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Appendix HA **Suggestions on the Selection and Treatment of Austenitic Chromium–Nickel and Ferritic and Martensitic High Chromium Steels (Informative and Nonmandatory)**

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PART UHA
REQUIREMENTS FOR PRESSURE VESSELS CONSTRUCTED OF HIGH ALLOY STEEL

GENERAL

UHA-1 SCOPE

The rules in Part UHA are applicable to pressure vessels and vessel parts that are constructed of high alloy steel 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.

UHA-5 USES

Some of the uses of high alloy steel are to resist corrosion, to avoid contamination of contents with iron, to facilitate cleaning of vessels for processing foods, to provide strength or scaling resistance at high temperatures, and to provide impact resistance at low temperatures.

UHA-6 CONDITIONS OF SERVICE

Specific chemical compositions, heat treatment procedures, fabrication requirements, and supplementary tests may be required to assure that the vessel will be in its most favorable condition for the intended service. This is particularly true for vessels subject to severe corrosion. These rules do not indicate the selection of an alloy suitable for the intended service or the amount of the corrosion allowance to be provided.

It is recommended that users assure themselves by appropriate tests, or otherwise, that the high alloy steel selected and its heat treatment during fabrication will be suitable for the intended service both with respect to corrosion resistance and to retention of satisfactory mechanical properties during the desired service life. (See Appendix HA, Suggestions on the Selection and Treatment of Austenitic Chromium–Nickel Steels.)

UHA-8 MATERIAL

(a) Approved specifications for castings of high alloy steel are given in Table UHA-23. A tabulation of allowable stress values at different temperatures is given in Section II, Part D, Table 3 (for bolting) and Table 1A (for other materials). 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.

(b) Cast high alloy steel flanges and fittings complying with ASME/ANSI B16.5 shall be used within the ratings assigned in these standards.

MATERIALS

UHA-11 GENERAL

(a) All materials 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 UHA-23 except as otherwise provided in (b) and UG-4.

(b) The specifications listed in Tables 1A and 3 of Section II, Part D do not use a uniform system for designating the Grade number of materials that have approximately the same range of chemical composition. To provide a uniform system of reference, these tables include a column of UNS (Unified Numbering System) numbers assigned to identify the various alloy compositions. When these particular UNS numbers were assigned, the familiar AISI type numbers for stainless steels were incorporated into the designation. These type numbers are used in the rules of Part UHA whenever reference is made to materials of approximately the same chemical composition that are furnished under more than one approved specification or in more than one product form.

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UHA-12 BOLT MATERIALS

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

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

UHA-13 NUTS AND WASHERS

Nuts and washers shall conform to the requirements in UCS-11.

DESIGN

UHA-20 GENERAL

The rules in the following paragraphs apply specifically to the design of pressure vessels and vessel parts that are constructed of high 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.

UHA-21 WELDED JOINTS

When radiographic examination is required for butt welded joints by UHA-33, joints of Categories A and B (see UW-3) shall be of Type Nos. (1) and (2) of Table UW-12.

UHA-23 MAXIMUM ALLOWABLE STRESS VALUES

(a) Tables 3 (for bolting) and 1A (for other materials) of Section II, Part D give the maximum allowable stress values at the temperatures indicated for the materials conforming to the specifications listed therein. Values may be interpolated for intermediate temperatures [see UG-23 and UG-31(a)].

(b) Shells of pressure vessels may be made from welded pipe or tubing listed in Table UHA-23.

(c) 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 1A or 3 of Section II, Part D for temperatures of −20°F to 100°F (−29°C to 38°C).

UHA-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.

UHA-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.

UHA-30 ATTACHMENT OF STIFFENING RINGS TO SHELL

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

UHA-31 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 the figures for high alloy steels or Fig. CS-2 in Subpart 3 of Section II, Part D. Examples illustrating the application of this paragraph are given in Appendix L.

UHA-32 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. Welds in pressure vessels or pressure vessel parts shall be given a postweld heat treatment at a temperature not less than specified in Table UHA-32 when the nominal thickness, as defined in UW-40(f), including corrosion allowance, exceeds the limits in the Notes to Table UHA-32. The exemptions provided for in the Notes to Table UHA-32 are not permitted when postweld heat treatment is

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TABLE UHA-32
POSTWELD HEAT TREATMENT REQUIREMENTS FOR HIGH ALLOY STEELS

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 6 Gr. Nos. 1, 2, 3	1250 (677)	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) Postweld heat treatment is not required for vessels constructed of Type 410 material for SA-182 Grade F6a, SA-240, SA-268, and SA-479 with carbon content not to exceed 0.08% and welded with electrodes that produce an austenitic chromium–nickel weld deposit or a non-air-hardening nickel–chromium–iron weld deposit, provided the plate thickness at the welded joint does not exceed $^{3}/_{8}$ in. (10 mm), and for thicknesses over $^{3}/_{8}$ in. (10 mm) to $1^{1}/_{2}$ in. (38 mm) provided a preheat of 450°F (232°C) is maintained during welding and that the joints are completely radiographed.
(2) Postweld heat treatment shall be performed as prescribed in UW-40 and UCS-56(e).

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 7 Gr. Nos. 1, 2	1350 (732)	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) Postweld heat treatment is not required for vessels constructed of Type 405 or Type 410S materials for SA-240 and SA-268 with carbon content not to exceed 0.08%, welded with electrodes that produce an austenitic–chromium–nickel weld deposit or a non-air-hardening nickel–chromium–iron weld deposit, provided the plate thickness at the welded joint does not exceed $^{3}/_{8}$ in. (10 mm) and for thicknesses over $^{3}/_{8}$ in. (10 mm) to $1^{1}/_{2}$ in. (38 mm) provided a preheat of 450°F (232°C) is maintained during welding and that the joints are completely radiographed.
(2) Postweld heat treatment shall be performed as prescribed in UW-40 and UCS-56(e) except that the cooling rate shall be a maximum of 100°F (56°C)/hr in the range above 1200°F (649°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(3) Postweld heat treatment is not required for vessels constructed of Grade TP XM-8 material for SA-268 and SA-479 or of Grade TP 18Cr–2Mo for SA-240 and SA-268.

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 8 Gr. Nos. 1, 2, 3, 4	...	...	...	...

NOTE:
(1) Postweld heat treatment is neither required nor prohibited for joints between austenitic stainless steels of the P-No. 8 group. See nonmandatory Appendix HA, UHA-100 to UHA-108, inclusive.

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TABLE UHA-32
POSTWELD HEAT TREATMENT REQUIREMENTS FOR HIGH ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No 10E Gr. No. 1	1250 (677)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	1 hr/in. (25 mm)

NOTES:
(1) For SA-268 Grade TP446 material only, postweld heat treatment shall be performed as prescribed in UW-40 and UCS-56(d) except that the cooling rate shall be a maximum of 100°F (56°C)/hr in the range above 1200°F (649°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 10G Gr. No. 1	...	...	...	...

NOTE:
(1) Postweld heat treatment is neither required nor prohibited.

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 10H Gr. No. 1	...	...	...	...

NOTE:
(1) For the austenitic-ferritic wrought or cast duplex stainless steels listed below, postweld heat treatment is neither required nor prohibited, but any heat treatment applied shall be performed as listed below and followed by liquid quenching or rapid cooling by other means:

Alloy	Postweld Heat Treatment Temperature, °F (°C)	
S32550	1900–2050	(1038–1121)
S31260 and S31803	1870–2010	(1021–1099)
S32900 (0.08 max. C)	1725–1750	(941–954)
S31200	1900–2000	(1038–1093)
S31500	1785–1875	(974–1024)
S32304	1740–1920	(949–1049)
J93345	2050 minimum	(1121 minimum)
S32750	1800–2060	(982–1127)
S32950	1825–1875	(997–1024)

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TABLE UHA-32
POSTWELD HEAT TREATMENT REQUIREMENTS FOR HIGH ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 10I Gr. No. 1	1350 (732)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	1 hr/in. (25 mm)

NOTES:
(1) Postweld heat treatment shall be performed as prescribed in UW-40 and UCS-56(e) except that the cooling rate shall be a maximum of 100°F (56°C)/hr in the range above 1200°F (649°C) after which the cooling rate shall be rapid to prevent embrittlement.
(2) Postweld heat treatment is neither required nor prohibited for a thickness of $\frac{1}{2}$ in. (13 mm) or less.
(3) For Alloy S44635, the rules for ferritic chromium stainless steel shall apply, except that postweld heat treatment is neither prohibited nor required. If heat treatment is performed after forming or welding, it shall be performed at 1850°F (1010°C) minimum followed by rapid cooling to below 800°F (427°C).

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 10K Gr. No. 1	...	...	...	...

NOTE:
(1) For Alloy S44660, the rules for ferritic chromium stainless steel shall apply, except that postweld heat treatment is neither required nor prohibited. If heat treatment is performed after forming or welding, it shall be performed at 1500°F to 1950°F (816°C to 1066°C) for a period not to exceed 10 min followed by rapid cooling.

a service requirement as set forth in UHA-51 and UW-2, when welding ferritic materials greater than $\frac{1}{8}$ in. (3.2 mm) thick with the electron beam welding process, or when welding P-Nos. 6 and 7 (except for Type 405 and Type 410S) materials of any thickness using the inertia and continuous drive friction welding processes. The materials in Table UHA-32 are listed in accordance with the Section IX P-Number material groupings of QW-432 and are also listed in Table UHA-23.

(b) Holding temperatures and/or holding times in excess of the minimum values given in Table UHA-32 may be used. The holding time at temperature as specified in Table UHA-32 need not be continuous. It may be an accumulation of time of multiple postweld heat treat cycles. Long time exposure to postweld heat treatment temperatures may cause sigma phase formation (see UHA-104).

(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 UHA-32 or UCS-56, 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. Ferritic steel parts, when used in conjunction with austenitic chromium–nickel stainless steel parts or austenitic/ferritic duplex steel, shall not be subjected to the solution heat treatment described in UHA-105(b).

(d) The operation of postweld heat treatment shall be carried out by one of the procedures given in UW-40 in accordance with the requirements of UCS-56(d) except as modified by the Notes to Table UHA-32.

(e) 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 repairs have been made.

UHA-33 RADIOGRAPHIC EXAMINATION

(a) The requirements for radiographing prescribed in UW-11, UW-51, and UW-52 shall apply in high alloy vessels, except as provided in (b) below. (See UHA-21.)

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(b) Butt welded joints in vessels constructed of materials conforming to Type 405 welded with straight chromium electrodes, and to Types 410, 429, and 430 welded with any electrode, shall be radiographed in all thicknesses. The final radiographs of all straight chromium ferritic welds including major repairs to these welds shall be made after postweld heat treatment has been performed.

(c) Butt welded joints in vessels constructed of austenitic chromium–nickel stainless steels which are radiographed because of the thickness requirements of UW-11, or for lesser thicknesses where the joint efficiency reflects the credit for radiographic examination of Table UW-12, shall be radiographed following post heating if such is performed.

UHA-34 LIQUID PENETRANT EXAMINATION

All austenitic chromium–nickel alloy steel and austenitic/ferritic duplex steel welds, both groove and fillet, which exceed a nominal size of $^{3}/_{4}$ in. (19 mm), as defined in UW-40(f), shall be examined for the detection of cracks by the liquid penetrant method. This examination shall be made following heat treatment if heat treatment is performed. All cracks shall be eliminated.

FABRICATION

UHA-40 GENERAL

The rules in the following paragraphs apply specifically to the fabrication of pressure vessels and vessel parts that are constructed of high 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.

UHA-42 WELD METAL COMPOSITION

Welds that are exposed to the corrosive action of the contents of the vessel should have a resistance to corrosion that is not substantially less than that of the base metal. The use of filler metal that will deposit weld metal with practically the same composition as the material joined is recommended. When the manufacturer is of the opinion that a physically better joint can be made by departure from these limits, filler metal of a different composition may be used provided the strength of the weld metal at the operating temperature is not appreciably less than that of the high alloy material to be welded, and the user is satisfied that its resistance to corrosion is satisfactory for the intended service. The columbium content of weld metal shall not exceed 1.00%, except that ENiCrMo-3, ERNiCrMo-3, and ENiCrMo-12 weld filler metal made to SFA-5.11 and SFA-5.14 may be used to weld S31254, S31603, S31703, S31725, and S31726 to a maximum design temperature of 900°F (482°C).

UHA-44 REQUIREMENTS FOR POSTFABRICATION HEAT TREATMENT DUE TO STRAINING

UHA-44(a) The following rules shall apply in addition to general rules for forming given in UHA-40.

UHA-44(a)(1) If the following conditions prevail, the cold formed areas of pressure-retaining components manufactured of austenitic alloys shall be solution annealed by heating at the temperatures given in Table UHA-44 for 20 min/in. (20 min/25 mm) of thickness or 10 min, whichever is greater, followed by rapid cooling:

(a) the finishing-forming temperature is below the minimum heat-treating temperature given in Table UHA-44; and

(b) the design metal temperature and the forming strains exceed the limits shown in Table UHA-44.

UHA-44(a)(2) Forming strains shall be calculated as follows:

(a) cylinders formed from plate:

$$\%strain = \frac{50t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

(b) spherical or dished heads formed from plate:

$$\%strain = \frac{75t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

(c) tube and pipe bends: the larger of

$$\%strain = \frac{100r}{R_o}$$

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TABLE UHA-44
POSTFABRICATION STRAIN LIMITS AND REQUIRED HEAT TREATMENT

		Limitations in Lower Temperature Range			Limitations in Higher Temperature Range		
		For Design Temperature, °F (°C),					
Grade	UNS Number	Exceeding	But Less Than or Equal to	And Forming Strains Exceeding, %	For Design Temperature, °F (°C), Exceeding	And Forming Strains Exceeding, %	Minimum Heat-Treatment Temperature, °F (°C), When Design Temperature and Forming Strain Limits Are Exceeded [Notes (1) and (2)]
201LN	S20153 heads	All	All	All	All	All	1950 (1065)
201LN	S20153 all others	All	All	4	All	4	1950 (1065)
304	S30400	1075 (579)	1250 (676)	20	1250 (676)	10	1900 (1038)
304H	S30409	1075 (579)	1250 (676)	20	1250 (676)	10	1900 (1038)
304N	S30451	1075 (579)	1250 (676)	15	1250 (676)	10	1900 (1038)
309S	S30908	1075 (579)	1250 (676)	20	1250 (676)	10	2000 (1093)
310H	S31009	1075 (579)	1250 (676)	20	1250 (676)	10	2000 (1093)
310S	S31008	1075 (579)	1250 (676)	20	1250 (676)	10	2000 (1093)
316	S31600	1075 (579)	1250 (676)	20	1250 (676)	10	1900 (1038)
316H	S31609	1075 (579)	1250 (676)	20	1250 (676)	10	1900 (1038)
316N	S31651	1075 (579)	1250 (676)	15	1250 (676)	10	1900 (1038)
321	S32100	1000 (593)	1250 (676)	15 [Note (3)]	1250 (676)	10	1900 (1038)
321H	S32109	1000 (593)	1250 (676)	15 [Note (3)]	1250 (676)	10	2000 (1093)
347	S34700	1000 (593)	1250 (676)	15	1250 (676)	10	1900 (1038)
347H	S34709	1000 (593)	1250 (676)	15	1250 (676)	10	2000 (1093)
348	S34800	1000 (593)	1250 (676)	15	1250 (676)	10	1900 (1038)
348H	S34809	1000 (593)	1250 (676)	15	1250 (676)	10	2000 (1093)

GENERAL NOTES:
(a) The limits shown are for cylinders formed from plates, spherical or dished heads formed from plate, and tube and pipe bends.
(b) For flares, swages, and upsets, the forming strain limits shall be half those tabulated in this Table. When the forming strains cannot be calculated as shown in UHA-44(a), the forming strain limits shall be half those tabulated in this Table [see UHA-44(b)].

NOTES:
(1) Rate of cooling from heat-treatment temperature is not subject to specific control limits.
(2) While minimum heat-treatment temperatures are specified, it is recommended that the heat-treatment temperature range be limited to 150°F above that minimum (250°F temperature range for 347, 347H, 348, and 348H).
(3) For simple bends of tubes or pipes whose outside diameter is less than 3.5 in., this limit is 20%.

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or

$$\%strain = \left(\frac{t_A - t_B}{t_A}\right)100$$

(d) tube or pipe flares, swages, or upsets (see Fig. UHA-44); the larger of either the outside diameter or inside diameter hoop strain. The absolute value of the largest strain is to be used as the basis for evaluation:

(1) outside diameter hoop strain:

$$\%strain = \frac{(D - D_f)}{D}100$$

(2) inside diameter hoop strain:

$$\%strain = \frac{(d - d_f)}{d}100$$

(3) axial strain:

$$\%strain = \frac{(L - L_f)}{L}100$$

(4) radial strain:

$$\%strain = \frac{(t - t_f)}{t}100$$

where

D = original outside diameter of the pipe or tube
D_f = outside diameter of the pipe or tube after forming
d = original inside diameter of the pipe or tube
d_f = inside diameter of the pipe or tube after forming
L = original length of the constant volume process zone for the tube or pipe in flaring, swaging, or upsetting forming operations
L_f = final length of the constant volume process zone for the tube or pipe in flaring, swaging, or upsetting forming operations
R_f = nominal bending radius to center line of pipe or tube
R_o = original radius (equal to infinity for a flat plate)
r = nominal outside radius of pipe or tube
t = nominal thickness of the plate, pipe, or tube before forming
t_A = measured average wall thickness of pipe or tube
t_B = measured minimum wall thickness of the extrados of the bend
t_f = nominal thickness of the cylindrical portion after forming
V = volume of the cylindrical process zone prior to forming
$= (\pi/4)(D^2 - d^2)$
$V = V_f$, i.e., forming is a constant volume process
V_f = volume of the cylindrical process zone after forming
$= (\pi/4)(D_f^2 - d_f^2)$

UHA-44(b) When forming strains cannot be calculated as shown in (a) above, the manufacturer shall have the responsibility to determine the maximum forming strain. In such instances, the forming limits for flares, swages, or upsets in Table UHA-44 shall apply.

INSPECTION AND TESTS

UHA-50 GENERAL

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

UHA-51 IMPACT TESTS 01

Impact tests, as prescribed in UHA-51(a), shall be performed on materials listed in Table UHA-23 for all combinations of materials and minimum design metal temperatures (MDMT's) except as exempted in UHA-51(d), (e), (f) or (g).

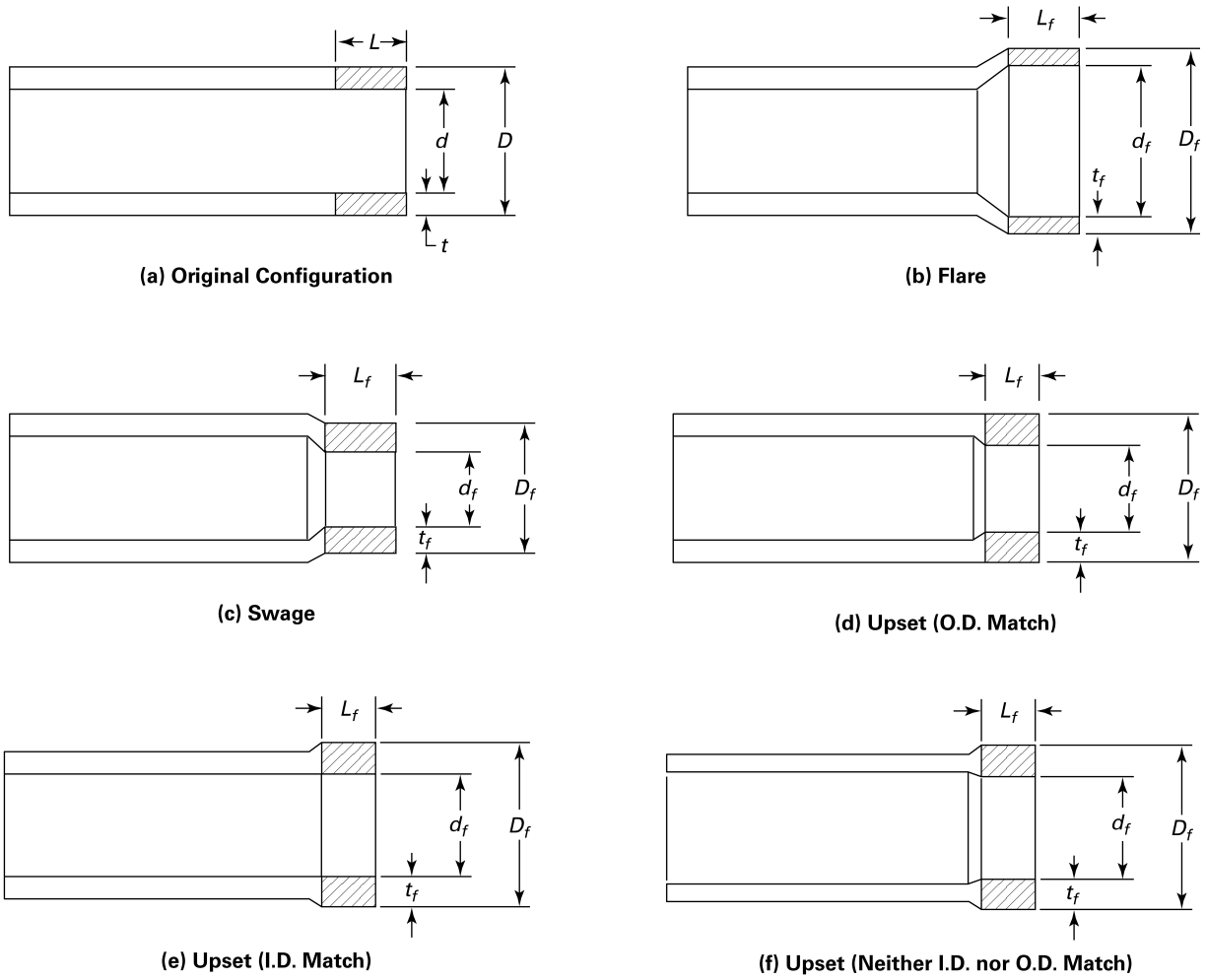
UHA-51(a) Required Impact Testing of Base Metal, Heat-Affected Zones, and Weld Metal

UHA-51(a)(1) Impact test shall be made from sets of three specimens. A set shall be tested from the base metal, a set shall be tested from the heat affected zone, and a set shall be tested from the weld metal. Specimens shall be subjected to the same thermal treatments[1] as the part or vessel which the specimens represent. Test procedures, size, location, and orientation of the specimens shall be the same as required in UG-84.

UHA-51(a)(2) Each of the three specimens tested in each set shall have a lateral expansion opposite the notch not less than 0.015 in. (0.38 mm) for MDMT's of −320°F (−196°C) and warmer.

[1] Thermal treatments of materials are not intended to include warming to temperatures not exceeding 600°F (316°C), thermal cutting, or welding.

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GENERAL NOTE: $V = V_f$

FIG. UHA-44 ILLUSTRATION OF COLD FORMING OPERATIONS FOR FLARING, SWAGING, AND UPSETTING OF TUBING
The Above Illustrations Are Diagrammatic Only

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UHA-51(a)(3) When the MDMT is −320°F (−196°C) and warmer, and the value of lateral expansion for one specimen of a set is less than 0.015 in. (0.38 mm) but not less than 0.010 in. (0.25 mm), a retest of three additional specimens may be made, each of which must equal or exceed 0.015 in. (0.38 mm). Such a retest shall be permitted only when the average value of the three specimens equals or exceeds 0.015 in. (0.38 mm). If the required values are not obtained in the retest or if the values in the initial test are less than minimum required for retest, the material may be reheat treated. After reheat treatment, new sets of specimens shall be made and retested; all specimens must meet the lateral expansion value of 0.015 in. minimum.

01 *UHA-51(a)(4)* When the MDMT is colder than −320°F (−196°C), production welding processes shall be limited to shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW). Notch toughness testing shall be performed as specified in (a) or (b) below, as appropriate.

(a) If using Type 316L weld filler metal:

(1) each heat of filler metal used in production shall have a Ferrite Number (FN) not greater than 5, as determined by applying the chemical composition from the test weld to Fig. ULT-82; and

(2) notch toughness testing of the base metal, weld metal, and heat affected zone (HAZ) shall be conducted using a test temperature of −320°F (−196°C); and

(3) each of the three specimens from each test set shall have a lateral expansion opposite the notch not less than 0.021 in. (0.53 mm).

(b) If using filler metals other than Type 316L; or when the base metal, weld metal, or filler metal are unable to meet the requirements of (a) above:

(1) notch toughness testing shall be conducted at a test temperature not warmer than MDMT, using the ASTM E 1820 J_{IC} method;

(2) a set of two specimens shall be tested in the TL orientation with a resulting K_{IC} (J) of not less than 120 ksi$\sqrt{\text{in.}}$;

(3) each heat or lot of filler metal used in production shall have a FN not greater than the FN determined for the test weld.

UHA-51(b) Required Impact Testing for Welding Procedure Qualifications. For welded construction the Welding Procedure Qualification shall include impact tests of welds and heat affected zones (HAZ's) made in accordance with UG-84(h) and with the requirements of UHA-51(a), when any of the components[2] of the welded joint are required to be impact tested by the rules of this Division.

UHA-51(c) Required Impact Testing When Thermal Treatments Are Peformed. Impact tests are required at the colder of 70°F (21°C) or the MDMT, whenever thermal treatments[1] within the temperature ranges listed for the following materials are applied:

UHA-51(c)(1) austenitic stainless steels thermally treated at temperatures between 900°F (482°C) and 1650°F (900°C); however, Types 304, 304L, 316, and 316L that are thermally treated at temperatures between 900°F (482°C) and 1300°F (704°C) are exempt from impact testing provided the MDMT is −20°F (−29°C) or warmer and vessel (production) impact tests of the thermally treated weld metal are performed for Category A and B joints;

UHA-51(c)(2) austenitic-ferritic duplex stainless steels thermally treated at temperatures between 600°F (316°C) and 1750°F (954°C);

UHA-51(c)(3) ferritic chromium stainless steels thermally treated at temperatures between 800°F (427°C) and 1350°F (732°C);

UHA-51(c)(4) martensitic chromium stainless steels thermally treated at temperatures between 800°F (427°C) and 1350°F (732°C).

UHA-51(d) Exemptions from Impact Testing for Base Metals and Heat Affected Zones. Impact testing is not required for Table UHA-23 base metals when the nominal thickness is less than 0.099 in. (2.5 mm) or for the following combinations of base metals and heat affected zones (if welded) and MDMT's, except as modified in UHA-51(c):

UHA-51(d)(1) for austenitic chromium–nickel 01 stainless steels as follows:

(a) Types 304, 304L, 316, 316L, 321 and 347 at MDMT's of −320°F (−196°C) and warmer;

(b) those types not listed in (d)(1)(a) above and having a carbon content not exceeding 0.10% at MDMT's of −320°F (−196°C) and warmer;

(c) having carbon content exceeding 0.10% at MDMT's of −55°F (−48°C) and warmer;

(d) for castings at MDMT's of −20°F (−29°C) and warmer;

UHA-51(d)(2) for austenitic chromium–manganese–nickel stainless steels (200 series) as follows:

(a) having a carbon content not exceeding 0.10% at MDMT's of −320°F (−196°C) and warmer;

(b) having a carbon content exceeding 0.10% at MDMT's of −55°F (−48°C) and warmer;

[2] Either base metal or weld metal.

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(c) for castings at MDMT's of −20°F (−29°C) and warmer;

UHA-51(d)(3) for the following steels in all product forms at MDMT's of −20°F (−29°C) and warmer:

(a) austenitic ferritic duplex steels with a nominal material thickness of $\frac{3}{8}$ in. (10 mm) and thinner;

(b) ferritic chromium stainless steels with a nominal material thickness of $\frac{1}{8}$ in. (3.2 mm) and thinner;

(c) martensitic chromium stainless steels with a nominal material thickness of $\frac{1}{4}$ in. (6 mm) and thinner.

Carbon content as used in (d)(1) and (d)(2) above is as specified by the purchaser and must be within the limits of the material specification.

UHA-51(e) Exemptions from Impact Testing for Welding Procedure Qualifications. For Welding Procedure Qualifications, impact testing is not required for the following combinations of weld metals and MDMT's except as modified in UHA-51(c):

UHA-51(e)(1) for austenitic-chromium–nickel stainless steel base materials having a carbon content not exceeding 0.10% welded without the addition of filler metal, at MDMT's of −155°F (−104°C) and warmer;

UHA-51(e)(2) for austenitic weld metal:

(a) having a carbon content not exceeding 0.10% and produced with filler metals conforming to SFA-5.4, SFA-5.9, SFA-5.11, SFA-5.14, and SFA-5.22 at MDMT's of −155°F (−104°C) and warmer;

(b) having a carbon content exceeding 0.10% and produced with filler metals conforming to SFA-5.4, SFA-5.9, SFA-5.11, SFA-5.14 and SFA-5.22 at MDMT's of −55°F (−48°C) and warmer;

UHA-51(e)(3) for the following weld metal, when the base metal of similar chemistry is exempt as stated in UHA-51(d)(3), then the weld metal shall also be exempt at MDMT's of −20°F (−29°C) and warmer:

(a) austenitic ferritic duplex steels;

(b) ferritic chromium stainless steels;

(c) martensitic chromuim stainless steels.

Carbon content as used in (e)(2) above is for weld metal produced with the addition of filler metal.

01 *UHA-51(f) Required Impact Testing for Vessel (Production) Plates.* For welded construction, vessel (production) impact tests in accordance with UG-84(i) are required when the MDMT is −320°F (−196°C) and warmer, if the Weld Procedure Qualification requires impact testing; unless otherwise exempted by the rules of this Division. When the MDMT is colder than −320°F (−196°C), vessel (production) impact tests or ASTM E 1820 J_{IC} tests shall be conducted in accordance with UHA-51(a)(4).

Vessel (production) impact tests are not required for welds joining austenitic chromiun–nickel or austenitic chromium–manganese–nickel stainless steels at MDMT's not colder than −320°F (−196°C) where all of the following conditions are satisfied.

UHA-51(f)(1) The welding processes are limited to shielded metal arc, submerged arc, gas metal arc, gas tungsten arc, and plasma arc.

UHA-51(f)(2) The applicable Welding Procedure Specifications (WPS's) are supported by Procedure Qualification Record's (PQR's) with impact testing in accordance with the requirements of UHA-51(a) at the MDMT or colder, or when the applicable PQR is exempted from impact testing by other provisions of this Division.

UHA-51(f)(3) The weld metal (produced with or without the addition of filler metal) has a carbon content not exceeding 0.10%.

UHA-51(f)(4) The weld metal is produced by filler metal conforming to SFA-5.4, SFA-5.9, SFA-5.11, SFA-5.14 and SFA-5.22 as modified below.

(a) Each heat and/or lot of welding consumables to be used in production welding with the shieldedmetal arc (SMAW), and gas metal arc (GMAW) processes shall be qualified by conducting impact tests at or below the MDMT except as exempted by UHA-51(e)(2) in accordance with Section II, Part C, SFA-5.4, A9.12. Acceptance criteria shall conform with UHA-51(a).

(b) Each heat of welding consumables to be used in production welding with the submerged arc (SAW) process shall be qualified by conducting impact tests with each lot and/or batch of flux at or below the MDMT except as exempted by UHA-51(e)(2) in accordance with Section II, Part C, SFA-5.4, A9.12. Acceptance criteria shall conform with UHA-51(a).

(c) Combining more than one welding process or more than one heat, lot, and/or batch of welding material into a single test coupon is unacceptable. Testing at or below the MDMT, except as exempted by UHA-51(e)(2), may be conducted by the welding consumable manufacturer provided certified mill test reports are furnished with the consumables.

(d) The following filler metals may be used without impact testing of each heat and/or lot provided that procedure qualification impact testing in accordance with UG-84(h) at the MDMT or colder is performed using the same manufacturer brand and type filler metal: ENiCrFe-2, ENiCrFe-3, ENiCrMo-3, ENiCrMo-4, ENiCrMo-6, ERNiCr-3, ERNiCrMo-3, ERNiCrMo-4, SFA-5.4 E310-15 or 16.

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(e) The following filler metals may be used without impact testing of each heat and/or lot provided that procedure qualification impact testing in accordance with UG-84(h) at the MDMT or colder is performed: ER308L, ER316L, and ER310 used with GMAW, GTAW, or PAW processes.

UHA-51(g) Exemption From Impact Testing Because of Low Stress. Impact testing of materials listed in Table UHA-23 is not required, except as modified by UHA-51(c), for vessels when the coincident ratio of design stress[3] in tension to allowable tensile stress is less than 0.35.

UHA-52 WELDED TEST PLATES

(a) For welded vessels constructed of Type 405 material which are not postweld heat treated, welded test plates shall be made to include material from each melt of plate steel used in the vessel. Plates from two different melts may be welded together and be represented by a single test plate.

(b) From each welded test plate there shall be taken two face-bend test specimens as prescribed in QW-461.2 of Section IX; these shall meet the requirements of QW-160, Section IX.

MARKING AND REPORTS

UHA-60 GENERAL

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

PRESSURE RELIEF DEVICES

UHA-65 GENERAL

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

[3] Calculated stress from pressure and nonpressure loadings, including those listed in UG-22 which result in general primary membrane tensile stress.

APPENDIX HA SUGGESTIONS ON THE SELECTION AND TREATMENT OF AUSTENITIC CHROMIUM–NICKEL AND FERRITIC AND MARTENSITIC HIGH CHROMIUM STEELS (INFORMATIVE AND NONMANDATORY)

UHA-100 GENERAL

The selection of the proper metal composition to resist a given corrosive medium and the choice of the proper heat treatment and surface preparation of the material selected are not within the scope of this Division. Appendix 6, 6-310 to 6-360, of Section II, Part D discusses some of the factors that should be considered in arriving at a proper selection.

UHA-101 STRUCTURE

See Appendix 6, 6-310, of Section II, Part D.

UHA-102 INTERGRANULAR CORROSION

See Appendix 6, 6-320, of Section II, Part D.

UHA-103 STRESS CORROSION CRACKING

See Appendix 6, 6-330, of Section II, Part D.

UHA-104 SIGMA PHASE EMBRITTLEMENT

See Appendix 6, 6-340, of Section II, Part D.

UHA-105 HEAT TREATMENT OF AUSTENITIC CHROMIUM–NICKEL STEELS

See Appendix 6, 6-350, of Section II, Part D.

UHA-107 DISSIMILAR WELD METAL

The difference between the coefficients of expansion of the base material and the weld should receive careful consideration before undertaking the welding of ferritic type stainless steels with austenitic electrodes for services involving severe temperature conditions, particularly those of a cyclic nature.

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UHA-108 FABRICATION

It is recommended that the user of austenitic chromium–nickel steel vessels in corrosive service consider the following additional fabrication test.

A welded guided-bend test specimen should be made as prescribed in QW-161.2 of Section IX from one of the heats of material used in the shell. The test plate should be welded by the procedure used in the longitudinal joints of the vessel and should be heat treated using the same temperature cycle as used for the vessel. The operations on the test plate should be such as to duplicate as closely as possible the physical conditions of the material in the vessel itself.

Grind and polish the specimen and immerse it for not less than 72 hr in a boiling solution consisting of 47 ml concentrated sulfuric acid and 13 g of crystalline copper sulfate ($CuSO_4 \cdot 5H_2O$) per liter of water. Then bend the specimen so as to produce an elongation of not less than 20% at a section in the base metal $\frac{1}{4}$ in. from the edge of the weld. The metal shall show no sign of disintegration after bending.

UHA-109 885°F (474°C) EMBRITTLEMENT

See Appendix 6, 6-360, of Section II, Part D.

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