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PART UCS
REQUIREMENTS FOR PRESSURE VESSELS CONSTRUCTED OF CARBON AND LOW ALLOY STEELS[1]

GENERAL

UCS-1 SCOPE

The rules in Part UCS are applicable to pressure vessels and vessel parts that are constructed of carbon and low alloy steels and shall be used in conjunction with the general requirements in Subsection A, and with the specific requirements in Subsection B that pertain to the method of fabrication used.

MATERIALS

UCS-5 GENERAL

(a) All carbon and low alloy steel material subject to stress due to pressure shall conform to one of the Specifications given in Section II and shall be limited to those listed in Table UCS-23 except as otherwise provided in UG-10 and UG-11.

(b) Carbon or low alloy steel having a carbon content of more than 0.35% by heat analysis shall not be used in welded construction or be shaped by oxygen cutting (except as provided elsewhere in this Division).

(c) Small parts used under the provisions of UG-11(a)(2) in welded construction shall be of good weldable quality.

UCS-6 STEEL PLATES

(a) Approved specifications for carbon and low alloy steel plates are given in Table UCS-23. A tabulation of allowable stress values at different temperatures are given in Table 1A of Section II, Part D (see UG-5).

(b) Steel plates conforming to SA-36, SA/CSA-G40.21 38W, and SA-283 Grades A, B, C, and D may be used for pressure parts in pressure vessels provided all of the following requirements are met.

(1) The vessels are not used to contain lethal substances, either liquid or gaseous.

(2) The material is not used in the construction of unfired steam boilers [see U-1(g)].

(3) With the exception of flanges, flat bolted covers, and stiffening rings, the thickness of plates on which strength welding is applied does not exceed $\frac{5}{8}$ in. (16 mm).

UCS-7 STEEL FORGINGS

Approved specifications for forgings of carbon and low alloy steel are given in Table UCS-23. A tabulation of allowable stress values at different temperatures are given in Table 1A of Section II, Part D (see UG-6).

UCS-8 STEEL CASTINGS

Approved specifications for castings of carbon and low alloy steel are given in Table UCS-23. A tabulation of allowable stress values at different temperatures are given in Table 1A of Section II, Part D. These stress values are to be multiplied by the casting quality factors of UG-24. Castings that are to be welded shall be of weldable grade.

UCS-9 STEEL PIPE AND TUBES

Approved specifications for pipe and tubes of carbon and low alloy steel are given in Table UCS-23. A tabulation of allowable stress values of the materials from which the pipe or tubes are manufactured are given in Table 1A of Section II, Part D. Net allowable

[1] Low alloy steels — those alloy steels listed in Table UCS-23.

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stress values for pipe or tubes of welded manufacture are given in Table 1A of Section II, Part D.

UCS-10 BOLT MATERIALS

(a) Approved specifications for bolt materials of carbon steel and low alloy steel are given in Table UCS-23. A tabulation of allowable stress values at different temperatures (see UG-12) are given in Table 3 of Section II, Part D.

(b) Nonferrous and high alloy steel bolts, studs, and nuts may be used provided they are suitable for the application. They shall conform to the requirements of Part UNF or UHA, as applicable.

UCS-11 NUTS AND WASHERS

(a) Except as otherwise provided in (b)(4) below, materials for nuts shall conform to SA-194, SA-563, or to the requirements for nuts in the specification for the bolting material with which they are to be used. Nuts of special design, such as wing nuts, may be made of any suitable wrought material listed in Table UCS-23 or Table UHA-23 and shall be either: hot or cold forged; or machined from hot-forged, hot-rolled, or cold-drawn bars. Washers may be made from any suitable material listed in Table UCS-23 and Table UHA-23.

(b) Materials for nuts and washers shall be selected as follows.

(1) Carbon steel nuts and carbon steel washers may be used with carbon steel bolts or studs.

(2) Carbon or alloy steel nuts and carbon or alloy steel washers of approximately the same hardness as the nuts may be used with alloy steel bolts or studs for metal temperatures not exceeding 900°F (482°C).

(3) Alloy steel nuts shall be used with alloy steel studs or bolts for metal temperatures exceeding 900°F (482°C). Washers, if used, shall be of alloy steel equivalent to the nut material.

(4) Nonferrous nuts and washers may be used with ferrous bolts and studs provided they are suitable for the application. Consideration shall be given to the differences in thermal expansion and possible corrosion resulting from the combination of dissimilar metals. Nonferrous nuts and washers shall conform to the requirements of UNF-13.

(c) Nuts shall be semifinished, chamfered, and trimmed. Nuts shall be threaded to Class 2B or finer tolerances according to ASME B1.1. For use with flanges conforming to the standards listed in UG-44, nuts shall conform at least to the dimensions given in ASME/ANSI B18.2.2 for Heavy Series Nuts. For use with connections designed in accordance with the rules in Appendix 2, nuts may be of the ANSI Heavy Series, or they may be of other dimensions as permitted in (d) below.

(d) Nuts of special design or of dimensions other than ANSI Heavy Series may be used provided their strength is equal to that of the bolting, giving due consideration to bolt hole clearance, bearing area, thread form and class of fit, thread shear, and radial thrust from threads [see U-2(g)].

UCS-12 BARS AND SHAPES

(a) Approved specifications for bar and shape materials of carbon steel are given in Table UCS-23. A tabulation of allowable stress values at different temperatures are given in Table 1A of Section II, Part D.

(b) Bolt materials as described in UCS-10 may be used as bar materials.

(c) Parts made from bars, on which welding is done, shall be of material for which a P-Number for procedure qualification is given in Section IX, QW-422 (see UW-5).

DESIGN

UCS-16 GENERAL

The rules in the following paragraphs apply specifically to the design of pressure vessels and vessel parts that are constructed of carbon and low alloy steel and shall be used in conjunction with the general requirements for *Design* in Subsection A and with the specific requirements for *Design* in Subsection B that pertain to the method of fabrication used.

UCS-19 WELDED JOINTS

When radiographic examination is required for butt welded joints by UCS-57, joints of Categories A and B (see UW-3) shall be of Type No. (1) or No. (2) of Table UW-12.

UCS-23 MAXIMUM ALLOWABLE STRESS VALUES

Tables 3 (for bolting) and 1A (other materials) in Section II, Part D give the maximum allowable stress values at the temperature indicated for materials con-

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forming to the specifications listed therein.[2] Values may be interpolated for intermediate temperatures. (See UG-23.) For vessels designed to operate at a temperature below −20°F (−29°C), the allowable stress values to be used in design shall not exceed those given in Table 3 or 1A in Section II, Part D for 100°F (38°C).

UCS-27 SHELLS MADE FROM PIPE

(a) Shells of pressure vessels may be made from seamless pipe or tubing listed in Table 1A of Section II, Part D provided the material of the pipe is manufactured by the open-hearth, basic oxygen, or electric-furnace process.

(b) Shells of pressure vessels may be made from electric resistance welded pipe or tubing listed in Table 1A of Section II, Part D in nominal diameters up to 30 in. (762 mm) provided the material is manufactured by the open-hearth, basic oxygen, or electric-furnace process [see UG-16(d)].

UCS-28 THICKNESS OF SHELLS UNDER EXTERNAL PRESSURE

(a) Cylindrical and spherical shells under external pressure shall be designed by the rules in UG-28, using the applicable figures in Subpart 3 of Section II, Part D and the temperature limits of UG-20(c).

(b) Examples illustrating the use of the charts in the figures for the design of vessels under external pressure are given in Appendix L.

(c) Corrugated shells subject to external pressure may be used in pressure vessels in accordance with PFT-19 of Section I.

UCS-29 STIFFENING RINGS FOR SHELLS UNDER EXTERNAL PRESSURE

Rules covering the design of stiffening rings are given in UG-29. An example illustrating the use of these rules is given in Appendix L.

UCS-30 ATTACHMENT OF STIFFENING RINGS TO SHELL

Rules covering the attachment of stiffening rings are given in UG-30.

[2] See Appendix 1 of Section II, Part D for the basis on which the allowable stress values have been established.

UCS-33 FORMED HEADS, PRESSURE ON CONVEX SIDE

Ellipsoidal, torispherical, hemispherical, and conical heads having pressure on the convex side (minus heads) shall be designed by the rules of UG-33, using Fig. CS-1 or Fig. CS-2 of Subpart 3 of Section II, Part D. Examples illustrating the application of this paragraph are given in Appendix L.

UCS-56 REQUIREMENTS FOR POSTWELD HEAT TREATMENT

(a) Before applying the detailed requirements and exemptions in these paragraphs, satisfactory weld procedure qualifications of the procedures to be used shall be performed in accordance with all the essential variables of Section IX including conditions of postweld heat treatment or lack of postweld heat treatment and including other restrictions listed below.

Except as otherwise specifically provided in the notes to Table UCS-56 and Table UCS-56.1, all welds in pressure vessels or pressure vessel parts shall be given a postweld heat treatment at a temperature not less than specified in those Tables when the nominal thickness, as defined in UW-40(f), including corrosion allowance, exceeds the limits in those Tables. The exemptions provided in Table UCS-56 or Table UCS-56.1 are not permitted when postweld heat treatment is a service requirement as set forth in UCS-68, when welding ferritic materials greater than $\frac{1}{8}$ in. (3.2 mm) thick with the electron beam welding process, or when welding P-No. 3, P-No. 4, P-Nos. 5A, 5B, and 5C, and P-No. 10 materials of any thickness using the inertia and continuous drive friction welding processes. Electroslag welds in ferritic materials over $1\frac{1}{2}$ in. (38 mm) thickness at the joint shall be given a grain refining (austenitizing) heat treatment. Electrogas welds in ferritic materials with any single pass greater than $1\frac{1}{2}$ in. (38 mm) shall be given a grain refining (austenitizing) heat treatment. For P-No. 1 materials only, the heating and cooling rate restrictions of (d)(2) and (d)(5) below do not apply when the heat treatment following welding is in the austenitizing range.

The materials in Table UCS-56 are listed in accordance with Section IX P-Number material groupings of QW-422 and also listed in Table UCS-23.

(b) Except where prohibited in Table UCS-56, holding temperatures and/or holding times in excess of the minimum values given in Table UCS-56 may be used. Intermediate postweld heat treatments need not conform to the requirements of Table UCS-56. The holding time

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1100 (593)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (51 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (51 mm)
Gr. No. 4	NA	None	None	None

NOTES:
(1) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
(2) Postweld heat treatment is mandatory under the following conditions:
(a) for welded joints over 1½ in. (38 mm) nominal thickness;
(b) for welded joints over 1¼ in. (32 mm) nominal thickness through 1½ in. (38 mm) nominal thickness unless preheat is applied at a minimum temperature of 200°F (93°C) during welding;
(c) for welded joints of all thicknesses if required by UW-2, except postweld heat treatment is not mandatory under the conditions specified below:
(1) for groove welds not over ½ in. (13 mm) size and fillet welds with a throat not over ½ in. (13 mm) that attach nozzle connections that have a finished inside diameter not greater than 2 in. (51 mm), provided the connections do not form ligaments that require an increase in shell or head thickness, and preheat to a minimum temperature of 200°F (93°C) is applied;
(2) for groove welds not over ½ in. (13 mm) in size or fillet welds with a throat thickness of ½ in. (13 mm) or less that attach tubes to a tubesheet when the tube diameter does not exceed 2 in. (51 mm). A preheat of 200°F (93°C) minimum must be applied when the carbon content of the tubesheet exceeds 0.22%.
(3) for groove welds not over ½ in. (13 mm) in size or fillet welds with a throat thickness of ½ in. (13 mm) or less used for attaching nonpressure parts to pressure parts provided preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds 1¼ in. (32 mm);
(4) for studs welded to pressure parts provided preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds 1¼ in. (32 mm);
(5) for corrosion resistant weld metal overlay cladding or for welds attaching corrosion resistant applied lining (see UCL-34) provided preheat to a minimum temperature of 200°F (93°C) is maintained during application of the first layer when the thickness of the pressure part exceeds 1¼ in. (32 mm).

NA = not applicable

at temperature as specified in Table UCS-56 need not be continuous. It may be an accumulation of time of multiple postweld heat treatment cycles.

(c) When pressure parts of two different P-Number groups are joined by welding, the postweld heat treatment shall be that specified in either of Tables UCS-56 or UHA-32, with applicable notes, 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 shall control.

(d) The operation of postweld heat treatment shall be carried out by one of the procedures given in UW-40 in accordance with the following requirements.

(1) The temperature of the furnace shall not exceed 800°F (427°C) at the time the vessel or part is placed in it.

(2) Above 800°F (427°C), the rate[3] of heating shall be not more than 400°F/hr (222°C/hr) divided by the maximum metal thickness of the shell or head plate in inches, but in no case more than 400°F/hr (222°C/hr). During the heating period there shall not be a greater variation in temperature throughout the portion of the vessel being heated than 250°F (139°C) within any 15 ft (4.6 m) interval of length. 01

(3) The vessel or vessel part shall be held at or above the temperature specified in Table UCS-56 or Table UCS-56.1 for the period of time specified in the Tables. During the holding period, there shall not be

[3] The rates of heating and cooling need not be less than 100°F/hr. However, in all cases consideration of closed chambers and complex structures may indicate reduced rates of heating and cooling to avoid structural damage due to excessive thermal gradients.

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 3 Gr. Nos. 1, 2, 3	1100 (593)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (51 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (51 mm)

NOTES:
(1) When it is impractical to postweld heat treat at the temperatures specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
(2) Postweld heat treatment is mandatory on P-No. 3 Gr. No. 3 material in all thicknesses.
(3) Except for the exemptions in Note (4), postweld heat treatment is mandatory under the following conditions:
  (a) on P-No. 3 Gr. No. 1 and P-No. 3 Gr. No. 2 over $\frac{5}{8}$ in. (16 mm) nominal thickness. For these materials, postweld heat treatment is mandatory on material up to and including $\frac{5}{8}$ in. (16 mm) nominal thickness unless a welding procedure qualification described in UCS-56(a) has been made in equal or greater thickness than the production weld.
  (b) on material in all thicknesses if required by UW-2.
(4) For welding connections and attachments to pressure parts, postweld heat treatment is not mandatory under the conditions specified below:
  (a) for attaching to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits) or nonpressure parts with groove welds not over $\frac{1}{2}$ in. (13 mm) in size or fillet welds that have a throat thickness of $\frac{1}{2}$ in. (13 mm) or less, provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (b) for circumferential butt welds in pipe or tube where the pipe or tube have both a nominal wall thickness of $\frac{1}{2}$ in. (13 mm) or less and a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
  (c) for studs welded to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits) provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (d) for corrosion resistant weld metal overlay cladding or for welds attaching corrosion resistant applied lining (see UCL-34) when welded to pressure parts which have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits) provided preheat to a minimum temperature of 200°F (93°C) is maintained during application of the first layer.

a greater difference than 150°F (83°C) between the highest and lowest temperature throughout the portion of the vessel being heated, except where the range is further limited in Table UCS-56.

(4) During the heating and holding periods, the furnace atmosphere shall be so controlled as to avoid excessive oxidation of the surface of the vessel. The furnace shall be of such design as to prevent direct impingement of the flame on the vessel.

(5) Above 800°F (427°C), cooling shall be done in a closed furnace or cooling chamber at a rate[3] not greater than 500°F/hr divided by the maximum metal thickness of the shell or head plate in inches, but in no case more than 500°F/hr (278°C). From 800°F (427°C) the vessel may be cooled in still air.

(e) Except as permitted in (f) below, vessels or parts of vessels that have been postweld heat treated in accordance with the requirements of this paragraph shall again be postweld heat treated after welded repairs have been made.

(f) Weld repairs to P-No. 1 Group Nos. 1, 2, and 3 materials and to P-No. 3 Group Nos. 1, 2, and 3 materials and to the weld metals used to join these materials may be made after the final PWHT but prior to the final hydrostatic test, without additional PWHT, provided that PWHT is not required as a service requirement in accordance with UW-2(a), except for the exemptions in Table UCS-56, or as a service requirement in accordance with UCS-68. The welded repairs shall meet the requirements of (1) through (6) below. These requirements do not apply when the welded repairs are minor restorations of the material surface, such as those required after removal of construction fixtures, and provided that the surface is not exposed to the vessel contents.

(1) The Manufacturer shall give prior notification of the repair to the user or to his designated agent and shall not proceed until acceptance has been obtained. Such repairs shall be recorded on the Data Report.

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 4 Gr. Nos. 1, 2	1100 (593)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (127 mm)

NOTES:
(1) Except for exemptions in Note (2), postweld heat treatment is mandatory under the following conditions:
  (a) on material of SA-202 Grades A and B over $^5/_8$ in. (16 mm) nominal thickness. For these materials postweld heat treatment is mandatory up to and including $^5/_8$ in. (16 mm) nominal thickness unless a welding procedure qualification described in UCS-56(a) has been made in equal or greater thickness than the production weld.
  (b) on material of all thicknesses if required by UW-2
  (c) on all other P-No. 4 Gr. Nos. 1 and 2 materials.
(2) Postweld heat treatment is not mandatory under the conditions specified below:
  (a) for circumferential butt welds in pipe or tube of P-No. 4 materials where the pipe or tubes comply with all of the following conditions:
    (1) a maximum nominal outside diameter of 4 in. (DN 100);
    (2) a maximum nominal thickness of $^5/_8$ in. (16 mm);
    (3) a maximum specified carbon content of not more than 0.15% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
    (4) a minimum preheat of 250°F (121°C).
  (b) for P-No. 4 pipe or tube materials meeting the requirements of (2)(a)(1), (2)(a)(2), and (2)(a)(3) above, having nonpressure attachments fillet welded to them provided:
    (1) the fillet welds have a maximum throat thickness of $^1/_2$ in. (13 mm);
    (2) a minimum preheat temperature of 250°F (121°C) is applied.
  (c) for P-No. 4 pipe or tube materials meeting the requirements of (2)(a)(1), (2)(a)(2), and (2)(a)(3) above, having studs welded to them, a minimum preheat temperature of 250°F (121°C) is applied.

(2) The total repair depth shall not exceed $1^1/_2$ in. (38 mm) for P-No. 1 Group Nos. 1, 2, and 3 materials and $^5/_8$ in. (16 mm) for P-No. 3 Group Nos. 1, 2, and 3 materials. The total depth of a weld repair shall be taken as the sum of the depths for repairs made from both sides of a weld at a given location.

(3) After removal of the defect, the groove shall be examined, using either the magnetic particle or the liquid penetrant examination methods, in accordance with Appendix 6 for MT and Appendix 8 for PT.

(4) In addition to the requirements of Section IX for qualification of Welding Procedure Specifications for groove welds, the following requirements shall apply.

(a) The weld metal shall be deposited by the manual shielded metal arc process using low hydrogen electrodes. The electrodes shall be properly conditioned in accordance with Section II, Part C, SFA-5.5, Appendix A5.6. The maximum bead width shall be four times the electrode core diameter.

(b) For P-No. 1 Group Nos. 1, 2, and 3 materials, the repair area shall be preheated and maintained at a minimum temperature of 200°F (93°C) during welding.

(c) For P-No. 3 Group Nos. 1, 2, and 3 materials, the repair weld method shall be limited to the half bead weld repair and weld temper bead reinforcement technique. The repair area shall be preheated and maintained at a minimum temperature of 350°F (177°C) during welding. The maximum interpass temperature shall be 450°F (232°C). The initial layer of weld metal shall be deposited over the entire area using $^1/_8$ in. (3.2 mm) maximum diameter electrodes. Approximately one-half the thickness of this layer shall be removed by grinding before depositing subsequent layers. The subsequent weld layers shall be deposited using $^5/_{32}$ in. (4 mm) maximum diameter electrodes in such a manner as to assure tempering of the prior weld beads and their heat affected zones. A final temper bead weld shall be applied to a level above the surface being repaired without contacting the base material but close enough to the edge of the underlying weld bead to

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-Nos. 5A, 5B Gr. No. 1, and 5C Gr. No. 1	1250 (677)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (127 mm)
P-No. 5B Gr. No. 2	1300 (704)			

NOTES:
(1) Except for exemptions in Note (2), postweld heat treatment is mandatory under all conditions.
(2) Postweld heat treatment is not mandatory under the following conditions:
  (a) for circumferential butt welds in pipe or tube where the pipe or tubes comply with all of the following conditions:
    (1) a maximum specified chromium content of 3.00%;
    (2) a maximum nominal outside diameter of 4 in. (DN 100);
    (3) a maximum nominal thickness of $\frac{5}{8}$ in. (16 mm);
    (4) a maximum specified carbon content of not more than 0.15% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
    (5) a minimum preheat of 300°F (149°C) is applied.
  (b) for pipe or tube materials meeting the requirements of (2)(a)(1), (2)(a)(2), (2)(a)(3), and (2)(a)(4) having nonpressure attachments fillet welded to them provided:
    (1) the fillet welds have a maximum throat thickness of $\frac{1}{2}$ in. (13 mm);
    (2) a minimum preheat temperature of 300°F (149°C) is applied.
  (c) for pipe or tube materials meeting the requirements of (2)(a)(1), (2)(a)(2), (2)(a)(3), and (2)(a)(4) having studs welded to them provided a minimum preheat temperature of 300°F (149°C) is applied.
(3) When it is impractical to postweld heat P-Nos. 5A, 5B Gr. No. 1, and 5C Gr. No. 1 materials at the temperature specified in this Table, it is permissible to perform the postweld heat treatment at 1200°F (649°C) minimum provided that, for material up to 2 in. (51 mm) nominal thickness, the holding time is increased to the greater of 4 hr minimum or 4 hr/in. (25 mm) of thickness; for thickness over 2 in. (51 mm), the specified holding times are multiplied by 4. The requirements of UCS-85 must be accommodated in this reduction in postweld heat treatment.

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]
P-No. 9A Gr. No. 1	1100 (593)	1 hr minimum, plus 15 min/in. (25 mm) for thickness over 1 in. (25 mm)

NOTES:
(1) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures [1000°F (538°C) minimum] for longer periods of time in accordance with Table UCS-56.1.
(2) Except for exemptions in Note (3), postweld heat treatment is mandatory under the following conditions:
  (a) on material over $\frac{5}{8}$ in. (16 mm) nominal thickness. For material up to and including $\frac{5}{8}$ in. (16 mm) nominal thickness, postweld heat treatment is mandatory unless a welding procedure qualification described in UCS-56(a) has been made in equal or greater thickness than the production weld.
  (b) on material of all thicknesses if required by UW-2.
(3) Postweld heat treatment is not mandatory under conditions specified below:
  (a) for circumferential butt welds in pipe or tubes where the pipe or tubes comply with all the following conditions:
    (1) a maximum nominal outside diameter of 4 in. (DN 100);
    (2) a maximum thickness of $\frac{1}{2}$ in. (13 mm);
    (3) a maximum specified carbon content of not more than 0.15% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
    (4) a minimum preheat of 250°F (121°C).
  (b) for pipe or tube materials meeting the requirements of (3)(a)(1), (3)(a)(2), and (3)(a)(3) above, having attachments fillet welded to them, provided:
    (1) the fillet welds have a throat thickness of $\frac{1}{2}$ in. (13 mm) or less;
    (2) the material is preheated to 250°F (121°C) minimum. A lower preheating temperature may be used provided specifically controlled procedures necessary to produce sound welded joints are used. Such procedures shall include but shall not be limited to the following:
      (a) The throat thickness of fillet welds shall be $\frac{1}{2}$ in. (13 mm) or less.
      (b) The maximum continuous length of fillet welds shall be not over 4 in. (102 mm).
      (c) The thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded.
  (c) for attaching nonpressure parts to pressure parts with groove welds not over $\frac{1}{2}$ in. (13 mm) in size or fillet welds that have a throat thickness of $\frac{1}{2}$ in. (13 mm) or less, provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (d) for studs welded to pressure parts provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (e) for corrosion resistant weld metal overlay cladding or for welds attaching corrosion resistant applied lining (see UCL-34) provided preheat to a minimum temperature of 200°F (93°C) is maintained during application of the first layer.
(4) When the heating rate is less than 50°F (28°C)/hr between 800°F (427°C) and the holding temperature, the additional 15 min/in. (25 mm) holding time is not required. Additionally, where the manufacturer can provide evidence that the minimum temperature has been achieved throughout the thickness, the additional 15 min/in. (25 mm) holding time is not required.

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]
P-No. 9B Gr. No. 1	1100 (593)	1 hr minimum, plus 15 min/in. (25 mm) for thickness over 1 in. (25 mm)

NOTES:
(1) When it is impractical to postweld heat treat at the temperatures specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures [1000°F (538°C) minimum] for longer periods of time in accordance with Table UCS-56.1.
(2) The holding temperature for postweld heat treatment shall not exceed 1175°F (635°C).
(3) Except for exemptions in Note (4), postweld heat treatment is mandatory under the following conditions:
  (a) on material over $\frac{5}{8}$ in. (16 mm) nominal thickness. For material up to and including $\frac{5}{8}$ in. (16 mm) nominal thickness, postweld heat treatment is mandatory unless a welding procedure qualification described in UCS-56(a) has been made in equal or greater thickness than the production weld.
  (b) on material of all thicknesses if required by UW-2.
(4) Postweld heat treatment is not mandatory under the conditions specified below:
  (a) for attaching nonpressure parts to pressure parts with groove welds not over $\frac{1}{2}$ in. (13 mm) in size or fillet welds that have a throat thickness of $\frac{1}{2}$ in. (13 mm) or less, provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (b) for studs welded to pressure parts provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (c) for corrosion resistant weld metal overlay cladding or for welds attaching corrosion resistant applied lining (see UCL-34) provided preheat to a minimum temperature of 200°F (93°C) is maintained during application of the first layer.
(5) When the heating rate is less than 50°F (28°C)/hr between 800°F (427°C) and the holding temperature, the additional 15 min/in. (25 mm) holding time is not required. Additionally, where the manufacturer can provide evidence that the minimum temperature has been achieved throughout the thickness, the additional 15 min/in. (25 mm) holding time is not required.

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]
P-No. 10A Gr. No. 1	1100 (593)	1 hr minimum, plus 15 min/in. (25 mm) for thickness over 1 in. (25 mm)

NOTES:
(1) (a) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
  (b) Consideration should be given for possible embrittlement of materials containing up to 0.15% vanadium when postweld heat treating at the minimum temperature and at lower temperature for longer holding times.
(2) Except for exemptions in Note (3), postweld heat treatment is mandatory under the following conditions:
  (a) on all thicknesses of SA-487 Class 1Q material;
  (b) on all other P-No. 10A materials over $\frac{5}{8}$ in. (16 mm) nominal thickness. For these materials up to and including $\frac{5}{8}$ in. (16 mm) nominal thickness, postweld heat treatment is mandatory unless a welding procedure qualification described in UCS-56(a) has been made in equal or greater thickness than the production weld.
  (c) on material of all thicknesses if required by UW-2.
(3) Postweld heat treatment is not mandatory under the conditions specified below:
  (a) for attaching to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits) or nonpressure parts with groove weld not over $\frac{1}{2}$ in. (13 mm) in size or fillet welds having a throat thickness of $\frac{1}{2}$ in. (13 mm) or less, provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (b) for circumferential butt welds in pipes or tube where the pipe or tube has both a nominal wall thickness of $\frac{1}{2}$ in. (13 mm) or less and a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by purchaser to a value within the specification limits) provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (c) for studs welded to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by purchaser to a value within the specification limits) provided preheat to a minimum temperature of 200°F (93°C) is applied;
  (d) for corrosion resistant weld metal overlay cladding or for welds attaching corrosion resistant applied lining (see UCL-34) when welded to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits) provided preheat to a minimum temperature of 200°F (93°C) is maintained during application of the first layer.
(4) When the heating rate is less than 50°F (28°C)/hr between 800°F (427°C) and the holding temperature, the additional 15 min/in. (25 mm) holding time is not required. Additionally, where the manufacturer can provide evidence that the minimum temperature has been achieved throughout the thickness, the additional 15 min/in. (25 mm) holding time is not required.

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TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]
P-No. 10B Gr. No. 1	1100 (593)	1 hr minimum, plus 15 min/in. (25 mm) for thickness over 1 in. (25 mm)

NOTES:
(1) Postweld heat treatment is mandatory for P-No. 10B materials for all thicknesses.
(2) When the heating rate is less than 50°F (28°C)/hr between 800°F (427°C) and the holding temperature, the additional 15 min/in. (25 mm) holding time is not required. Additionally, where the manufacturer can provide evidence that the minimum temperature has been achieved throughout the thickness, the additional 15 min/in. (25 mm) holding time is not required.

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]
P-No. 10C Gr. No. 1	1000 (538)	1 hr minimum, plus 15 min/in. (25 mm) for thickness over 1 in. (25 mm)

NOTES:
(1) When it is impractical to postweld heat treat at the temperatures specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
(2) Except for exemptions in Note (3), postweld heat treatment is mandatory under the following conditions:
  (a) for material over $1\frac{1}{2}$ in. (38 mm) nominal thickness. Postweld heat treatment is mandatory on materials over $1\frac{1}{4}$ in. (32 mm) nominal thickness through $1\frac{1}{2}$ in. (38 mm) nominal thickness unless preheat is applied at a minimum temperature of 200°F (93°C) during welding.
  (b) on material of all thicknesses if required by UW-2.
(3) Postweld heat treatment is not mandatory under the conditions specified below:
  (a) for groove welds not over $\frac{1}{2}$ in. (13 mm) in size and fillet welds with throat not over $\frac{1}{2}$ in. (13 mm) that attach nozzle connections that have a finished inside diameter not greater than 2 in. (51 mm) provided the connections do not form ligaments that require an increase in shell or head thickness and preheat to a minimum temperature of 200°F (93°C) is applied;
  (b) for groove welds not over $\frac{1}{2}$ in. (13 mm) in size or fillet welds having throat thickness of $\frac{1}{2}$ in. (13 mm) or less used for attaching nonpressure parts to pressure parts and preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds $1\frac{1}{4}$ in. (32 mm);
  (c) for studs welded to pressure parts provided preheat to a minimum temperature of 200°F (93°C) is applied when the thickness of the pressure part exceeds $1\frac{1}{4}$ in. (32 mm);
  (d) for corrosion resistant weld metal overlay cladding or for welds attaching corrosion resistant applied lining (see UCL-34) provided preheat to a minimum temperature of 200°F (93°C) is maintained during application of the first layer when the thickness of the pressure part exceeds $1\frac{1}{4}$ in. (32 mm).
(4) When the heating rate is less than 50°F (28°C)/hr between 800°F (427°C) and the holding temperature, the additional 15 min/in. (25 mm) holding time is not required. Additionally, where the manufacturer can provide evidence that the minimum temperature has been achieved throughout the thickness, the additional 15 min/in. (25 mm) holding time is not required.

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]
P-No. 10F Gr. No. 1	1000 (538)	1 hr minimum, plus 15 min/in. (25 mm) for thickness over 1 in. (25 mm)

NOTES:
(1) Postweld heat treatment is mandatory for P-No. 10F materials for all thicknesses.
(2) When the heating rate is less than 50°F (28°C)/hr between 800°F (427°C) and the holding temperature, the additional 15 min/in. (25 mm) holding time is not required. Additionally, where the manufacturer can provide evidence that the minimum temperature has been achieved throughout the thickness, the additional 15 min/in. (25 mm) holding time is not required.

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TABLE UCS-56.1
ALTERNATIVE POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS
Applicable Only When Permitted in Table UCS-56

Decrease in Temperature Below Minimum Specified Temperature, °F (°C)	Minimum Holding Time [Note (1)] at Decreased Temperature, hr	Notes
50 (28)	2	...
100 (56)	4	...
150 (83)	10	(2)
200 (111)	20	(2)

NOTES:
(1) Minimum holding time for 1 in. (25 mm) thickness or less. Add 15 minutes per inch (25 mm) of thickness for thicknesses greater than 1 in. (25 mm).
(2) These lower postweld heat treatment temperatures permitted only for P-No. 1 Gr. Nos. 1 and 2 materials.

assure tempering of the base material heat affected zone. After completing all welding, the repair area shall be maintained at a temperature of 400°F–500°F (204°C–260°C) for a minimum period of 4 hr. The final temper bead reinforcement layer shall be removed substantially flush with the surface of the base material.

(5) After the finished repair weld has reached ambient temperature, it shall be inspected using the same nondestructive examination that was used in (f)(3) above, except that for P-No. 3, Group No. 3 materials, the examination shall be made after the material has been at ambient temperature for a minimum period of 48 hr to determine the presence of possible delayed cracking of the weld. If the examination is by the magnetic particle method, only the alternating current yoke type is acceptable. In addition, welded repairs greater than $\frac{3}{8}$ in. (10 mm) deep in materials and in welds that are required to be radiographed by the rules of this Division, shall be radiographically examined to the requirements of UW-51.

(6) The vessel shall be hydrostatically tested after making the welded repair.

UCS-57 RADIOGRAPHIC EXAMINATION

In addition to the requirements of UW-11, complete radiographic examination is required for each butt welded joint at which the thinner of the plate or vessel wall thicknesses at the welded joint exceeds the thickness limit above which full radiography is required in Table UCS-57.

TABLE UCS-57
THICKNESS ABOVE WHICH FULL RADIOGRAPHIC EXAMINATION OF BUTT WELDED JOINTS IS MANDATORY

P-No. & Gr. No. Classification of Material	Nominal Thickness Above Which Butt Welded Joints Shall Be Fully Radiographed, in. (mm)
1 Gr. 1, 2, 3	$1\frac{1}{4}$ (32)
3 Gr. 1, 2, 3	$\frac{3}{4}$ (19)
4 Gr. 1, 2	$\frac{5}{8}$ (16)
5A, 5B Gr. 1	0 (0)
9A Gr. 1	$\frac{5}{8}$ (16)
9B Gr. 1	$\frac{5}{8}$ (16)
10A Gr. 1	$\frac{3}{4}$ (19)
10B Gr. 2	$\frac{5}{8}$ (16)
10C Gr. 1	$\frac{5}{8}$ (16)
10F Gr. 6	$\frac{3}{4}$ (19)

LOW TEMPERATURE OPERATION

UCS-65 SCOPE

The following paragraphs contain requirements for vessels and vessel parts constructed of carbon and low alloy steels with respect to minimum design metal temperatures.

UCS-66 MATERIALS

(a) Figure UCS-66 shall be used to establish impact testing exemptions for steels listed in Part UCS. Unless otherwise exempted by the rules of this Division, impact testing is required for a combination of minimum design metal temperature (see UG-20) and thickness (as defined below) which is below the curve assigned to the subject material. If a minimum design metal temperature and thickness combination is on or above the curve, impact testing is not required by the rules of this Division, except as required by (j) below and UCS-67(a)(2) for weld metal.

Components, such as shells, heads, nozzles, manways, reinforcing pads, flanges, tubesheets, flat cover plates, backing strips which remain in place, and attachments which are essential to the structural integrity of the vessel when welded to pressure retaining components, shall be treated as separate components. Each component shall be evaluated for impact test requirements based on its individual material classification, thickness as

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defined in (1), (2), or (3) below, and the minimum design metal temperature.

The following thickness limitations apply when using Fig. UCS-66.

(1) Excluding castings, the governing thickness t_g of a welded part is as follows:

(a) for butt joints except those in flat heads and tubesheets, the nominal thickness of the thickest welded joint [see Fig. UCS-66.3 sketch (a)];

(b) for corner, fillet, or lap welded joints, including attachments as defined above, the thinner of the two parts joined;

(c) for flat heads or tubesheets, the larger of (b) above or the flat component thickness divided by 4;

(d) for welded assemblies comprised of more than two components (e.g., nozzle-to-shell joint with reinforcing pad), the governing thickness and permissible minimum design metal temperature of each of the individual welded joints of the assembly shall be determined, and the warmest of the minimum design metal temperatures shall be used as the permissible minimum design metal temperature of the welded assembly. [See Fig. UCS-66.3 sketch (b), L-9.3.1, and L-9.5.2.]

If the governing thickness at any welded joint exceeds 4 in. and the minimum design metal temperature is colder than 120°F (49°C), impact tested material shall be used.

(2) The governing thickness of a casting shall be its largest nominal thickness.

(3) The governing thickness of flat nonwelded parts, such as bolted flanges, tubesheets, and flat heads, is the flat component thickness divided by 4.

(4) The governing thickness of a nonwelded dished head [see Fig. 1-6 sketch (c)] is the greater of the flat flange thickness divided by 4 or the minimum thickness of the dished portion.

(5) If the governing thickness of the nonwelded part exceeds 6 in. (152 mm) and the minimum design metal temperature is colder than 120°F (49°C), impact tested material shall be used.

Examples of the governing thickness for some typical vessel details are shown in Fig. UCS-66.3.

NOTE: The use of provisions in UCS-66 which waive the requirements for impact testing does not provide assurance that all test results for these materials would satisfy the impact energy requirements of UG-84 if tested.

(b) When the coincident ratio defined in Fig. UCS-66.1 is less than one, Fig. UCS-66.1 provides a basis for the use of components made of Part UCS materials to have a colder MDMT than that derived from (a) above without impact testing.

(1)(a) For such components, and for a MDMT of −55°F (48°C) and warmer, the MDMT without impact testing determined in (a) above for the given material and thickness may be reduced as determined from Fig. UCS-66.2. If the resulting temperature is colder than the required MDMT, impact testing of the material is not required.

(b) Figure UCS-66.1 may also be used for components not stressed in general primary membrane tensile stress, such as flat heads, covers, tubesheets, and flanges (including bolts and nuts). The MDMT of these components without impact testing as determined in UCS-66(a) or (c) may be reduced as determined from Fig. UCS-66.2. The ratio used in Step 3 of Fig. UCS-66.2 shall be the ratio of maximum design pressure at the MDMT to the maximum allowable pressure (MAP) of the component at the MDMT. If the resulting temperature is colder than the required MDMT, impact testing of the material is not required, provided the MDMT is not colder than −55°F (48°C).

(c) In lieu of using (b)(1)(b) above, the MDMT determined in UCS-66(a) or (c) may be reduced for a flange attached by welding, by the same reduction as determined in (b)(1)(a) above for the neck or shell which the flange is attached.

NOTE: The bolt-up condition need not be considered when determining the temperature reduction for flanges.

(2) For minimum design temperatures colder than −55°F (−48°C), impact testing is required for all materials, except as allowed in (b)(3) below and in UCS-68(c).

(3) When the minimum design metal temperature is colder than −55°F (−48°C) and no colder than −155°F (−104°C), and the coincident ratio defined in Fig. UCS-66.1 is less than or equal to 0.35, impact testing is not required.

(c) No impact testing is required for the following flanges when used at minimum design metal temperatures no colder than −20°F (−29°C):

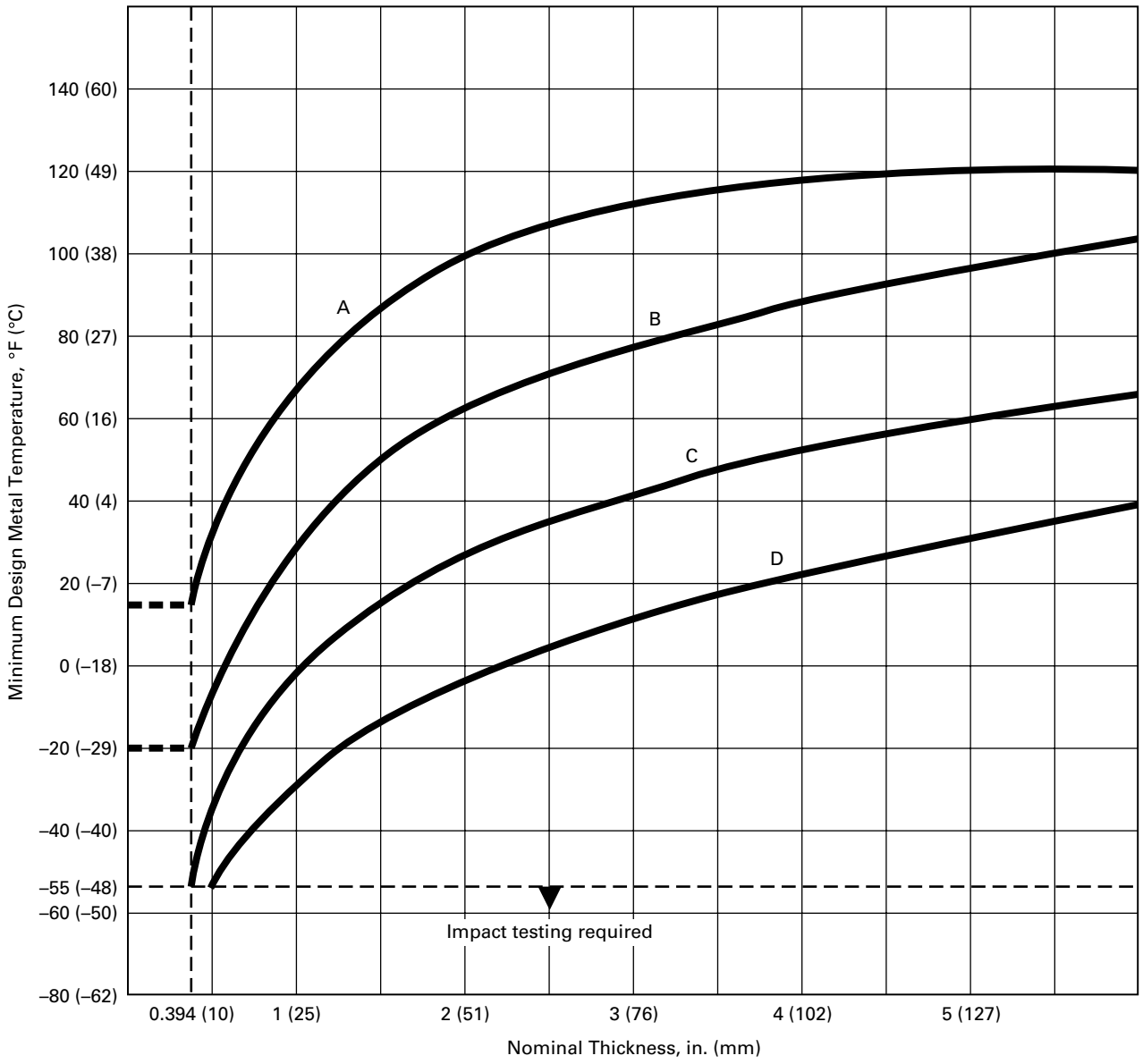
(1) ASME B16.5 flanges of ferritic steel;

(2) ASME B16.47 flanges of ferritic steel;

(3) split loose flanges of SA-216 GR WCB when the outside diameter and bolting dimensions are either ASME B16.5 Class 150 or Class 300, and the flange thicknesses are not greater than that of either ASME B16.5 Class 150 or Class 300, respectively.

(4) Carbon and Low Alloy Steel Long Weld Neck Flanges. Long weld neck flanges are defined as flanges having the flange dimensions of ASME B16.5 but having a straight hub. The neck inside diameter shall not be less than the nominal size of the flange and

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[Limited to 4 in. (102 mm) for Welded Construction]

General Notes and Notes follow on next two pages

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES [SEE NOTES (1) AND (2)] [SEE UCS-66(a)]

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FIG. UCS-66 (CONT'D)

GENERAL NOTES ON ASSIGNMENT OF MATERIALS TO CURVES:

(a) Curve A applies to:
- (1) all carbon and all low alloy steel plates, structural shapes, and bars not listed in Curves B, C, and D below;
- (2) SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA-217 Grade WC6 if normalized and tempered or water-quenched and tempered.

(b) Curve B applies to:
- (1) SA-216 Grade WCA if normalized and tempered or water-quenched and tempered
  SA-216 Grades WCB and WCC for thicknesses not exceeding 2 in. (51 mm), if produced to fine grain practice and water-quenched and tempered
  SA-217 Grade WC9 if normalized and tempered
  SA-285 Grades A and B
  SA-414 Grade A
  SA-515 Grade 60
  SA-516 Grades 65 and 70 if not normalized
  SA-612 if not normalized
  SA-62 Grade B if not normalized;
- (2) except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed in Curves C and D below;
- (3) all pipe, fittings, forgings and tubing not listed for Curves C and D below;
- (4) parts permitted under UG-11 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.

(c) Curve C
- (1) SA-182 Grades 21 and 22 if normalized and tempered
  SA-302 Grades C and D
  SA-336 F21 and F22 if normalized and tempered
  SA-387 Grades 21 and 22 if normalized and tempered
  SA-516 Grades 55 and 60 if not normalized
  SA-533 Grades B and C
  SA-662 Grade A;
- (2) all material of Curve B if produced to fine grain practice and normalized and not listed for Curve D below.

(d) Curve D
SA-203
SA-508 Grade 1
SA-516 if normalized
SA-524 Classes 1 and 2
SA-537 Classes 1, 2, and 3
SA-612 if normalized
SA-662 if normalized
SA-738 Grade A
SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than – 20°F (–29°C)
SA-738 Grade B not colder than –20°F (–29°C)

(e) For bolting and nuts, the following impact test exemption temperature shall apply:

Bolting		
Spec. No.	Grade	Impact Test Exemption Temperature, °F (°C)
SA-193	B5	–20 (–29)
SA-193	B7 [$2\frac{1}{2}$ in. (64 mm) dia. and under]	–55 (–48)
	[Over $2\frac{1}{2}$ in. to 7 in. (64 mm to 178 mm), incl.]	–40 (–40)
SA-193	B7M	–55 (–48)
SA-193	B16	–20 (–29)
SA-307	B	–20 (–29)
SA-320	L7, L7A, L7M, L43	Impact tested
SA-325	1, 2	–20 (–29)
SA-354	BC	0 (–18)
SA-354	BD	+20 (–7)
SA-449	. . .	–20 (–29)
SA-540	B23/24	+10 (–12)

General Notes and Notes continue on next page

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FIG. UCS-66 (CONT'D)

GENERAL NOTES ON ASSIGNMENT OF MATERIALS TO CURVES (CONT'D):

Nuts		
Spec. No.	Grade	Impact Test Exemption Temperature, °F (°C)
SA-194	2, 2H, 2HM, 3, 4, 7, 7M, and 16	−55 (−48)
SA-540	B23/B24	−55 (−48)

(f) When no class or grade is shown, all classes or grades are included.

(g) The following shall apply to all material assignment notes.

(1) Cooling rates faster than those obtained by cooling in air, followed by tempering, as permitted by the material specification, are considered to be equivalent to normalizing or normalizing and tempering heat treatments.

(2) Fine grain practice is defined as the procedure necessary to obtain a fine austenitic grain size as described in SA-20.

NOTES:

(1) Tabular values for this Figure are provided in Table UCS-66.

(2) Castings not listed in General Notes (a) and (b) above shall be impact tested.

the outside diameter of the neck shall not exceed the diameter of the hub as specified in ASME B16.5.

(d) No impact testing is required for UCS materials 0.10 in. (2.5 mm) in thickness and thinner, but such exempted UCS materials shall not be used at design metal temperatures colder than −55°F (−48°C). For vessels or components made from NPS 4 (DN 100) or smaller tubes or pipe of P-No. 1 materials, the following exemptions from impact testing are also permitted as a function of the material specified minimum yield strength (SMYS) for metal temperatures of −155°F (−104°C) and warmer:

SMYS, ksi (MPa)	Thickness, in. (mm)
20 to 35 (138 to 241)	0.237 (6.0)
36 to 45 (248 to 310)	0.125 (3.2)
46 (317) and higher	0.10 (2.5)

(e) The material manufacturer's identification marking required by the material specification shall not be stamped on plate material less than $\frac{1}{4}$ in. (6 mm) in thickness unless the following requirements are met.

(1) The materials shall be limited to P-No. 1 Gr. Nos. 1 and 2.

(2) The minimum nominal plate thickness shall be 0.1875 in. (4.8 mm), or the minimum nominal pipe wall thickness shall be 0.154 in. (3.9 mm).

(3) The minimum design metal temperature shall be no colder than −20°F (−29°C).

(f) Unless specifically exempted in Fig. UCS-66, materials having a specified minimum yield strength greater than 65 ksi (448 MPa) must be impact tested.

(g) Materials produced and impact tested in accordance with the requirements of the specifications listed in Fig. UG-84.1, General Note (c), are exempt from impact testing by the rules of this Division at minimum design metal temperatures not more than 5°F (3°C) colder than the test temperature required by the specification.

(h) No impact testing is required for metal backing strips which remain in place made of materials assigned to Curve A of Fig. UCS-66 in thicknesses not exceeding $\frac{1}{4}$ in. when the minimum design metal temperature is −20°F (−29°C) or warmer.

(i) For components made of Part UCS materials that are impact tested, Fig. UCS-66.1 provides a basis for the use of these components at MDMT colder than the impact test temperature, provided the coincident ratio defined in Fig. UCS-66.1 is less than one, and the MDMT is not colder than −155°F (−104°C).

(1) For such components, the MDMT shall not be colder than the impact test temperature less the allowable temperature reduction as determined from Fig. UCS-66.2.

(2) Figure UCS-66.1 may also be used for components not stressed in general primary membrane tensile stress, such as flat heads, covers, tubesheets, and flanges (including bolts and nuts). The MDMT shall not be colder than the impact test temperature less the allowable temperature reduction as determined from Fig. UCS-66.2. The ratio used in Step 3 of Fig. UCS-66.2 shall be the ratio of maximum design pressure at the MDMT to the maximum allowable pressure (MAP) of the component at the MDMT.

(3) In lieu of using (i)(2) above, the MDMT for a flange attached by welding shall not be colder than the impact test temperature less the allowable temperature reduction as determined in (i)(1) above for the neck or shell to which the flange is attached.

(j) When the base metal is exempt from impact testing by (g) above or by Fig. UCS-66 Curves C or D, −20°F is the coldest MDMT to be assigned for

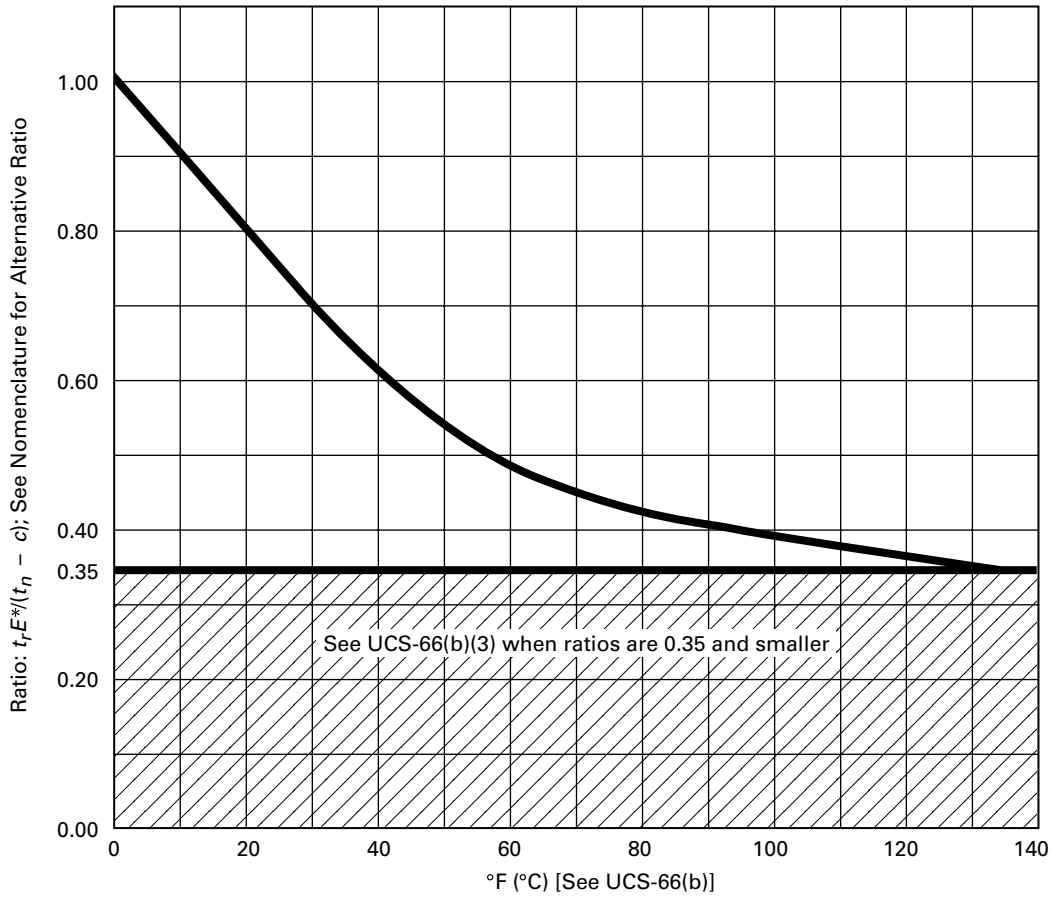
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TABLE UCS-66
TABULAR VALUES FOR FIG. UCS-66

Thick., in.	Curve A, °F	Curve B, °F	Curve C, °F	Curve D, °F	Thick., in.	Curve A, °F	Curve B, °F	Curve C, °F	Curve D, °F
0.25	18	−20	−55	−55	3.1875	112	80	44	13
0.3125	18	−20	−55	−55	3.25	112	80	44	14
0.375	18	−20	−55	−55	3.3125	113	81	45	15
0.4375	25	−13	−34	−55	3.375	113	82	46	15
0.5	32	−7	−30	−55	3.4375	114	83	46	16
					3.5	114	83	47	17
0.5625	37	−1	−26	−55					
0.625	43	5	−22	−48	3.5625	114	84	48	17
0.6875	48	10	−18	−45	3.625	115	85	49	18
0.75	53	15	−15	−42	3.6875	115	85	49	19
0.8125	57	19	−12	−38	3.75	116	86	50	20
0.875	61	23	−9	−36	3.8125	116	87	51	21
0.9375	65	27	−6	−33	3.875	116	88	51	21
1	68	31	−3	−30	3.9375	117	88	52	22
					4	117	89	52	23
1.0625	72	34	−1	−28					
1.125	75	37	2	−26	4.0625	117	90	53	23
1.1875	77	40	4	−23	4.125	118	90	54	24
1.25	80	43	6	−21	4.1875	118	91	54	25
1.3125	82	45	8	−19	4.25	118	91	55	25
1.375	84	47	10	−18	4.3125	118	92	55	26
1.4375	86	49	12	−16	4.375	119	93	56	27
1.5	88	51	14	−14	4.4375	119	93	56	27
					4.5	119	94	57	28
1.5625	90	53	16	−13					
1.625	92	55	17	−11	4.5625	119	94	57	29
1.6875	93	57	19	−10	4.625	119	95	58	29
1.75	94	58	20	−8	4.6875	119	95	58	30
1.8125	96	59	22	−7	4.75	119	96	59	30
1.875	97	61	23	−6	4.8125	119	96	59	31
1.9375	98	62	24	−5	4.875	119	97	60	31
2	99	63	26	−4	4.9375	119	97	60	32
					5	119	97	60	32
2.0625	100	64	27	−3					
2.125	101	65	28	−2	5.0625	119	98	61	33
2.1875	102	66	29	−1	5.125	119	98	61	33
2.25	102	67	30	0	5.1875	119	98	62	34
2.3125	103	68	31	1	5.25	119	99	62	34
2.375	104	69	32	2	5.3125	119	99	62	35
2.4375	105	70	33	3	5.375	119	100	63	35
2.5	105	71	34	4	5.4375	119	100	63	36
					5.5	119	100	63	36
2.5625	106	71	35	5					
2.625	107	73	36	6	5.5625	119	101	64	36
2.6875	107	73	37	7	5.625	119	101	64	37
2.75	108	74	38	8	5.6875	119	102	64	37
2.8125	108	75	39	8	5.75	120	102	65	38
2.875	109	76	40	9	5.8125	120	103	65	38
2.9375	109	77	40	10	5.875	120	103	66	38
3	110	77	41	11	5.9375	120	104	66	39
					6	120	104	66	39
3.0625	111	78	42	12					
3.125	111	79	43	12					

GENERAL NOTE: See Fig. UCS-66 for SI values.

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Nomenclature (Note reference to General Notes of Fig. UCS-66-2.)

t_r = required thickness of the component under consideration in the corroded condition for all applicable loadings [General Note (2)], based on the applicable joint efficiency E [General Note (3)], in. (mm)

t_n = nominal thickness of the component under consideration before corrosion allowance is deducted, in. (mm)

c = corrosion allowance, in. (mm)

E^* = as defined in General Note (3).

Alternative Ratio = S^*E^* divided by the product of the maximum allowable stress value from Table UCS-23 times E, where S^* is the applied general primary membrane tensile stress and E and E^* are as defined in General Note (3).

FIG. UCS-66.1 REDUCTION IN MINIMUM DESIGN METAL TEMPERATURE WITHOUT IMPACT TESTING

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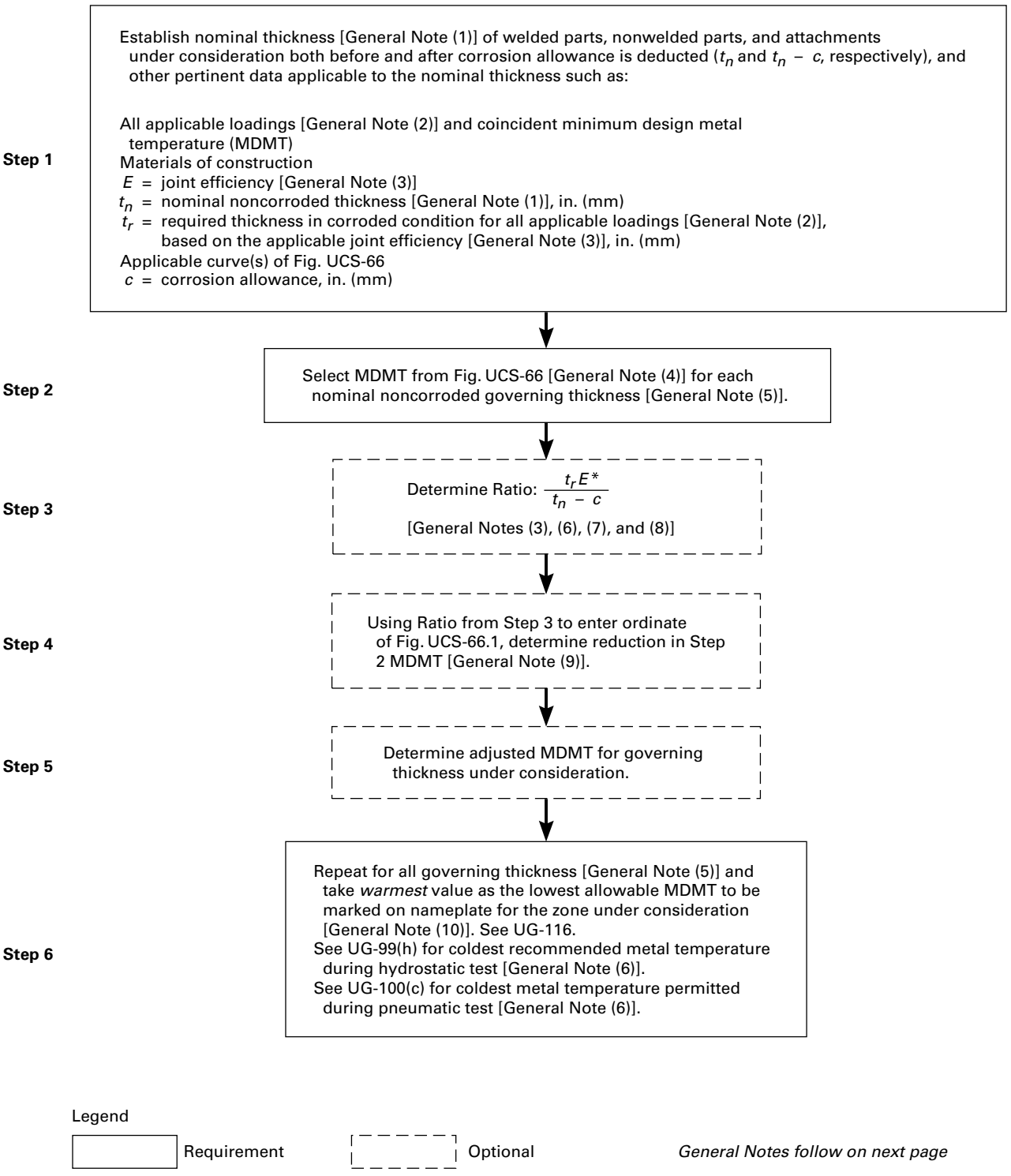


FIG. UCS-66.2 DIAGRAM OF UCS-66 RULES FOR DETERMINING LOWEST MINIMUM DESIGN METAL TEMPERATURE (MDMT) WITHOUT IMPACT TESTING

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FIG. UCS-66.2 (CONT'D)

GENERAL NOTES:

(1) For pipe where a mill undertolerance is allowed by the material specification, the thickness after mill undertolerance has been deducted shall be taken as the noncorroded nominal thickness t_n for determination of the MDMT to be stamped on the nameplate. Likewise, for formed heads, the minimum specified thickness after forming shall be used as t_n.

(2) Loadings, including those listed in UG-22, which result in general primary membrane tensile stress at the coincident MDMT.

(3) E is the joint efficiency (Table UW-12) used in the calculation of t_r; E^* has a value equal to E except that E^* shall not be less than 0.80. For castings, use quality factor or joint efficiency E whichever governs design.

(4) The construction of Fig. UCS-66 is such that the MDMT so selected is considered to occur coincidentally with an applied general primary membrane tensile stress at the maximum allowable stress value in tension from Table 1A of Section II Part D, Tabular values for Fig. UCS-66 are shown in Table UCS-66.

(5) See UCS-66(a)(1), (2), and (3) for definitions of governing thickness.

(6) If the basis for calculated test pressure is greater than the design pressure [UG-99(c) test], a Ratio based on the t_r determined from the basis for calculated test pressure and associated appropriate value of $t_n - c$ shall be used to determine the recommended coldest metal temperature during hydrostatic test and the coldest metal temperature permitted during the pneumatic test. See UG-99(h) and UG-100(c).

(7) Alternatively, a Ratio of S^*E^* divided by the product of the maximum allowable stress value in tension from Table 1A of Section II Part D times E may be used, where S^* is the applied general primary membrane tensile stress and E and E^* are as defined in General Note (3).

(8) For UCS-66(b)(1)(b) and (i)(2), a ratio of the maximum design pressure at the MDMT to the maximum allowable pressure (MAP) at the MDMT shall be used. The MAP is defined as the highest permissible pressure as determined by the design formulas for a component using the nominal thickness less corrosion allowance and the maximum allowable stress value from the Table 1A of Section II, Part D at the MDMT. For ferritic steel flanges defined in UCS-66(c), the flange rating at the warmer of the MDMT or 100°F may be used as the MAP.

(9) For reductions in MDMT up to and including 40°F, the reduction can be determined by: reduction in MDMT = (1 − Ratio) 100°F.

(10) A colder MDMT may be obtained by selective use of impact tested materials as appropriate to the need (see UG-84). See also UCS-68(c).

welded components that do not meet the requirements of UCS-67(a)(2).

UCS-67 IMPACT TESTS OF WELDING PROCEDURES

Except as exempted in UG-20(f), the Welding Procedure Qualification shall include impact tests of welds and heat affected zones (HAZ) made in accordance with UG-84 when required by the following provisions. The MDMT used below shall be the MDMT stamped on the nameplate or the exemption temperature of the welded component before applying the temperature reduction permitted by UCS-66(b) or UCS-68(c).

UCS-67(a) Welds made with filler metal shall be impact tested in accordance with UG-84 when any of the following apply:

UCS-67(a)(1) when either base metal is required to be impact tested by the rules of this Division; or

UCS-67(a)(2) when joining base metals exempt from impact testing by UCS-66(g) or Fig. UCS-66 Curve C or D and the minimum design metal temperature is colder than −20°F (−29°C) but not colder than −55°F (−48°C), unless welding consumables which have been classified by impact tests at a temperature not warmer than the MDMT by the applicable SFA specification are used; or

UCS-67(a)(3) when joining base metals exempt from impact testing by UCS-66(g) when the minimum design metal temperature is colder than −55°F (−48°C).

UCS-67(b) Welds in UCS materials made without the use of filler metal shall be impact tested when the thickness at the weld exceeds $\frac{1}{2}$ in. (13 mm) for all minimum design metal temperatures or when the thickness at the weld exceeds $\frac{5}{16}$ in. (8 mm) and the minimum design metal temperature is colder than 50°F (10°C).

UCS-67(c) Weld heat affected zones produced with or without the addition of filler metal shall be impact tested whenever any of the following apply:

UCS-67(c)(1) when the base metal is required to be impact tested by the rules of this Division; or

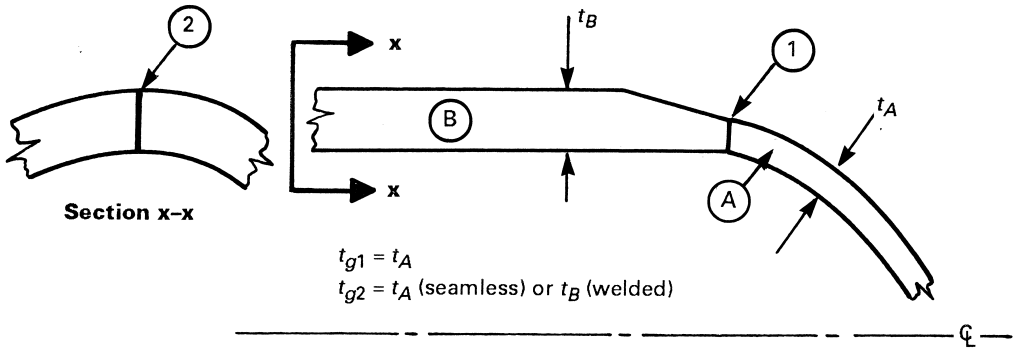
UCS-67(c)(2) when the welds have any individual weld pass exceeding $\frac{1}{2}$ in. (13 mm) in thickness, and the minimum design metal temperature is colder than 70°F (21°C); or

UCS-67(c)(3) when joining base metals exempt from impact testing by UCS-66(g) when the minimum design metal temperature is colder than −55°F (−48°C).

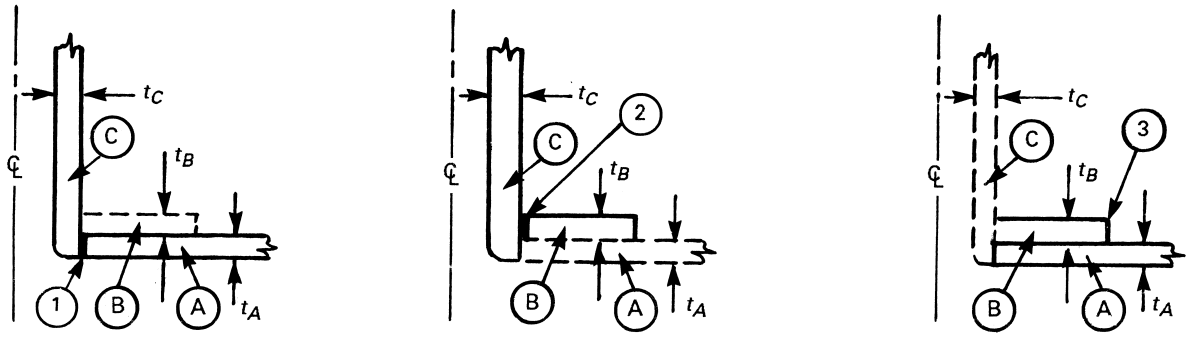
UCS-67(d) Vessel (production) impact tests in accordance with UG-84(i) may be waived for any of the following:

UCS-67(d)(1) weld metals joining steels exempted from impact testing by UCS-66 for minimum design metal temperatures of −20°F (−29°C) and warmer; or

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(a) Butt Welded Components

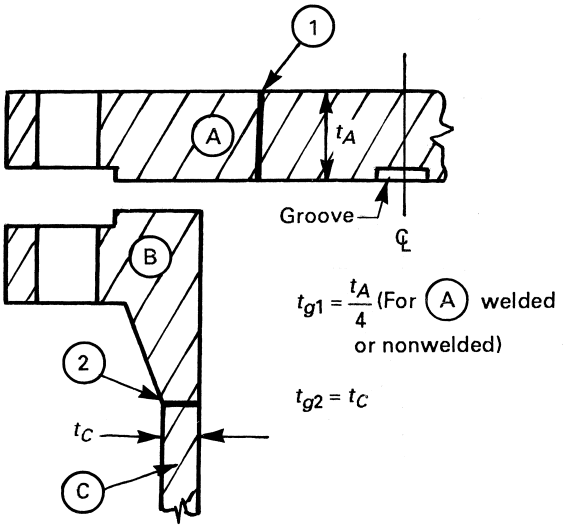


NOTE: Using t_{g1}, t_{g2}, and t_{g3}, determine the warmest MDMT and use that as the permissible MDMT for the welded assembly.

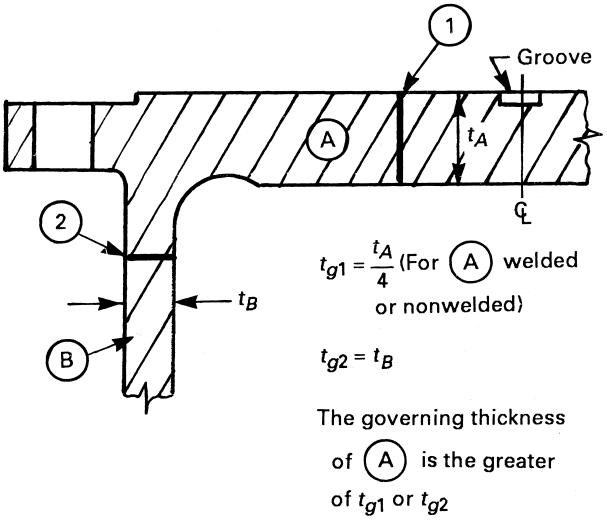
(b) Welded Connection with Reinforcement Plate Added

FIG. UCS-66.3 SOME TYPICAL VESSEL DETAILS SHOWING THE GOVERNING THICKNESSES AS DEFINED IN UCS-66

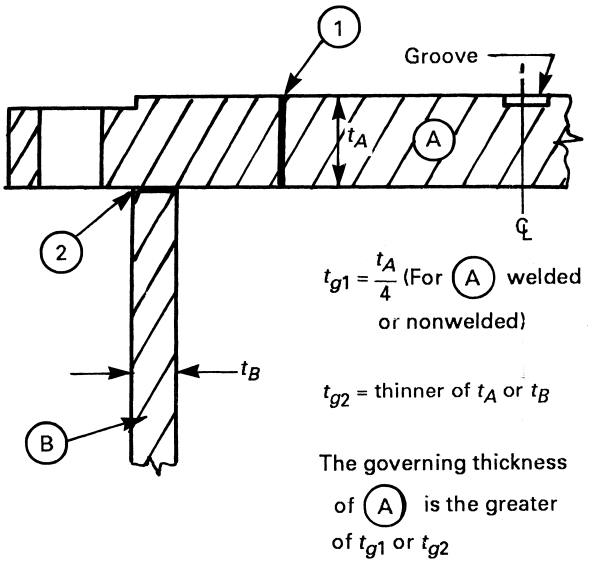
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(c) Bolted Flat Head or Tubesheet and Flange



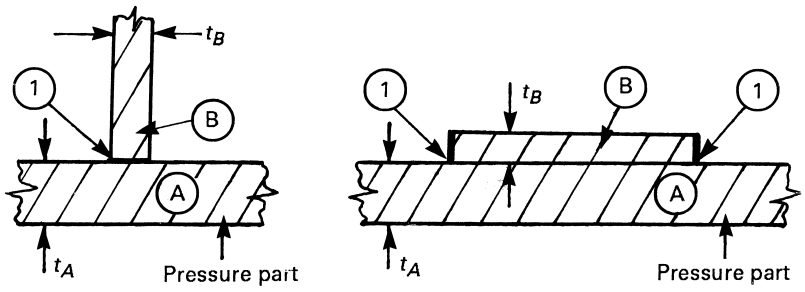
(d) Integral Flat Head or Tubesheet



(e) Flat Head or Tubesheet With a Corner Joint

FIG. UCS-66.3 SOME TYPICAL VESSEL DETAILS SHOWING THE GOVERNING THICKNESSES AS DEFINED IN UCS-66 (CONT'D)

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t_{g1} = thinner of t_A or t_B

(f) Welded Attachments as Defined in UCS-66(a)

NOTE: t_g = governing thickness of the welded joint as defined in UCS-66.

FIG. UCS-66.3 SOME TYPICAL VESSEL DETAILS SHOWING THE GOVERNING THICKNESSES AS DEFINED IN UCS-66 (CONT'D)

UCS-67(d)(2) weld metals defined in (a)(2) above; or

UCS-67(d)(3) heat affected zones (HAZ) in steels exempted from impact testing by UCS-66, except when (c)(3) above applies.

UCS-68 DESIGN[4]

UCS-68(a) Welded joints shall comply with UW-2(b) when the minimum design metal temperature is colder than −55°F (−48°C), unless the coincident ratio defined in Fig. UCS-66.1 is less than 0.35.

UCS-68(b) Welded joints shall be postweld heat treated in accordance with the requirements of UW-40 when required by other rules of this Division or when the minimum design metal temperature is colder than −55°F (−48°C), and the coincident ratio defined in Fig. UCS-66.1 is 0.35 or greater.

UCS-68(c) If postweld heat treating is performed when it is not otherwise a requirement of this Division, a 30°F (17°C) reduction in impact testing exemption temperature may be given to the minimum permissible temperature from Fig. UCS-66 for P-No. 1 materials. The resulting exemption temperature may be colder than −55°F (−48°C).

UCS-68(d) The allowable stress values to be used in design at the minimum design metal temperature shall not exceed those given in Section II, Part D, Tables 3 for bolting and 1A for other materials for temperatures of 100°F (38°C).

[4] No provisions of this paragraph waive other requirements of this Division, such as UW-2(a), UW-2(d), UW-10, and UCS-56.

FABRICATION

UCS-75 GENERAL

The rules in the following paragraphs apply specifically to the fabrication of pressure vessels and vessel parts that are constructed of carbon and low alloy steel and shall be used in conjunction with the general requirements for *Fabrication* in Subsection A, and with the specific requirements for *Fabrication* in Subsection B that pertain to the method of fabrication used.

UCS-79 FORMING SHELL SECTIONS AND HEADS

(a) The following provisions shall apply in addition to the general rules for forming given in UG-79.

(b) Carbon and low alloy steel plates shall not be formed cold by blows.

(c) Carbon and low alloy steel plates may be formed by blows at a forging temperature provided the blows do not objectionably deform the plate and it is subsequently postweld heat treated.

(d) Vessel shell sections, heads, and other pressure boundary parts of carbon and low alloy steel plates

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fabricated by cold forming shall be heat treated subsequently (see UCS-56) when the resulting extreme fiber elongation is more than 5% from the as-rolled condition and any of the following conditions exist.

(1) The vessel will contain lethal substances either liquid or gaseous (see UW-2).

(2) The material requires impact testing.

(3) The thickness of the part before cold forming exceeds $^5/_8$ in. (16 mm).

(4) The reduction by cold forming from the as-rolled thickness is more than 10%.

(5) The temperature of the material during forming is in the range of 250°F to 900°F (121°C to 482°C).

For P-No. 1 Group Nos. 1 and 2 materials the extreme fiber elongation may be as great as 40% when none of the conditions listed above in (1) through (5) exist.

The extreme fiber elongation shall be determined by the following formulas:

For double curvature (for example, heads),

$$\% \text{ extreme fiber elongation} = \frac{75t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

For single curvature (for example, cylinders),

$$\% \text{ extreme fiber elongation} = \frac{50t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

where

t = plate thickness, in. (mm)
R_f = final center line radius, in. (mm)
R_o = original center line radius (equals infinity for flat plate), in. (mm)

(e) When vessel shell sections, heads, or other pressure boundary parts of carbon or low alloy steel plate are cold formed by other than the Manufacturer of the vessel, the required certification for the part shall indicate whether or not the part has been heat treated.

UCS-85 HEAT TREATMENT OF TEST SPECIMENS

UCS-85(a) The following provisions shall apply in addition to, or as exceptions to the general rules for heat treatment given in UG-85.

UCS-85(b) Heat treatment as used in this section shall include all thermal treatments of the material during fabrication exceeding 900°F (482°C), except as exempted below.

UCS-85(c) The material used in the vessel shall be represented by test specimens which have been subjected to the same heat treatments above the lower transformation temperature and postweld heat treatment except as provided in (e), (f), (g), (h), and (i) below. The kind and number of tests and test results shall be as required by the material specification. The vessel Manufacturer shall specify the temperature, time, and cooling rates to which the material will be subjected during fabrication, except as permitted in (h) below. Material from which the specimens are prepared shall be heated at the specified temperature within reasonable tolerances such as are normal in actual fabrication. The total time at temperature shall be at least 80% of the total time at temperature during actual heat treatment of the product and may be performed in a single cycle.

UCS-85(d) Thermal treatment of material is not intended to include such local heating as thermal cutting, preheating, welding, or heating below the lower transformation temperature of tubing and pipe for bending or sizing.

UCS-85(e) An exception to the requirements of (c) above and UG-85 shall apply to standard items such as described in UG-11(a). These may be subject to postweld heat treatment with the vessel or vessel part without the same treatment being required of the test specimens. This exception shall not apply to specially designed cast or wrought fittings.

UCS-85(f) Materials conforming to one of the specifications listed in P-No. 1 Group Nos. 1 and 2 of QW-422 and all carbon and low alloy steels used in the annealed condition as permitted by the material specification are exempt from the requirements of (c) above when the heat treatment during fabrication is limited to postweld heat treatment at temperatures below the lower transformation temperature of the steel.

UCS-85(g) Materials listed in QW-422 as P-No. 1 Group No. 3 and P-No. 3 Group Nos. 1 and 2 that are certified in accordance with (c) above from test specimens subjected to the PWHT requirements of Table UCS-56 need not be recertified if subjected to the alternate PWHT conditions permitted by Table UCS-56.1.

UCS-85(h) The simulation of cooling rates for test specimens from nonimpact tested materials 3 in. and under in thickness is not required for heat treatments below the lower transformation temperature.

UCS-85(i) All thermal treatments which precede a thermal treatment that fully austenitizes the material need not be accounted for by the specimen heat treatments, provided the austenitizing temperature is at least as high as any of the preceding thermal treatments.

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INSPECTION AND TESTS

UCS-90 GENERAL

The provisions for inspection and testing in Subsections A and B shall apply without supplement to vessels constructed of carbon and low alloy steels.

MARKING AND REPORTS

UCS-115 GENERAL

The provisions for marking and reports in UG-115 through UG-120 shall apply without supplement to pressure vessels constructed of carbon and low alloy steels.

PRESSURE RELIEF DEVICES

UCS-125 GENERAL

The provisions for pressure relief devices in UG-125 through UG-136 shall apply without supplement to pressure vessels constructed of carbon and low alloy steels.

NONMANDATORY APPENDIX CS

UCS-150 GENERAL

See Appendix 6, 6-100, of Section II, Part D.

UCS-151 CREEP-RUPTURE PROPERTIES OF CARBON STEELS

See Appendix 6, 6-200, of Section II, Part D.

UCS-160 VESSELS OPERATING AT TEMPERATURES COLDER THAN THE MDMT STAMPED ON THE NAMEPLATE

(a) Vessels or components may be operated at temperatures colder than the MDMT stamped on the nameplate, provided the provisions of UCS-66, UCS-67 and UCS-68 are met when using the reduced (colder) operating temperature as the MDMT, but in no case shall the operating temperature be colder than −155°F (−104°C).

(b) As an alternative to (a) above, for vessels or components whose thicknesses are based on pressure loading only, the coincident operating temperature may be as cold as the MDMT stamped on the nameplate less the allowable temperature reduction as determined from Fig. UCS-66.2. The ratio used in Step 3 of Fig. UCS-66.2 shall be the ratio of maximum pressure at the coincident operating temperature to the MAWP of the vessel at the stamped MDMT, but in no case shall the operating temperature be colder than −155°F (−104°C).

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