9 Chemical Composition

9.1 Ladle Analysis

The material is to conform to the chemical requirements specified below.

Element	*Content*, in percent*
Nickel	63.0 min.
Copper	28.0 to 34.0
Iron	2.5
Manganese	2.0
Carbon	0.3
Silicon	0.5
Sulfur	0.024

* Single values are maxima, unless noted.

9.3 Chemical Composition – Check Analysis

A check analysis may be made where so specified by the purchaser. The chemical composition thus determined is to conform to the requirements specified in 2-3-21/9.1, as modified by the product analysis tolerances of the relevant ASTM specification.

11 Tension Test

11.1 Tension Test Specimens

Tensile 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 Annealed Tensile Properties

Annealed pipe and tube, Grades M1 and M3, is to conform to the applicable requirements as to the tensile properties shown.

Outside Diameter in mm (in.)	*Tensile Strength, min in N/mm^2 (ksi)*	*0.2% Offset Yield Strength, min in N/mm^2 (ksi)*	*Percent Elongation, min, in 50 mm (2 in.), or 4 D*
127 mm (5 in.) and less	480 (70)	195 (28)	35
Over 127 mm (5 in.)	480 (70)	170 (25)	35

11.5 Stress Relieved Tensile Properties

Stress relieved pipe and tube, Grades M2 and M4, is to conform to the applicable requirements as to the tensile properties shown.

Tensile Strength, min in N/mm^2 (ksi)	*0.2% Offset Yield Strength, min in N/mm^2 (ksi)*	*Percent Elongation, min, in 50 mm (2 in.), or 4 D*
585 (85)	380 (55)	15

13 Flattening Test

Test specimens taken from samples of welded pipe and tube, Grades M3 or M4, having lengths not less than three times the specified outside diameter or 102 mm (4 in.), whichever is longer, are to be flattened under a load applied gradually at room temperature until the distance between the platens is not greater than five times the wall thickness. The weld is to be positioned 90 degrees from the direction of the applied flattening force. The flattened specimen is to show no cracking, breaks or ruptures on any surface when viewed with the unaided eye.

15 Flare Test

Grades M1 and M3 pipe and tube 76 mm (3 in.) or less in specified outside diameter are to be subjected to a flare test. The flare test specimen is to be expanded by means of an expanding tool having an included angle of 60 degrees until the specified outside diameter has been increased by 30 percent. The expanded specimen is to show no cracking or rupture visible to the unaided eye.

17 Flange Test

Test specimens taken from samples of welded pipe and tube, Grade M4, having lengths not less than three times the specified outside diameter or 102 mm (4 in.), whichever is longer, are to be flanged at a right angle to the tube until the width of the flange is not less than 15 percent the diameter of the tube. The flanged specimen is to show no cracking, breaks or ruptures on any surface when viewed with the unaided eye.

19 Number of Tests

19.1 Chemical Analysis

A chemical analysis (ladle) is to be carried out for each heat of material. Certificates issued by the material producer may be used to satisfy this requirement.

19.3 Other Tests

The lot is to consist of tubulars of the same heat, same size (diameter and wall), same condition, and heat treated together in the same batch or in a continuous furnace under the same conditions of temperature, time at temperature, furnace speed, and furnace atmosphere. The lot size for continuously heat treated tubulars is to be 9100 kg (20,000 lb) or a fraction thereof. Where the material cannot be identified by heat, the lot weight is not to exceed 277 kg (500 lb). For test purposes, sample pieces are to be taken at random from each lot at the following frequency for each of the following tests, as specified.

Test or Examination	*Frequency*
Tension	One
Flattening	One
Flare	One
Flange	One
Hydrostatic	Every Piece
Nondestructive	Every Piece
Finish	1%, minimum of 1, maximum of 10
Dimensions	1%, minimum of 1, maximum of 10

21 Hydrostatic Test

21.1 Limiting Test Pressures

Each pipe or tube is to stand, without showing evidence of leakage, an internal hydrostatic pressure of 69 bar (70.3 kgf/cm^2, 1000 psi), provided the fiber stress as calculated from the following equation does not exceed the allowable fiber stress for the material under test.

$$P = KSt/D$$

where

K = 20 (200, 2)

P = pressure, in bar (kgf/cm^2, psi)

t = thickness of tubular wall, in mm (in.)

D = outside diameter of the tubular, in mm (in.)

S = allowable fiber stress of the material, in N/mm^2 (kgf/mm^2, psi)

Condition	*Grade*	*Outside Diameter*	*Allowable Fiber Stress, S*
Annealed	M1, M3	127 mm (5 in.) and less	120 N/mm^2, (12 kgf/mm^2, 17,500 psi)
	M1	Over 127 mm (5 in.)	115 N/mm^2, (11.5 kgf/mm^2, 16,700 psi)
	M3	Over 127 mm (5 in.)	120 N/mm^2, (12 kgf/mm^2, 17,500 psi)
Stress Relieved	All	All diameters	145 N/mm^2, (14.5 kgf/mm^2, 21,200 psi)

21.3 Exceeding Limiting Test Pressures

When so agreed, the hydrostatic test pressure may exceed the limits stated in Section 2-3-3 to a maximum of 1.5 times the allowable fiber stress values shown above.

21.5 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 Electric Test (NDET)

23.1 General

When specified by the purchaser, welded pipe or tube is to be tested in accordance with ASTM E213, for Ultrasonic Inspection of Metal Pipe and Tubing, ASTM E571, for Electromagnetic (Eddy-current) Examination of Nickel and Nickel Alloy Tubular Products, or other approved standard. It is the intent of these tests to reject tubes containing defects, and the Surveyor is to be satisfied that the nondestructive testing procedures are used in a satisfactory manner.

23.3 Ultrasonic Calibration Standards

Longitudinal notches machined on the outside surface and on the inside surface are to be used. The notch depth is to not exceed 12.5% of the specified wall thickness or 0.004 inch (0.10 mm), whichever is greater. The notch is to be placed in the weld if visible.

23.5 Eddy-Current Calibration Standards

In order to accommodate the various types of nondestructive electrical testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used at the option of the producer to establish a minimum sensitivity level for rejection. The holes and notches are to be placed in the weld, if visible.

23.5.1 Drilled Hole

A hole not larger than 0.79 mm (0.031 in.) in diameter is to be drilled radially and completely through tube wall, care being taken to avoid distortion of the tube while drilling.

23.5.2 Transverse Tangential Notch

Using a round file or tool with a 6.4 mm (0.25 in.) diameter, a notch is to be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. Said notch is to have a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.10 mm (0.004 in.), whichever is greater.

23.5.3 Longitudinal Notch

A notch 0.79 mm. (0.031 in.) or less in width is to be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to a depth not exceeding 12.5% of the nominal wall thickness of the tube or 0.10 mm (0.004 in.), whichever is greater. The length of the notch is to be compatible with the testing method.

23.7 Rejection

Tubulars producing a signal equal to or greater than the calibration defect are to be subject to rejection.

23.9 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

If the results of the test on one of the specimens made to determine the mechanical properties, fails to meet the requirements, 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 Finish

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

Pipe or tube selected for testing is to be examined and measured for dimensions and tolerances.

29.1 Diameter

The outside diameter of pipe and tube, including ovality, is not to exceed the following permissible variations.

Nominal Outside Diameter in mm (in.)	*Over and Under Tolerances in mm (in.)*
Over 3.2 (0.125) to 16 ($^5/_8$), excl.	0.13 (0.005)
16 ($^5/_8$) to 38 ($1^1/_2$), incl.	0.19 (0.0075)
Over 38 ($1^1/_2$) to 76 (3), incl.	0.25 (0.010)
Over 76 (3) to 114 ($4^1/_2$), incl.	0.38 (0.015)
Over 114 ($4^1/_2$) to 152 (6), incl.	0.51(0.020)
Over 152 (6) to 168 ($6^5/_8$), incl.	0.64 (0.025)
Over 168 ($6^5/_8$) to 219 ($8^5/_8$), incl.	0.79 (0.031)

For pipe and tube having a nominal wall thickness of 3% or less of the nominal outside diameter, the mean outside diameter is to conform to the above permissible variations and individual measurements (including ovality) are to conform to the over and under values, with the values increased by 0.5% of the nominal outside diameter. For pipe and tube over 114 mm ($4^1/_2$ in.) in outside diameter with a nominal wall thickness greater than 3% of the nominal outside diameter, the mean outside diameter is to conform to the above permissible variations, and individual measurements are not to exceed twice the above permissible variations.

29.3 Wall Thickness – Seamless

The wall thickness of seamless pipe and tube is not to exceed the permissible variations shown below for the type (nominal or minimum) of specified wall thickness ordered.

Nominal Outside Diameter in mm (in.)	*Variation in Thickness of Specified Nominal Wall*		*Variation in Thickness of Specified Minimum Wall*	
	Over in percent	*Under in percent*	*Over in percent*	*Under in percent*
Over 10 (0.400) to 16 ($^5/_8$), excl.	15.0	15.0	30	0
16 ($^5/_8$) to 38 ($1^1/_2$), incl.	10.0	10.0	22	0
Over 38 ($1^1/_2$) to 76 (3), incl.	10.0	10.0	22	0
Over 76 (3) to 114 ($4^1/_2$), incl.	10.0	10.0	22	0
Over 114 ($4^1/_2$) to 152 (6), incl.	12.5	12.5	28	0
Over 152 (6) to 168 ($6^5/_8$), incl.	12.5	12.5	28	0
Over 168 ($6^5/_8$) to 219 ($8^5/_8$), incl.	12.5	12.5	28	0

29.5 Wall Thickness – Welded

The wall thickness of welded pipe and tube is not to exceed the permissible variations shown below for the type (nominal or minimum) of specified wall thickness ordered.

Nominal Outside Diameter in mm (in.)	*Variation in Thickness of Specified Nominal Wall*		*Variation in Thickness of Specified Minimum Wall*	
	Over in percent	*Under in percent*	*Over in percent*	*Under in percent*
Over 3.2 (0.125) to 16 ($^5/_8$), excl.	15.0	15.0	30	0
16 ($^5/_8$) to 38 ($1^1/_2$), incl.	12.5	12.5	28	0
Over 38 ($1^1/_2$) to 76 (3), incl.	12.5	12.5	28	0
Over 76 (3) to 114 ($4^1/_2$), incl.	12.5	12.5	28	0
Over 114 ($4^1/_2$) to 152 (6), incl.	12.5	12.5	28	0
Over 152 (6) to 168 ($6^5/_8$), incl.	12.5	12.5	28	0
Over 168 ($6^5/_8$) to 219 ($8^5/_8$), incl.	12.5	12.5	28	0

29.7 Cut Ends

Ends are to be plain or cut and deburred unless otherwise specified.

29.9 Straightness

Pipe and tube are to be reasonably straight and free of bends and kinks.

PART

2

Rules for Welding and Fabrication

CHAPTER 4 Welding and Fabrication

CONTENTS

PART

2

CHAPTER 4 Welding and Fabrication

SECTION 1 Hull Construction

1 General

1.1 Hull Welding

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.

1.3 Plans and Specifications

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 are to be shown on the detail drawings or in separate specifications submitted for approval which should 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 and welding of the important structural members.

1.5 Workmanship and Supervision

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 ensure a thorough supervision and control of all welding operations. Inspection of 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

1.7.1 General

Procedures for the welding of all joints are to be established before construction for the welding processes, types of electrodes, 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.

1.7.2 Weld Metal Toughness – Criteria for ABS Grades of Steel

For steels shown in 2-1-2/Table 4 and 2-1-3/Table 4, Approved filler metals appropriate to the grades shown in Part 2, Appendix 3 may be used.

1.7.3 Weld Metal Toughness – Criteria for Other Steels

Weld metal is to exhibit Charpy V-notch toughness values at least equivalent to transverse base metal requirements ($^2/_3$ of the longitudinal base metal requirements).

1.9 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

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. 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 on a case-by-case basis, provided the Surveyor is notified of such cases before the members are welded together. Where plates to be joined differ in thickness and have an offset on either side of more than 3 mm ($^1/_8$ 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.

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 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

All surfaces to be welded are to be free from moisture, grease, loose mill scale, excessive rust or paint. 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. 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

Tack welds of consistently good quality, made with the same 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. Preheat may be necessary prior to tack welding when the materials to be joined are highly restrained. Special consideration is to be given to use the same preheat as specified in the 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.

3.9 Run-on and Run-off Tabs

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.

3.11 Stud Welding

The attachment of pins, hangers, studs, and other related items to ordinary and higher-strength hull structural steels or equivalent by stud welding may be approved at the discretion of the Surveyor. Stud welded attachment to quenched and tempered steel is to be specially 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 special approval and may require special procedure tests appropriate to each application.

3.13 Forming

Steel is not to be formed between the upper and lower critical temperatures; forming in the range between 205°C (400°F) and 425°C (800°F) should be avoided. 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 assure 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/Table 2), when steel is formed below 650°C (1200°F) beyond 3% strain* on the outer fiber, supporting data is to be provided to the satisfaction of the Surveyor indicating that 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 288°C (550°F) for one (1) hour before testing. Rule steels of 2-1-2/Table 5 and 2-1-3/Table 5 or equivalent steels used for radius gunwales (in accordance with 3-1-2/Table 1) 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 to insure 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

Welding is to be planned to progress symmetrically so that shrinkage on both sides of the structure will be equalized. The ends of frames and stiffeners should 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 specially approved.

5.5 Preheat

The use of preheat and interpass temperature control are to be considered when welding higher-strength steels, materials of thick cross-section or materials subject to high restraint. 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 16°C (60°F) or temperature appropriate to the alloy and the thickness, whichever is higher. The control of interpass temperature is to be specially considered when welding quenched and tempered higher-strength steels. When preheat is used, the preheat and interpass temperatures are to be in accordance with the accepted welding procedure and to the satisfaction of the Surveyor. 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.

5.7 Low-hydrogen Electrodes or Welding Processes

5.7.1 Welding of Ordinary and Higher Strength Steel

The use of low-hydrogen electrodes or welding processes is recommended 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 ensure that the electrodes, fluxes and gases used for welding are clean and dry.

5.7.2 Welding of Quenched and Tempered Steels

Unless approved otherwise, matching strength, low-hydrogen electrodes or welding processes are to be used for welding quenched and tempered steels and overmatching should be generally avoided. When welding quenched and tempered steels to other steels, the weld filler metal selection is to be based on the lower strength base material being joined and low hydrogen practice being comparable to that for the higher strength material. In all cases, filler metal strength is to be no less than that of the lowest strength member of the joint unless approved otherwise. The Surveyor is to be satisfied that the procedures for handling and baking filler metals and fluxes are commensurate with the low-hydrogen practices appropriate to the highest strength steel.

5.9 Back Gouging

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. 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

The use of peening is not recommended for single-pass welds and the root or cover passes on multipass welds. Peening, when used to correct distortion or to reduce residual stresses, is to be effected immediately after depositing and cleaning each weld pass.

5.13 Fairing and Flame Shrinking

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.

5.15 Surface Appearance and Weld Soundness

5.15.1 Surface Appearance

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 undercut and overlap. Welds and adjacent base metal are to be free from injurious arc strikes.

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 should generally 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

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. The Bureau's separately issued *Guide for Nondestructive Inspection of Hull Welds* 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, [415-690 N/mm^2 (42-70 kgf/mm^2, 60,000-100,000 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. 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 should 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 *(2006)*

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.

7 Butt Welds

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

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 of 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.

7.5 Gas Metal-arc and Flux Cored-arc Welding *(2005)*

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.) unless specially approved otherwise (see 2-4-3/11.3 for special requirement for welder qualification).

7.7 Electroslag and Electrogas Welding

The use of electroslag and electrogas welding processes will be subject to special consideration, depending upon the specific application and the mechanical properties of the resulting welds and heat-affected zones. See 2-4-1/1.9.

7.9 Special Welding Processes and Techniques *(2008)*

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 specially considered, 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 special consideration, depending upon the application and whether welding is manual or mechanized. Welding processes such as friction stir welding and hybrid laser welding will be specially considered.

PART

2

CHAPTER 4 Welding and Fabrication

SECTION 2 Boilers, Unfired Pressure Vessels, Piping & Engineering Structures*

* *Note:* 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 Steel Vessels (SVR)* and the ABS *Guide for Building and Classing High Speed Naval Craft (HSNC)*. For piping for installation on vessels to be built in accordance with the ABS *Rules for Building and Classing Steel Vessels (SVR)* or the ABS *Guide for Building and Classing High Speed Naval Craft (HSNC)*, see Section 2-4-4.

1 General Considerations

1.1 Fabrication

Drums or shells, other pressure parts of boilers, unfired pressure vessels, pipes and pipe connections, and other engineering structures may be fabricated by means of an approved process of fusion welding in accordance with the following requirements, provided they comply in all other respects with the applicable requirements of Part 4, Chapter 4 and Part 4, Chapter 6, respectively.

1.3 Welding Approval

Before undertaking the welding of any structure subject to the requirements of these Rules, a manufacturer is to prove to the satisfaction of the Surveyor that electrodes and the process the manufacturer proposes to use have been approved and that his welders and welding operators are duly qualified for the work intended. See 2-4-3/3 and 2-4-2/5.

1.5 Grouping of Welded Structures

While, in general, all welding and tests are to be executed in accordance with the requirements of this section, the Rules necessarily 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	Boilers: All pressure parts.	Over 3.4 bar (3.5 kgf/cm^2, 50 psi)	All	None
Group I Pressure Vessels	Unfired Pressure Vessels for:			
	a Vapors or Gases	Over 41.4 bar (42.2 kgf/cm^2, 600 psi)	Over 371°C (700°F)	None
	b Liquids	Over 41.4 bar (42.2 kgf/cm^2, 600 psi)	Over 204°C (400°F)	None
Group II Pressure Vessels	Unfired Pressure Vessels for:			
	a Vapors or Gases	41.4 bar (42.2 kgf/cm^2, 600 psi) and under	371°C (700°F) and under	38.1 mm (1.5 in.)
	b Liquids	41.4 bar (42.2 kgf/cm^2, 600 psi) and under (See Note 2)	204°C (400°F) and under	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 Steel Vessels. For piping intended for vessels to be built in accordance with the *Rules for Building and Classing Steel Vessels (SVR)*, the pipe classes are as defined in 4-6-1/Table 1 of the *Rules for Building and Classing Steel 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. 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 4-6-2/5.13.

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 soundness in 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

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 specially approved otherwise.

5 Workmanship and Supervision

5.1 Construction

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 satisfy himself 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 2-4-3/9.3.

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 should 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 should 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

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

Butt joints are to have complete joint penetration 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.

7.9 Lap Joints

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/Figure 1.

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/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/Figure 1, subject to the tabulated limitations in 4-4-1A1/Table 1.

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/Figure 1(m)]. Corner welds are not to be used unless the plates forming the corner are supported independently of the welds.

7.15 Connections

All welding for fusion-welded connections is to be equivalent to that required for the joints of the vessel to which they are attached.

7.17 Nozzles

Acceptable types of fusion-welded nozzle connections are illustrated in 2-4-2/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/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/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/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/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/Figure 2(w-3).

For all cases, the strength of the welded connection is to be in accordance with the requirements of 4-4-1A1/7.9.3ii).

7.19 Limitations

The use of various types of welded construction is subject to the limitations of the group for which it is intended as well as the limitations tabulated in 4-4-1A1/Table 1.

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/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/Figure 1(g) or (h) and 4-4-1A1/Figure 7.

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 4-4-1A1/Table 1. 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 4-4-1A1/Table 1. See also 2-4-2/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

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 may be not 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.

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 recommended 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

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.

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. 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.

9.11 Engineering Structures

The type of welded joints used in either Group I or II in this class of construction is subject to special consideration in connection with the design in each case

11 Preheat

11.1 Boilers, Pressure Vessels, and Group I Piping

When ambient temperatures are below 10°C (50°F), the welded parts of boilers, pressure vessels, and Group I piping are to be preheated prior to welding, so that the parts to be joined by welding will be at a temperature not less than 10°C (50°F). Higher preheat is required for material composition, thicknesses, and carbon content in accordance with the following paragraphs.

11.1.1 General

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 2-3-2/1, 2-3-2/3, 2-3-2/5, 2-3-2/7, Section 2-3-5 and Section 2-3-12.

11.1.2 Preheat Temperatures

Welds joining pressure parts or attachments to pressure parts are to be preheated to not less than the following temperatures.

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/mm^2 (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.

11.1.2(e) Other Materials. The preheating of other materials will be subject to special consideration.

11.3 Group I Pipe Connections

All Group I pipe connections defined in 2-4-2/1.5.2 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

15.1 Postweld Heat Treatment

All boilers of plate, pipe and tube materials listed in 2-3-2/3, 2-3-2/5, 2-3-2/7, 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

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)	3
510 (950)	5
482 (900)	10

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

Postweld heat treatment of other materials for boilerplate and tubes will be subject to special consideration.

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

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.

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/ Figure 1(f).

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 post-weld heat-treated. See also 2-4-2/21.11 for nozzles or other welded attachments for which postweld heat treatment is not required.

17.9 Other Materials

Postweld heat treatment of other materials for boiler plate and tubes will be subject to special consideration.

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

19.1 Group I Pipe Welded Joints

All Group I Pipe welded joints, defined in 2-4-2/1.5, 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

Postweld heat treatment of structures under this group depends on the type and purpose of the construction, and the matter will be subject to special consideration 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 Postweld Heat-treatment Details

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

The postweld heat treatment of other steels not specifically covered in Part 2, Chapter 3 will be subject to special consideration.

21.7 Clad Pressure Vessels

Postweld heat treatment of vessels or parts of vessels constructed of integrally clad or applied corrosion-resistant lining material will be subject to special consideration.

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 4-4-1A1/Table 1.

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 special consideration.

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 4-4-1A1/Table 1. 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

The radiographic examination of vessels or parts of vessels constructed of alloy, integrally clad or applied corrosion-resistant lining materials, will be subject to special consideration.

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 4-4-1A1/Table 1 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 4-4-1A1/Table 1 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

25.1 Boilers and Pressure Vessels

Hydrostatic tests are to be conducted in accordance with 4-4-1/7.11 and 4-4-1A1/21.

25.3 Piping

Hydrostatic tests are to be conducted in accordance with the Table 1 below:

TABLE 1
Hydrostatic Testing of Piping

*SVR**			*SVR<90m**		*MODU**	
Class I	*Class II*	*Class III*	*Group I*	*Group II*	*Group I*	*Group II*
4-6-2/7.3	4-6-2/7.3	4-6-2/7.3.1	4-4-2/3	4-4-2/3	6-1-1/13	6-1-1/13
4-6-7/7.7			4-4-2/5.1		6-1-1/21	

** Notes*
SVR – Rules for Building and Classing Steel Vessels
SVR<90m – Rules for Building and Classing Steel Vessels Under 90 meters (295 feet) in Length
MODU – Rules for Building and Classing Mobile Offshore Drilling Units

For conditions of hydrostatic testing in other Rules and Guides, see the requirements within the relevant Rules or Guides.

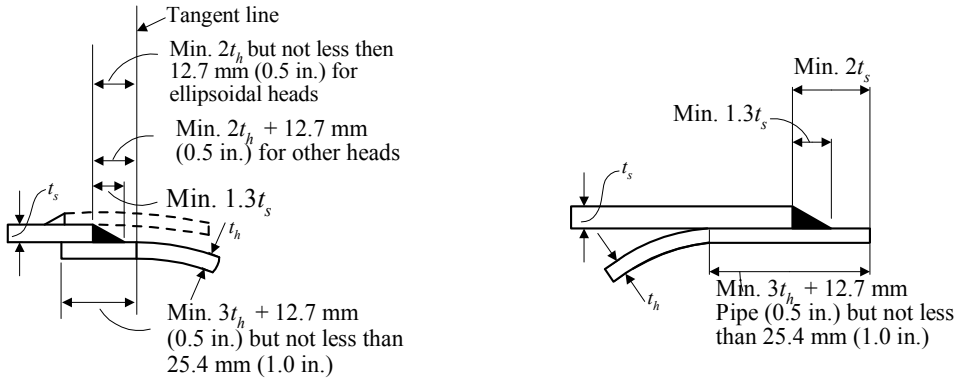
25.5 Defects

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.

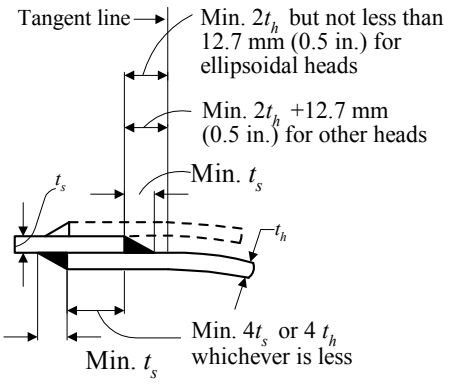
25.7 Retest

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.

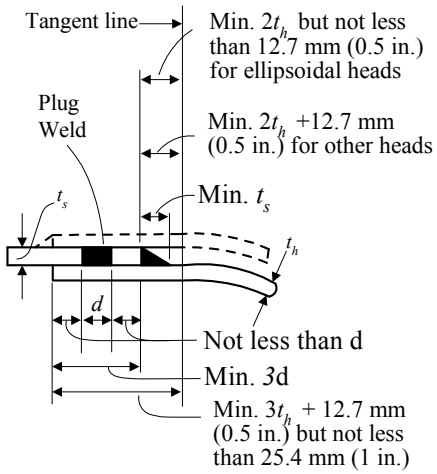
FIGURE 1
Head to Shell Attachments



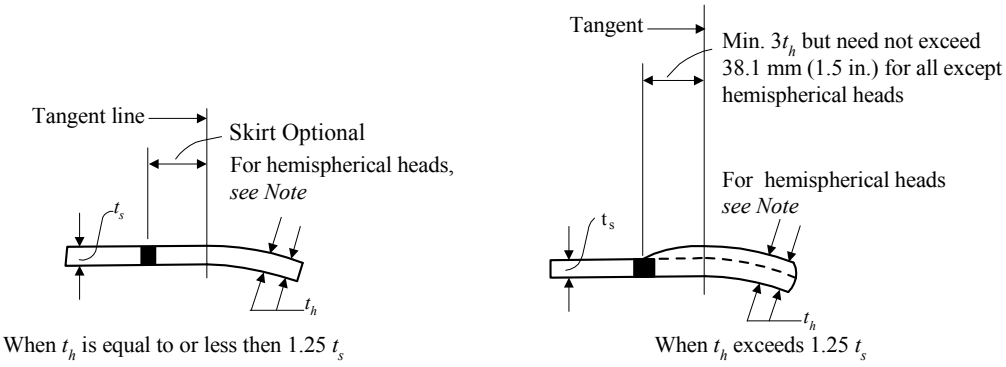
a. Single fillet lap weld



b. Double fillet lap weld

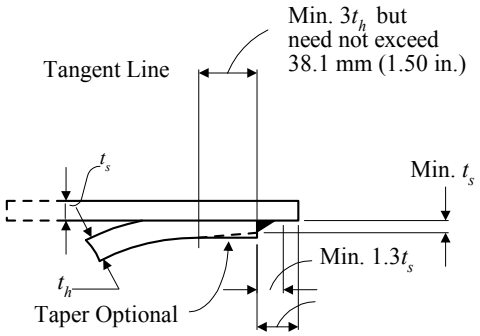


c. Single fillet lap weld with plug welds

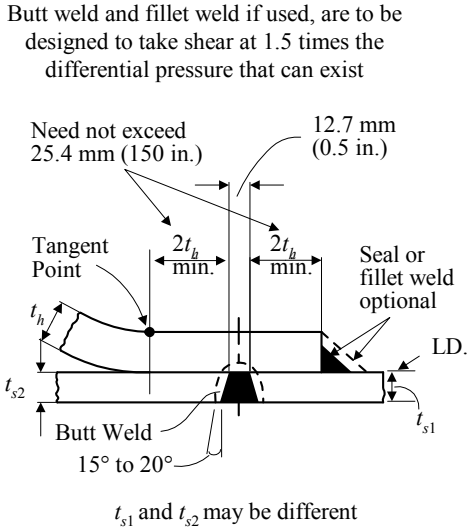


d. Butt weld

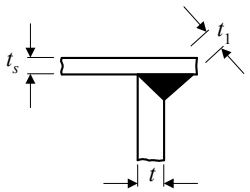
FIGURE 1 (continued)
Head to Shell Attachments



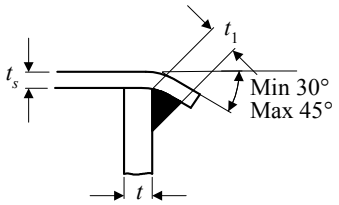
e. Single fillet lap weld



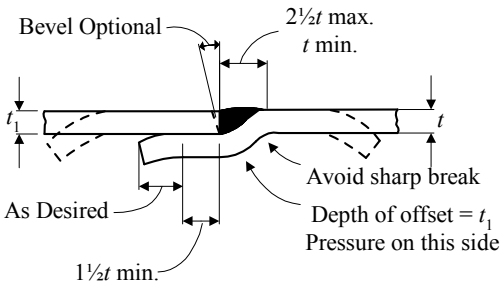
f. Intermediate head



g.

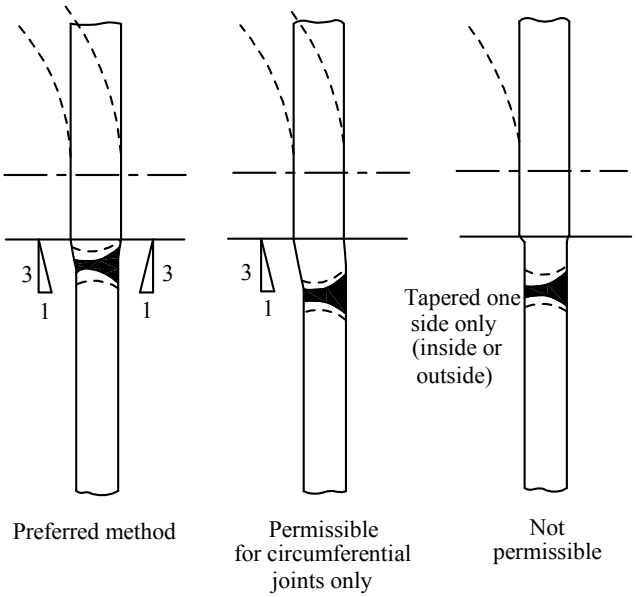


h.

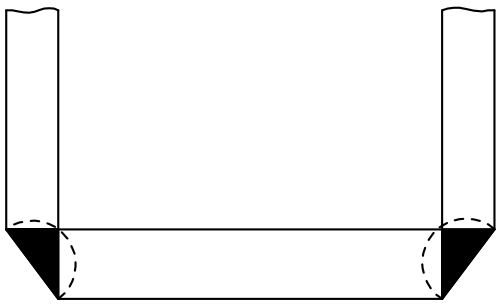


j. Butt weld with one plate edge offset

FIGURE 1 (continued)
Head to Shell Attachments



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.