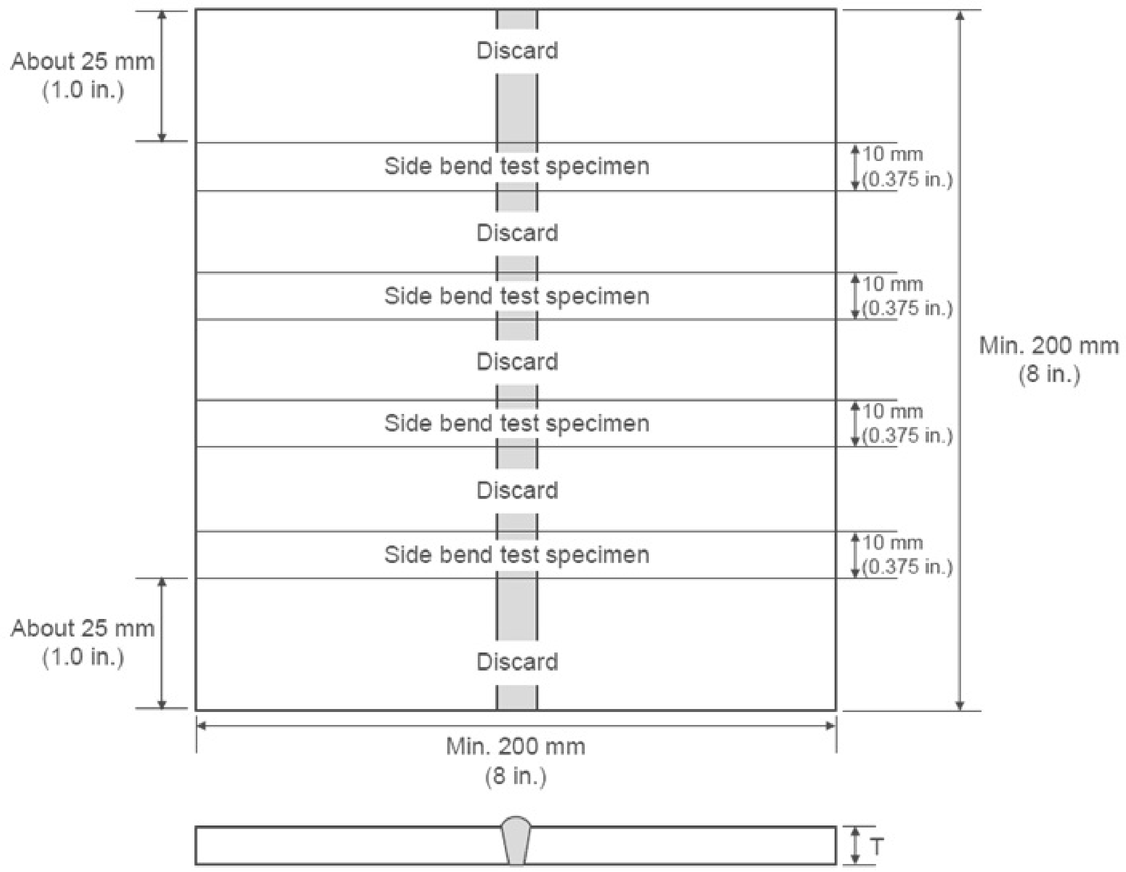


Discard between specimens approx. 10 mm (0.375 in.).

Notes:

1. Welding is to be performed 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.).
3. Machine reinforcement and backing strap flush. Any undercutting is not to be removed.
4. Machining is to be done transverse to the weld.
5. All specimens are to be machined or sawed from plate.
6. When used, 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 performed from one side only.
9. Break edges of specimens to a radius of t/6 maximum.
10. Bend specimens in Guided Bend Test Jig (2-4-3/11.5.4 FIGURE 7).
11. 2 Face Bend and 2 Root Bend are required.

FIGURE 3
Dimensions and Types of Test Assembly for Butt Welds ($t \geq 12$ mm (0.5 in.)) *(2024)*



Discard between specimens approx. 36 mm (1 4 in.).

Notes:

1 When welding in the flat and vertical positions, 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 performed from one side only.

6 Machine reinforcement and backing strap flush. Any undercutting is not to be removed.

7 All specimens are to be machined or sawed from plate.

8 Machining is to be done transverse to the weld.

9 Break edges of specimens to a radius of $t/6$ maximum.

10 Bend Specimen in Guided Bend Test Jig (2-4-3/11.5.4 FIGURE 7).

11 2 Side Bends are required for plate.

FIGURE 4
Dimensions and Types of Test Assembly for Fillet Welds *(1 July 2018)*

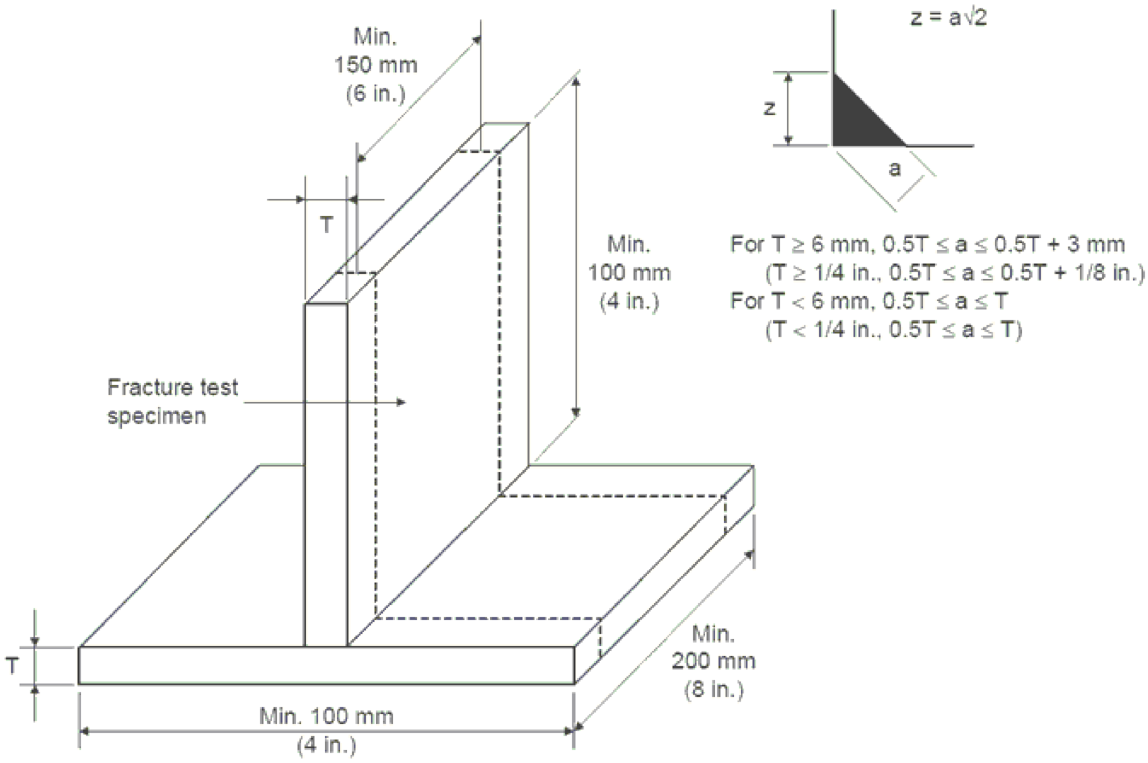


FIGURE 5
Dimensions and Types of Test Assembly for Tack Butt Welds *(1 July 2018)*

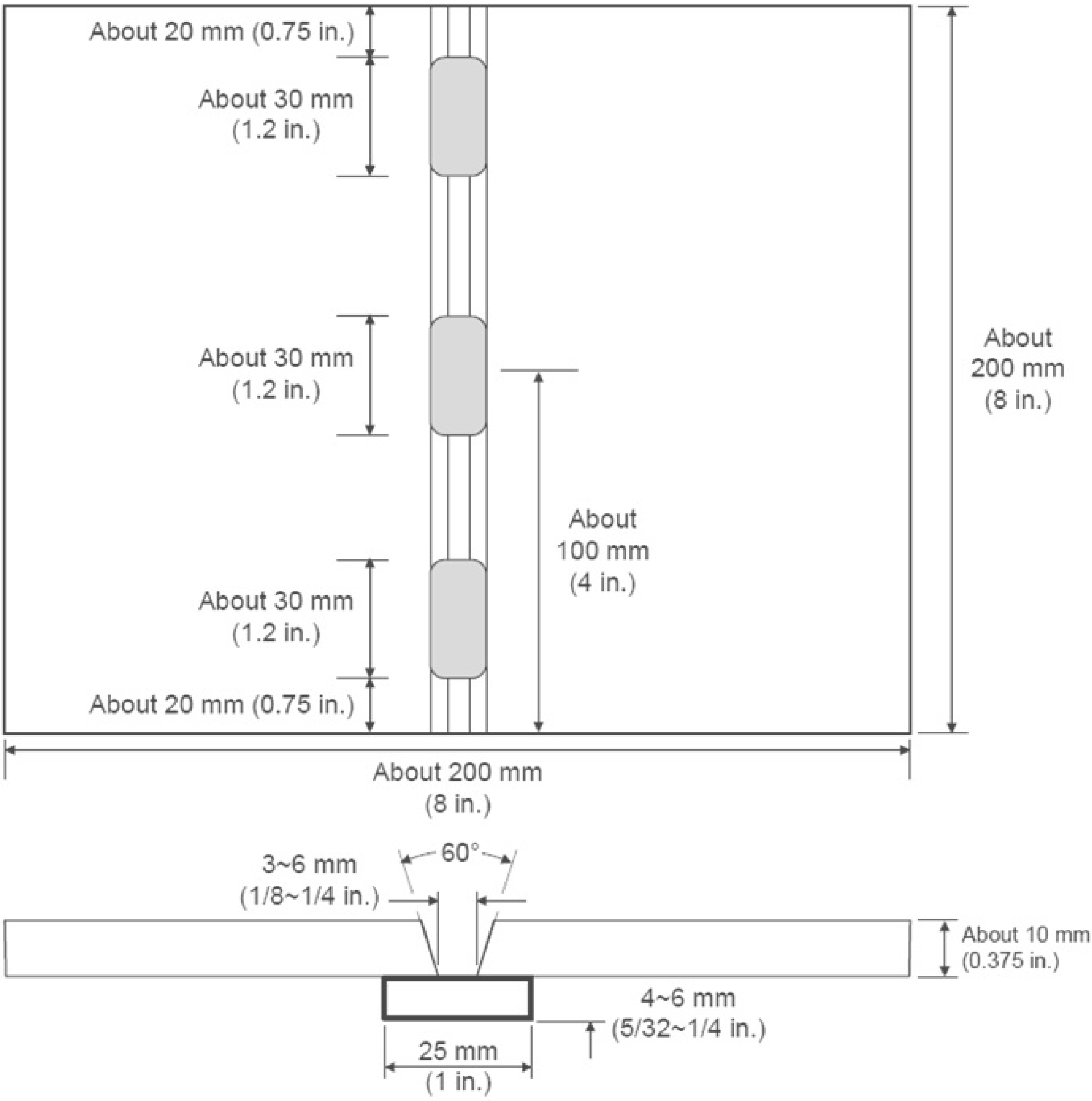
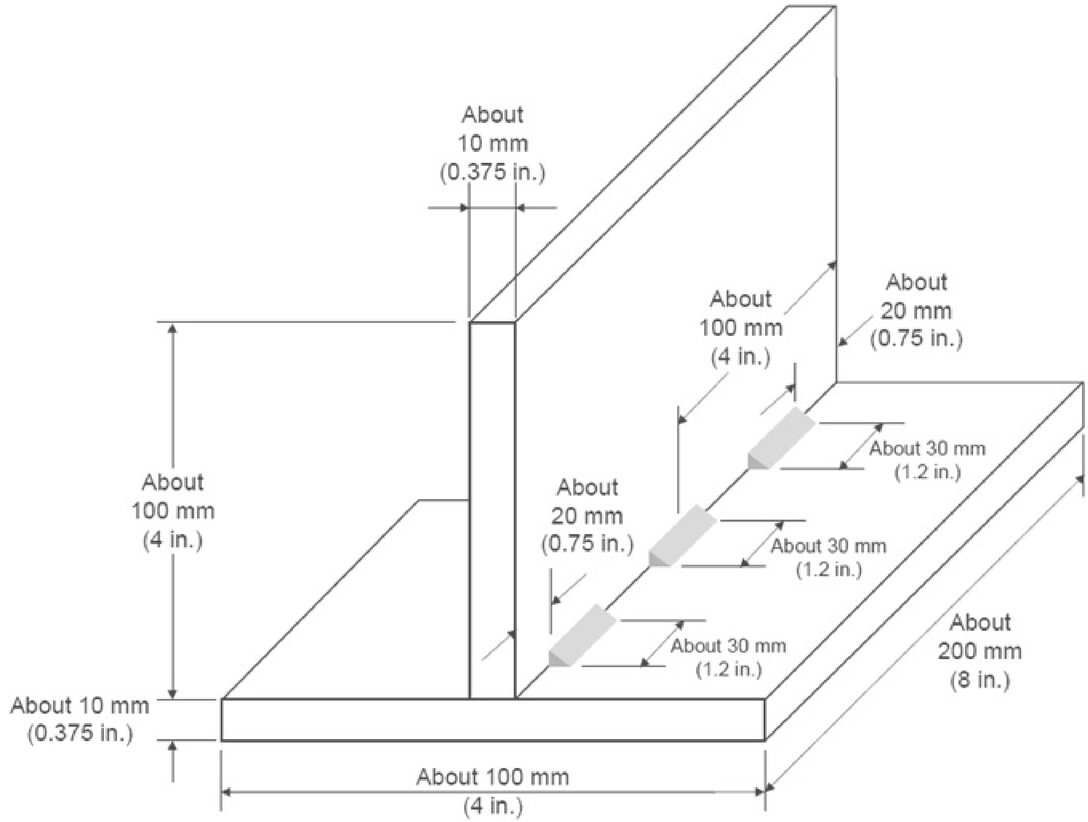


FIGURE 6
Dimensions and Types of Test Assembly for Tack Fillet Welds *(1 July 2018)*



9 Examination and Test

9.1 Types of Tests

Testing of test specimens is to be witnessed by the Surveyor. The test assemblies specified in 2-A11-2/7.3 are to be examined and tested as follows:

i) For butt welds:

- Visual examination
- Bend test

Note:

Radiography can be used to qualify the welder, except for GMAW with short circuit transfer technique for which bend tests are required.

ii) For fillet welds:

- Visual examination
- Fracture test

Note:

Two macro sections are to be taken in lieu of the fracture test.

iii) For tack welds:

- Visual examination
- Fracture test

9.3 Visual Examination

The welds are to be visually examined prior to the cutting of the test specimen for the bend test and fracture test. The result of the examination is to show the absence of cracks or other serious imperfections.

Imperfections detected are to be assessed in accordance with quality level B in ISO 5817, except for the following imperfection types for which level C applies:

- Excess weld metal
- Excess penetration
- Excessive convexity
- Excessive throat thickness

9.5 Bend Test

Transverse bend test specimens are to be in accordance with 2-4-3/11.5.4 FIGURE 5.

The mandrel diameter to thickness ratio (i.e., *D*/*T*) is to be as follows,

Ordinary Strength	Four times the thickness of the specimen
Y and Y400	Four times the thickness of the specimen
YQ420, YQ460 & YQ500	Five times the thickness of the specimen
YQ550, YQ620 & YQ690	Six times the thickness of the specimen.

For normal and high strength steels, forgings, and castings, the test specimens are to be bent on a mandrel with diameter 4t, where t is the thickness of the specimen. For extra high strength steels with H47 grade, the mandrel diameter is to be 5t.

Two face bend test and two root bend test specimens are to be tested for initial qualification test, and one face and one root bend test specimens for extension of approval. For thickness 12 mm (0.5 in.) and over, four side specimens (two side specimens for extension of approval) with 10 mm (0.375 in.) in thickness are to be tested as an alternative.

At least one bend test specimen is to include one stop and restart in the bending part, for root run or for cap run.

The test specimens are to be bent through 180 degrees shown in 2-4-3/11.5.4 FIGURE 7. After the test, the test specimens are not to reveal any open defects in any direction greater than 3 mm (0.125 in.). Defects appearing at the corners of a test specimen during testing are to be investigated on a case-by-case basis.

9.7 Radiographic Test

When radiographic testing is used for butt welds, imperfections detected are to be assessed in accordance with ISO 5817, level B.

9.9 Fracture Test (Butt Welds)

When fracture test is used for butt welds, full test specimen in length is to be tested in accordance with ISO 9017. Imperfections detected are to be assessed in accordance with ISO 5817, level B.

9.11 Fracture Test (Fillet Welds)

The fracture test is to be performed by folding the upright plate onto the through plate.

Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion, and incomplete penetration. Imperfections that are detected are to be assessed in accordance with ISO 5817, level B.

9.13 Macro Examination (Fillet Welds)

When macro examination is used for fillet welds, two test specimens are to be prepared from different cutting positions. At least one macro examination specimen is to be cut at the position of one stop and restart in either root run or cap run. These specimens are to be etched on one side to clearly reveal the weld metal, fusion line, root penetration, and the heat affected zone.

Macro sections are to include at least 10 mm (0.375 in.) of unaffected base metal.

The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration, and the absence of defects such as cracks, lack of fusion, etc.

11 Retest

11.1 *(2024)*

When a welder fails a qualification test, the following is to apply.

i) In cases where the welder fails to meet the requirements in part of the tests, a retest may be welded immediately, consisting of another test assembly of each type of welded joint and position that the welder failed. In this case, the test is to be done for duplicate test specimens of each failed test.

All retest specimens are to meet all of the specified requirements.

ii) In cases where the welder fails to meet the requirements in all parts of the required tests or in the retest, the welder is to undertake further training and practice designed to correct the reasons for previous failures.

iii) When there is specific reason to question the welder's ability or the period of effectiveness has lapsed, the welder is to be requalified.

11.3

Where any test specimen does not comply with dimensional specifications due to poor machining, a replacement test assembly is to be welded and tested.

13 Certification

13.1

Qualification certificates are normally issued when the welder has passed the qualification test by ABS. Each Shipyard, Manufacturer and Subcontractor is to be responsible for the control of the validity of the certificate and the range of the approval.

13.3

The following items are to be specified in the certificate:

i) Range of qualification for base metal, welding processes, filler metal type, types of welded joint, plate thicknesses, and welding positions

ii) Expiry date of the validity of the qualification

iii) Name, identification, and the photograph of the welder *iv)* Name of shipbuilder/manufacturer/subcontractor

13.5

When a certificate is issued, the relative documents such as test reports and/or re-validation records are to be archived as annexes to the copy of the certificate according to the ABS Rules.

13.7

The status of approvals of each individual qualification is to be demonstrated to ABS when requested.

15 Period of Validity of Initial Approval

15.1

Normally, the validity of the welder's approval begins from the issue date of qualification certificate when all the required tests are satisfactorily completed.

15.3

The validity is to be confirmed at six-month intervals by the shipyards, manufacturers, or subcontractor personnel who are responsible for production weld quality, provided that all the following conditions are fulfilled to the satisfaction of the attending Surveyor:

i) The welder has been engaged with reasonable continuity on welding work containing the current range of approval without interruption longer than six months.

ii) The welder's work is to be in accordance with the technical conditions under which the approval test is carried out.

iii) There is to be no specific reason to question the welder's skill and knowledge.

15.5

If any of these conditions are not fulfilled, ABS is to be informed and the certificate is to be withdrawn.

The validity of the certificate may be maintained in agreement with ABS as specified in 2-A11-2/17. The maintenance scheme of qualification is in accordance with 2-A11-2/17.1.i, 2-A11-2/17.1.ii or 2-A11-2/17.1.iii.

17 Maintenance of the Approval

17.1

Revalidation is to be carried out by ABS. The skill of the welder is to be periodically verified by one of the following to the satisfaction of the attending Surveyor:

i) The welder is to be tested every three years.

ii) Every two years, two welds made during the last six months of the two years' validity period are to be tested by radiographic or ultrasonic testing or destructive testing and are to be recorded. The weld tested is to reproduce the initial test conditions except for the thickness. These tests revalidate the welder's qualifications for an additional two years.

iii) The manufacturer is to maintain the qualification and revalidation per the practice of AWS D1.1, or equivalent standards, refer to 2-A11-2/3.5 of this Appendix.

- The welder has been engaged with reasonable continuity on welding work containing the essential welding variables without interruption longer than six months.

The manufacturer's quality program is to be verified in accordance with ISO 3834-2, 3834-3 or equivalent requirement.

17.3

ABS or the builder, manufacturer, or subcontractor is to verify compliance with the above conditions and sign the maintenance of the welder's qualification certificate.

PART 2

APPENDIX 11

Qualification for Welders and Welding Operators

SECTION 3

Welding Operators Qualification *(1 July 2018)*

1 General *(2024)*

1.1 Objective

This section includes a sample welder's/welding operator's qualification to support meeting the goals and functional requirements of Appendix 2-A11-2.

2 *(2024)*

The welding operator(s) responsible for setting up and/or adjustment of fully mechanized and automatic equipment, such as submerged arc welding, gravity welding, electro-gas welding, and MAG welding with auto-carriage, etc., are to be qualified. Competence of the welding operators to operate the welding equipment is to be determined by performing a qualification test.

3

ISO 14732 can be referred as the qualification test and approval range for the welding operator. At the discretion of ABS, the records for welding operator are to give the evidence with adequate regular training to set up, program, and operate welding equipment in accordance with the applicable WPS (welding procedure specification).

5

In addition to the above requirements, the welding operator qualification is to include, but not limited to, the following training and skills for:

i) Groove dimension

ii) Groove cleanliness

iii) Weather and wind

iv) Storing and handling of welding consumables

7 *(2024)*

Appropriate records are to be maintained by shipbuilder, manufacturer, or subcontractor and are to be provided at the Surveyor's request.

For automatic welding, a change from automatic welding to machine welding and vice versa requires requalification.

For machine welding, a change from direct visual control to remote visual control and vice versa requires requalification.

All essential variables for the welding process, qualification test report and ranges qualified are to be recorded on the qualification record.

At the discretion of ABS, the alternative welder operator certificate maybe accepted, per the applicable standards such as ISO 14732, ISO 9606-1, AWS D1.1, ASME IX, or equivalent standards.

PART 2

APPENDIX 11
Qualification for Welders and Welding Operators

SECTION 4
Certification Process *(1 July 2018)*

1 General *(2024)*

1.1 Objective

This section includes guidance on the welder/welding operator qualification process to meet the goals and functional requirements provided in Appendix 2-A11-2.

2

Test assemblies welding and testing are to be witnessed by the Surveyor. On the client's request, ABS will certify the welder after the welder passes the qualification tests.

3

At the discretion of ABS, a welder or operator certified by other classification society or independent organization can be evaluated and accepted on a case-by-case basis. ABS reserves the right to re-validate, which may include testing prior to production, additional NDT and/or welding production tests may be required.

PART 2

APPENDIX 11

Qualification for Welders and Welding Operators

ANNEX 1

Example of Welder's/Welding Operator's Qualification Certificate *(2024)*

1 General *(2024)*

1.1 Objective *(2024)*

This Annex provides a sample welder's/welding operator's qualification certificate.

WELDER'S/WELDING OPERATOR'S QUALIFICATION CERTIFICATE *(2024)*

<table>
<tr><td>Welder's/Welding Operator's name:</td><td colspan="2"></td><td rowspan="6">Photograph</td></tr>
<tr><td>Cert. No:</td><td colspan="2"></td></tr>
<tr><td>Identification No.</td><td colspan="2"></td></tr>
<tr><td>Employer's name and address</td><td colspan="2"></td></tr>
<tr><td>WPS/pWPS No.</td><td colspan="2"></td></tr>
<tr><td>Date of initial approval</td><td colspan="2"></td></tr>
<tr><td colspan="4">This is to certify that the welder has passed the qualification test [/and re-validation record audit] according to the rules of ABS, and is qualified to undertake welding operation specified in range of qualification of this certificate.</td></tr>
<tr><td>Items</td><td>Test piece</td><td colspan="2">Range of qualification</td></tr>
<tr><td>Welding process and Type (Manual, Semiautomatic, Mechanized, Automatic)</td><td></td><td colspan="2"></td></tr>
<tr><td>Base metal and ABS Group Number</td><td></td><td colspan="2"></td></tr>
<tr><td>Filler metal type (Grade/ Classification, Diameter)</td><td></td><td colspan="2"></td></tr>
<tr><td>Plate thickness</td><td></td><td colspan="2"></td></tr>
<tr><td>Deposited Weld Metal Thickness</td><td></td><td colspan="2"></td></tr>
</table>

Type of welded joint (Groove or fillet; Backing or No backing)		
Welding position (Uphill or Downhill)		
Other details		

This certificate is issued at	[place], and valid until	[DD/MM/YYYY].
Signature/seal of examiner:	Issued on	[DD/MM/YYYY].

	Report No. to be reviewed	Date of report	Signature of Employee	Date of signature
1				
2				
3				
4				
5				
6				

TEST RECORD

Type of test	*Performed and accepted*	*Not required*
Visual examination		
Radiographic examination		
Surface examination		
Macro examination		
Fracture test		
Bend test		
Additional tests		

*	At the discretion of ABS, this page can be as the back page of a certificate, and also can be as a separate file.