



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION**3-11-5**

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**PRESSURE VESSELS
CARBON STEEL**

DATE	STATUS	APVD	AUTHD
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2. GENERAL**2.1 Scope**

- a. This Standard Specification covers the general requirements for design, materials, fabrication, inspection, and testing of carbon and killed carbon steel fusion welded pressure vessels.
- b. Exceptions or variations shown in the UOP Project Specifications take precedence over requirements shown herein.

2.2 References

Unless noted below, use the edition and addenda of each referenced document current on the date of this Standard Specification. When a referenced document incorporates another document, use the edition of that document required by the referenced document.

- a. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1, Rules for the Construction of Pressure Vessels.
- b. ASME Boiler and Pressure Vessel Code, Section I, Rules for the Construction of Power Boilers.
- c. ASME Boiler and Pressure Vessel Code, Section II, Materials, Part A, Ferrous Material Specifications.
- d. ASME SA-53, SA-105, SA-106, SA-234, SA-240, SA-263, SA-264, SA-265, SA-285, SA-388, SA-435, SA-516, SA 578, and SB-127.
- e. ASME Boiler and Pressure Vessel Code, Section II, Materials, Part C, Specifications for Welding Rods, Electrodes, and Filler Materials, SFA-5.1, SFA-5.4, SFA-5.9, SFA-5.11, SFA-5.14, SFA-5.17, SFA-5.18, and SFA-5.20.
- f. ASME Boiler and Pressure Vessel Code, Section II, Materials, Part D, Properties.
- g. ASME Boiler and Pressure Vessel Code, Section V, Nondestructive Examination.
- h. ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Rules for the Construction of Pressure Vessels – Alternative Rules
- i. ASME Boiler and Pressure Vessel Code, Code Case 2235, Use of Ultrasonic Examination in Lieu of Radiography, Section I and Section VIII, Divisions 1 and 2.
- j. American Society for Testing and Materials (ASTM), A 36, A53, A106, A 240, A283, A 285, A 913, A 992, E 165, and G 146.
- k. ASME B31.3, Process Piping.
- l. ASME B16.5, Pipe Flanges and Flanged Fittings NPS ½ Through NPS 24.

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- m. ASME B 16.47, Large Diameter Steel Flanges NPS 26 Through NPS 60.
- n. ASME B46.1, Surface Texture (Surface Roughness, Waviness, and Lay).
- o. ASME B16.20, Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral-Wound and Jacketed.
- p. American Welding Society (AWS) A4.2, Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal.
- q. American Petroleum Institute (API) Recommended Practice (RP) 582, Welding Guidelines for the Chemical, Oil, and Gas Industries
- r. National, state and local governmental regulations and laws

2.3 Definitions

- a. Hydrogen Service

- (1) Hydrogen partial pressure exceeding 50 psia {3.5 kg/cm² (a)}.
- (2) More than 90 percent hydrogen at any pressure level.

- b. Severe Cyclic Service

Cyclic service as defined in ASME B31.3, Section 300.2. Cyclic service may be mechanical, thermal, or a combination of both.

3. DESIGN
3.1 General Requirements

- a. The design, materials, fabrication, inspection, and testing of pressure vessels shall comply with the requirements of ASME Section VIII, Division 1 or, when specified in the UOP Project Specifications, ASME Section I.
- b. Allowable stresses for materials shall be in accordance with ASME Section II, Part D.
- c. The vessel designer shall be responsible for the stress and thermal analysis of the vessel and components.
- d. The Contractor shall determine the need for and method(s) of performing any special analyses above the minimum calculations required by the ASME Code.
- e. Where "M.R." or "MR" is specified in the UOP Project Specifications, it indicates that it is the Manufacturer's and/or Contractor's responsibility to meet the requirement in compliance with applicable codes and standards, including any additional requirements specified in the UOP Standard Specifications, UOP Standard Drawings, and UOP Project Specifications.



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- f. Thicknesses specified are minimum, after forming and fabrication.
- g. The vessel nameplate shall be fabricated from stainless steel and shall be visible and accessible at all times. If located in an insulated area, the nameplate shall be placed on standoffs so that the insulation passes beneath it.
- h. Vessels that will be buried or mounded shall be protected against external corrosion by coatings, wraps, and/or cathodic protection.

3.2 Loading

- a. The design temperature and pressure conditions specified on the UOP Project Specifications are at the top of the vessel in its operating position. Gauge pressures are relative to atmospheric pressure at sea level {15psia, 1.05 kg/cm²(a)}.
- b. Where "delta P vessel (total)" is specified on the UOP Project Specification, this pressure drop shall be combined with any static head and the specified design pressure in order to determine the design pressure at the bottom of the vessel.
- c. When design for external pressure is required, the minimum net external differential pressure shall be 15psi (1.05kg/cm²).
- d. Wind and earthquake loads and the applicable load combinations shall be determined in accordance with the governing Code(s), standard(s), and data specified in the UOP Project Specifications.
- e. Vertical vessels shall be evaluated for vibration, including vortex shedding, due to wind or other sources. Stress, deflection, and fatigue shall be evaluated when an analysis is necessary.
- f. Vessels and their supports shall be capable of supporting the vessel filled with water in the erected position. The corroded (i.e., nominal thickness minus the corrosion allowance) vessel shall be adequate for hydrotesting in the erected position.
- g. The maximum deflection of trayed columns, other than under earthquake loading, shall be no greater than the vessel height/200 (h/200), with a maximum deflection of one foot (300 mm).

3.3 Shells and Heads

- a. The design thickness shall not include any additional thickness provided as a corrosion allowance nor any lining material applied for corrosion resistance, e.g., weld deposit overlay or cladding.
- b. The minimum design thickness, excluding corrosion allowance, shall be $(D/1000) + 0.1$ inches $\{(D/1000) + 2.54\text{mm}\}$, where D = nominal vessel inside diameter in inches (mm).

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- c. The effects of external primary mechanical loads plus design pressure and the effects of secondary stresses, such as those due to differential thermal expansion, shall be a part of the design process, and the resulting combined stresses and deflections shall be evaluated. It is the responsibility of the contractor to specify the governing load cases and critical locations.
- d. The knuckles of elliptical, torispherical, and toriconical heads and reducers, with a special emphasis on those in large diameter, low pressure services, shall be designed to prevent buckling under internal and external operating and pressure testing conditions.
- e. Pressure containing weld seams shall not intersect nozzles or nozzle reinforcement.
- f. Vacuum stiffening rings shall be installed on the exterior surface of the vessel, and shall be insulated in a manner to maintain a temperature similar to that of the vessel shell. Internal stiffening rings may be considered if they do not:
 - (1) interfere with the process (e.g., fluid distribution or collection)
 - (2) interfere with the installation, maintenance, or removal of internals, catalyst, packing, etc
 - (3) impede physical access within the vessel
 - (4) obstruct visual or non-destructive examination of welds
 - (5) collect fluids, create low flow areas, or promote corrosion or coke formation

3.4 Vessel Supports

- a. Vessel supports (exclusive of allowances for corrosion) shall be designed to withstand the most severe combination of live and dead loads anticipated during the normal life of the vessel.
- b. Provide a minimum of 1/16 inch (1.6 mm) corrosion allowance on vessel supports.
- c. Stresses due to differential thermal expansion and frictional forces due to sliding supports shall be considered in the design.
- d. Horizontal vessels shall be supported by two saddle supports fabricated to fit the outside surface of the vessel within the applicable tolerances. Saddles shall extend over a vessel arc of at least 120°. Saddles shall not be placed over vessel girth welds. A corrosion or wear plate shall be provided between the saddle and the vessel shell. The corrosion or wear plate shall not be considered a part of the shell or the saddle for design purposes. The plate shall extend at least 2 inches (50 mm) in all directions beyond the saddle. The corners shall be rounded to a radius of at least 2 inches (50 mm). After removal of free moisture from between the shell and the plate, the plate shall be continuously seal welded to the shell around the plate's perimeter. At least one 1/4 inch NPS vent hole shall be provided in each plate section. Vent holes shall be tapped for future plugging. Vent holes shall remain open until the completion of pressure testing. The vent shall then be plugged with a material adequate for the operating temperature but not be capable of retaining pressure.



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- e. Support legs shall be attached to the exterior surface of the vessel shell. The legs shall extend far enough along the shell to prevent local buckling of the shell between or above the legs. The legs shall extend a minimum of 6 inches (150mm) above the bottom tangent line of the vessel.
- f. Skirt vent holes shall be provided at the top of the space enclosed by the skirt after application of fireproofing and vessel insulation. The vent holes shall be a minimum diameter of 3 inches (75 mm), equally spaced, and a maximum of 6 feet (1800 mm) apart. At least four vent holes are required. The vent holes shall be unobstructed at all times.
- g. Provide at least one access opening in skirts supporting vessels from below.
- h. Openings in support skirts shall be reinforced.

3.5 Non-Pressure Containing Components Welded to Pressure Containing Components

Load bearing welds attaching non-pressure containing parts to pressure containing parts shall be designed using the same allowable stress basis for primary membrane tensile, compressive, and shear stresses as required for pressure containing components of the same material.

3.6 Nozzles and Manways
a. General

- (1) Threaded fittings, unions, couplings, and tapped holes are not permitted.
- (2) The minimum nozzle size shall be 1 inch nominal pipe size (NPS) except that for alloy lined nozzles the minimum size is 1-1/2 inch NPS
- (3) When the inside diameters of nozzles and manways are specified, they shall be considered as minimum. In lined areas, the specified inside diameter is the inside diameter of the finished lining. Connections that receive equipment shall be checked to insure that the inside diameter is large enough and the flanges match.
- (4) Flanges and bolts shall be analyzed to ensure that they are not overstressed during gasket seating. Overstressing is more likely to occur when Class 300 and lower flanges are used with spiral wound or metal gaskets.
- (5) Nozzles and manways shall not be located in tray downcomers.
- (6) Flanges shall not be located inside of vessel support skirts or other confined areas.
- (7) Nozzles and their reinforcement in heads shall be entirely contained within the center 80 percent of the head unless a detailed analysis is performed to validate the design considering all mechanical and thermal loadings.



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b. Flanges

- (1) Flange classes are specified in accordance with ASME B16.5 or ASME B16.47, Series B. Flange classes listed in the UOP Project Specifications are based upon design pressure and temperature conditions only, and do not account for other loads. The final design of all flanges shall account for gasket seating and external loads. Differential thermal expansion of dissimilar joints and transient thermal conditions such as start-up/shutdown and operational upset shall be accommodated.
- (2) Class 150 flanges shall not be used for design temperatures over 700°F (370°C).
- (3) Class 300 flanges (minimum) shall be used for instrumentation pipe column attachments to the vessel. This requirement does not apply to individual transmitters or indicators mounted on pipe columns or directly connected to the vessel.
- (4) Slip-on flanges are not recommended for any service, and are only permitted when in accordance with all of the following:
 - (a) The hydrogen partial pressure (design) does not exceed 50 psia {3.5 kg/cm² (a)}.
 - (b) The fluid service is not corrosive {defined as a required corrosion allowance of 1/8 inch (3mm) or less} to the materials of construction. Slip-on flanges are not permitted in HF acid service
 - (c) Postweld heat treatment is not specified in the UOP Project or Standard Specifications.
 - (d) The flange is not in a severe cyclic service.
 - (e) The design temperature does not exceed 500°F (260°C) and the Minimum Design Metal Temperature (MDMT) is not below -20°F (-29°C)).
 - (f) With the exception of nozzles less than 4 inches NPS not subjected to external loads and manways, all flanges are Class 150. For nozzles less than 4 inches NPS not subjected to external loads and manways, flanges do not exceed Class 300.
 - (g) Slip-on flanges, when permitted, shall be double welded and vented through the hub with 1/8 inch (3 mm) diameter pre-drilled vent holes.
 - (h) The welds joining the flange to the pipe shall be visually and liquid dye penetrant examined.
- (5) Lap joint flanges shall not be used in severe cyclic services.
- (6) The design of slip-on and lap joint flanges subjected to external loads due to piping displacement shall consider the stress intensification factors (SIF's) from ASME B31.3, Appendix D. The design for primary mechanical loads shall limit the nominal stress in the neck of the flange to one-fourth (1/4) of the code allowable stress at temperature unless a detailed analysis is performed.



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- (7) Flanges that are intended for use with spiral wound gaskets shall have a flange surface finish of 125 microinch Ra minimum to 250 microinch Ra maximum. Flanges intended for use with other gaskets shall have a flange surface finish within the optimal range for the specified gasket. Finishes shall be judged by visual comparison with surface finish roughness standards conforming to ASME B46.1. Flange finishes shall be protected from damage during fabrication, heat treatment, shipping, storage and installation.
- (8) Ring joint flanges shall have a flat bottom groove with the intersection between the bottom and the sides of the groove machined to a smooth 0.125 inch (3 mm) minimum radius.
- (9) Flanged thermowells and other connections joining dissimilar materials require special consideration. The flange Class for both materials shall be determined and the higher Class used for both flanges.
- (10) Flanges designated as “special” in the UOP Project Specifications and other flanges that are not within the scope of ASME B16.5 or ASME B16.47 shall be designed in accordance with ASME Section VIII, Division 1, Appendix 2 and Appendix S. The bolt and gasket materials to be used in the design of these flanges are as noted in the UOP Pipe Class specified for the connection. The applicable UOP Pipe Class is that specified for the connected piping on the UOP Piping and Instrument Diagram (P&ID). Where there is no connected piping (e.g., a manway), use the miscellaneous connections Pipe Class specified for the vessel on the UOP P&ID. As a minimum, the flange shall be designed for use with spiral wound gaskets.
- (11) The Contractor shall be responsible for the compatibility of all flanges mating with piping, instruments, or equipment.

c.
Details

- (1) Either an integrally reinforced nozzle or balanced integral reinforcement in both the nozzle neck and vessel is required for hydrogen service and is preferred for all services. Built-up construction using pipe or rolled plate with a flange and reinforcing pad is permissible for non-hydrogen services. Gussets are not permitted.
- (2) When the design pressure exceeds 1000 psig {70 kg/cm²(g)} or the shell thickness exceeds 2 inches (50 mm), 4 inch NPS and greater nozzles shall utilize an integrally reinforced forging in accordance with ASME Section VIII, Division 1, Figure UW-16.1 (f-1), (f-2), (f-3), or (f-4). Nozzles smaller than 4 inch NPS shall be integrally reinforced.
- (3) When the design temperature is within the material’s creep range {above 700°F (370°C)}, 4 inch NPS and larger nozzles shall utilize integrally reinforced forgings in accordance with ASME Section VIII, Division 1, Figure UW-16.1 (f-1) or (f-4). Balanced reinforcement between the nozzle and the shell, designed to minimize the creep strain concentrations at the junction, is preferred. Nozzles smaller than 4 inch NPS shall be integrally reinforced.



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- (4) External reinforcing pads shall have a minimum of one 1/4 inch NPS vent hole. Pads for nozzles greater than 16 inch NPS shall have a minimum of 2 vent holes and pads for nozzles in excess of 36 inch NPS shall have a minimum of 4 vent holes. Pads installed in sections shall have at least one vent hole per section. Vent holes shall be tapped for future plugging. Vent holes shall remain open until the completion of pressure testing. The material used for plugging shall be adequate for the operating temperature but shall not be capable of retaining pressure.

3.7 Special Considerations for Low Temperature, Elevated Temperature or Severe Cyclic Service

For design temperatures of -20°F (-29°C) and lower or 700°F (370°C) and higher, or severe cyclic services, the design details for nozzles, supports, and other attachments to the vessel pressure containing components shall be free of high local stress concentrations, e.g., sharp discontinuities, immediate changes of direction of a surface, notches, weld undercuts, etc. Internal and external fillet welds shall be ground to a smooth and generous concave contour. Notches, weld undercuts, etc. shall be removed.

4. MATERIALS

4.1 General

- a. Pressure vessel materials shall be in accordance with ASME Section II, Part A. Non-pressure parts may be in accordance with American Society for Testing and Materials (ASTM) Specifications. ASME Specification numbers are prefixed by SA and the corresponding ASTM Specification numbers are prefixed by A.
- b. Low temperature services {per the applicable Minimum Design Metal Temperature (MDMT)} may utilize materials pretested and certified for low temperature applications. These materials are listed in ASME Section VIII, Division 1, Table UG-84.3.
- c. All material used in the vessel(s) shall be new.
- d. Each plate, forging, and other product form shall be legibly stamped or stenciled showing specification number, grade, and class. When metal stamping is used it shall be on the long edge of each component as it leaves the mill. Metal stamping on rolled surfaces shall be done with a "low stress" stamp. Markings shall be protected from erosion, wear, or other events that may render them unreadable.
- e. When the room temperature tensile strength of pressure containing components and welds is not limited to a lower value by the applicable product specification, it shall not exceed 100,000 psi (7030 kg/cm²).
- f. Accelerated cooling from the austenitizing temperature is acceptable where permitted by the applicable product specification.
- g. The tempering temperature for tempered material shall be at least 50°F (28°C) greater than the maximum intermediate or postweld heat treatment temperature.



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- h. The affect of heat treatment on tensile strength shall be determined by testing specimens from each heat of plate, pipe, and forgings {small forgings may be tested on a “lot” basis as defined in ASME Section VIII, Division 1, Section UG-84(e)(2)} and weldments representing each batch of welding consumables, covered electrodes, and wire-flux combinations used for each production welding process. The specimens shall be subjected to the maximum heat treatment as defined in Paragraph 4.1i. The results shall comply with the requirements of the subject material specification.
- i. When Charpy V-notch impact testing is required for a component or weld that will be heat treated, test specimens shall be provided in both the minimum and maximum heat-treated condition. Testing of welds shall include samples from each procedure, welder/welding operator and welding position. The minimum heat treated condition means subjected to the fewest heat treatment cycles and/or time-at-temperature anticipated for the component. The maximum heat treated condition means subjected to the maximum number of heat treatment cycles and/or time at temperature anticipated during fabrication (including intermediate stress relief and multiple heat treatment exposures) plus one additional heat treatment to simulate a future requirement

j. Plates and forgings over 4 inches (100mm) thick or used for pressure containment in HF acid or hydrogen service shall be:

- (1) Ultrasonically examined with 100% scanning in accordance with the following:
 - (a) Plates shall be examined before forming in accordance with ASME SA-435 including supplementary requirements S1.
 - (b) Forgings shall be examined in accordance with ASME SA-388 and ASME Section VIII, Division 2, AM-203.2.
- (2) Examined by either liquid penetrant (PT) or magnetic particle (MT) in accordance with the following:
 - (a) The entire surface of all forgings, after finish machining.
 - (b) Formed plate surfaces to be welded, i.e., the weld bevel area, and a minimum of 2 inches (50mm) of neighboring surfaces.
 - (c) Formed plate surfaces where weld overlay will be applied.

4.2 Shells, Heads, and Other Pressure Containing Components

- a. Shells may be fabricated from rolled plate, forgings, or pipe. Layered construction is prohibited.
- b. Carbon steel plate shall be ASME SA-285 Grade C. Other product forms shall be the equivalent grade of carbon steel.
- c. Killed carbon steel plate shall be ASME SA-516. Other product forms shall be the equivalent grade of killed carbon steel.



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- d. When the shell or head is internally lined or the thickness exceeds 2 inches (50 mm) a calibration block for ultrasonic examination shall be provided. The block shall be in accordance with ASME Section V, Article 5, and shall include a lining identical with the vessel lining.

4.3 Nozzles and Manways

- a. Flanges shall be forged.
- b. Material requirements:

Item	Carbon Steel Vessels	Killed Carbon Steel Vessels
Pipe	SA-53 type S, Grade B	SA-106 Grade B
Plate for nozzle necks	SA-285 Grade C	SA-516
Flanges	SA-105	SA-105
Plate for flanges (where permitted by ASME B16.5 or ASME B 16.47)	SA-516	SA-516
Fittings	SA-234 Grade WPB - Seamless	SA-234 Grade WPB – Seamless

- c. Solid alloy nozzles are not recommended for any service and shall not be used at design temperatures above 450°F (230°C).
- d. Austenitic stainless steel nozzles are not permitted.
- e. Reinforcing pads shall be the same material as the shell.
- f. Corrosion allowance for nozzles and manways shall be at least equal to that specified for the vessel shell.
- g. Bolting materials shall be as required by the UOP Pipe Class specified on the UOP Piping and Instrument Diagram (P&ID). The applicable UOP Pipe Class is that specified for the connected piping. When there is no connected piping (e.g., a manway), use the miscellaneous connections Pipe Class specified for the vessel on the UOP P&ID.

4.4 Vessel Supports and Exterior Attachments

- a. Material for rings, lugs, saddles, wear/corrosion plates, legs supporting vessels, and the upper three feet of support skirts welded directly to the vessel or to reinforcing rings welded to the vessel shall be the same material as the shell when the design temperature is greater than 650°F (340°C). Otherwise, the material shall be ASTM A285 or A516.
- c. External vacuum stiffening rings shall be the same material as the shell when the design temperature is greater than 650°F (340°C). When the design temperature is

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650°F (340°C) or less the material shall be ASTM A36, A283, A 285, A516, A913, or A992. Internal vacuum stiffening rings shall be the same material as the shell.

- c. Base rings, reinforcement for skirt openings, saddle base plates, external lugs for platforms, ladders, insulation supports, pipe supports and other non-pressure parts welded to the vessel shall be ASTM A36, A283, A 285, A516, A913, or A992. Angles and rods shall be ASTM A 36, A913, or A992.
- d. External supports and attachments may be exposed to low ambient temperatures. The effects of this exposure upon material selection, stress analysis, fabrication details, etc shall be addressed.

4.5 Internals, Internal Bolting, and Internal Supports

- a. The material for internals is specified on the UOP Project Specifications. When carbon steel is specified, pipe shall be ASTM A 106 or A 53 type S and plate, bars, and shapes shall be ASTM A 36, A 283, A 285, A516, A913 or A992.
- b. Internal support rings, lugs, brackets, and other items welded to the shell shall be the same material as the shell base metal in killed steel vessels, and ASTM A285 or A516 in carbon steel vessels. In lined portions of the vessel they shall be covered with alloy lining. When welded directly to the lining, they shall be an alloy corresponding to the lining.
- c. Bolting for distributors, baffles, or other miscellaneous items, not furnished by the tray supplier, shall be the same or similar alloy as the internals.
- d. Drawings and instructions for fabrication and installation of tray and mesh blanket supports attached to the vessel shall be furnished by the supplier of the vessel internals. The vessel manufacturer shall fabricate and install the vessel attachments in accordance with those instructions and the UOP Project and Standard Specifications and Drawings.
- e. As an alternative to welding rings, lugs, and brackets to the shell, they may be formed from weld build-up (using the same weld materials used for the vessel strength welds) or integrally forged with the shell and covered with alloy lining where required. The transition to the shell shall be machined to a smooth and generous concave contour prior to the application of alloy lining (if required). The top surface of the completed support rings (i.e., after the application of alloy lining, if required) shall be machined to provide a smooth, flat surface. The welding procedure, inspection and examination of weld build-ups shall be the same as required for the vessel strength welds.

4.6 Gaskets

- a. Gaskets shall conform to the requirements of the UOP Pipe Class specified on the UOP Piping and Instrument Diagram (P&ID). The applicable UOP Pipe Class is that specified for the connected piping. Where there is no connected piping (e.g., a manway), use the miscellaneous connections Pipe Class specified for the vessel on the UOP P&ID.
- b. Gaskets for use with raised face flanges shall be spiral wound per ASME B16.20 with a non-asbestos filler material. In lined portions of the vessel, the winding material shall be the same as the vessel lining. In unlined portions of the vessel, the winding material

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shall be a minimum of ASTM A 240 Type 304. Gaskets shall include an outer retainer ring. The outer ring may be carbon steel, protected against corrosion. Gaskets for Class 900 and greater flanges, flanges over 24 inch NPS, and gaskets in vacuum service shall have an inner retainer ring of the same material as the windings. Gaskets with an inner retainer ring shall also be used between flanges of different metallurgies with different coefficients of thermal expansion when they operate at an elevated temperature. The contractor shall verify the adequacy of all gaskets considering potential buckling of the outer or inner retaining ring(s) and the windings.

- c. The use of corrugated, double jacketed gaskets per ASME B16.20 may be considered for large diameter openings (over NPS 24 inch), especially when the sealing surface is vertical or when the surface to be sealed is not round (e.g., multi-pass exchanger channel to shell closure gaskets).
- d. Ring joint gaskets shall be per ASME B16.20.

5. FABRICATION
5.1 Details

- a. Shell and head joints, including nozzle attachments, shall be Type (1), full penetration, free of undercuts, double welded butt joints in accordance with ASME Section VIII, Division 1, Section UW-3 and table UW-12. The initial root pass of double welded groove joints, including root tack welds, shall be chipped, ground, and/or gouged to sound metal on the reverse side before welding on that side. The back-chipped welds, welding groove, and plate edges shall be magnetic particle or liquid penetrant examined to ensure that all cracks, pinholes, laminations, porosity, and other defects have been removed prior to welding on the reverse side. In cases where double welding is impractical (e.g., the groove joint backside is not accessible for chipping or gouging and welding) the root pass shall be made by the Gas Tungsten Arc Welding (GTAW).
- b. Pressure containing welds shall remain accessible for visual and nondestructive examination (e.g., radiography). Nozzles shall be located so that the nozzle, nozzle to vessel weld, and nozzle reinforcement are at least 3 inches (75mm) from all pressure containing shell and head welds. If intersecting or covering pressure containing welds cannot be avoided, the nozzle shall be fully reinforced and low stress welding details used (e.g., grind fillets to a smooth concave radius). Pressure containing welds beneath reinforcement shall be ground smooth and flush with the shell surface. All pressure containing welds shall be 100 percent radiographed after forming and nozzle installation but before reinforcing pad installation to a minimum of 6 inches (150mm) beyond the nozzle to vessel weld or the limits of the reinforcing pad.
- c. Longitudinal and circumferential pressure containing welds shall not be located in tray downcomers, behind permanent internals, or in other areas that prevent inspection from the inside of the vessel. Circumferential welds shall have a clearance of at least one inch (25mm) from tray support rings and welds and other circumferential attachments.



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- d. Nozzles shall penetrate through the shell, with the shell butt welded to the nozzle. Nozzles and their reinforcement (except the outer circumference of reinforcing pads) shall be attached to the vessel with full penetration welds. Connections at air cooler header boxes may use a “set –on” detail. Equipment nozzles meeting the following criteria may also utilize a “set-on” detail:
- (1) The nozzles are 3 inch NPS or smaller.
 - (2) The thickness of the component (shell, head, nozzle neck, blind flange, etc) to which the nozzle is attached exceeds 2 inches (50mm). This also applies to nozzles welded to other nozzles.
 - (3) When reinforcement is required, the nozzle shall be integrally reinforced.
 - (4) The nozzles are for instruments or another service without attached piping and without significant imposed loads.
 - (5) The nozzles are not subject to significant cyclic (thermal or mechanical) or fatigue loadings.
 - (6) The base metal adjacent to the nozzle opening shall be thoroughly ultrasonic and magnetic particle examined to ensure that there are no flaws (e.g., laminations).
 - (7) The nozzle to shell weld shall be full penetration with an external fillet ground to a smooth, concave contour.
 - (8) The weld geometry shall permit full, non-destructive examination of the nozzle to shell weld in both the shop and the field, after operation.
 - (9) When spot examination of the vessel welds is required, at least one randomly selected “set-on” weld shall be included in the examination.
 - (10) The nozzle to shell weld shall comply with the requirements for the other pressure containing welds (e.g., double welded, back-gouged, no permanent backing bars, etc).
- e. Nozzles, manways, and handholes shall be cut flush with the inside surface of the shell or head. When an internal projection is necessary, the internal projection shall not interfere with the process, internals, or the installation of internals or other vessel contents. The inside edge of nozzles, manways, and handholes shall be rounded.
- f. Pressure containing shell, head, and radiographable nozzle welds shall be located, designed, and ground to permit 100 percent on site radiographic examination.
- g. Pressure containing welds, internal attachment locations, and the method of vessel support attachment shall accommodate full on-site external ultrasonic angle beam examination and visual inspection of head and shell welds with all internal equipment in place. Welds shall be contoured to permit proper interpretation of ultrasonic examination.

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- h. Internal support rings shall be continuously welded to the shell on the top and intermittently welded on the bottom. Internal lugs and brackets shall be continuously welded on the top and sides only. In hydrogen service all internal and external welds shall be full penetration, free of undercuts, through the support side of the joint.
- i. Lugs and rings for internal supports in lined portions of vessels may be welded directly to the lining only if the vessel is lined with weld deposit overlay or integrally bonded cladding meeting the requirements of ASME Section VIII, Division 1, Paragraphs UCL-11 (a) and (c).
- j. In hydrogen services all fillet welds (internal and external) to pressure containing components shall be ground to a smooth and generous concave contour.
- k. When austenitic stainless steel support rings are joined to an austenitic stainless steel lining and the operating temperature is greater than 700°F (370°C), circumferential welds shall not be used. The rings shall continuously contact the lining and shall be supported by vertical lugs welded to the lining.
- l. Seams in supporting skirts shall be made with full penetration butt welds. Connections between straight skirts and vessel heads shall be made with a smooth flat-faced weld. The width of the weld shall be at least equal to the skirt thickness, and its height shall be approximately twice its width. When the shell thickness at the skirt connection exceeds 4 inches (100mm), the design temperature at the skirt to shell connection is within the materials' creep range {above 700°F (370°C)}, or the skirt to shell junction is subject to cyclic loading, the joint details shall be as specified on the UOP Project Specification.
- m. Details of flared skirts, lugs, and special vessel support systems are specified on the UOP Project Specifications

5.2 Welding Processes and Electrodes

- a. Welding shall be by a metal arc process. Welding electrodes shall be in accordance with ASME Section II Part C. Welding processes, materials, and procedures shall comply with the requirements of API RP 582 except as modified by this Standard Specification and the UOP Project Specifications. References to “should” within API RP 582 are replaced by “shall”.
- b. Chemistry and mechanical properties of the deposited weld metal shall conform to the ASME requirements for the base metal.
- c. The Flux Cored Arc Welding (FCAW) process shall utilize an external shielding gas and is not permitted for the root pass of joints made from one side. FCAW may be used for the root pass of joints made from both sides only if it is completely removed prior to welding from the reverse side.



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- d. The Gas Metal Arc Welding (GMAW) process in the short circuiting mode (GMAW - S) may be used for the following applications only:
 - (1) The root pass for any material thickness.
 - (2) Complete groove or fillet welds provided that the wall thickness of the thickest portion of the joint does not exceed 1/4 inch (6 mm).
 - (3) Tack welds, temporary attachments, and other applications where the weld made by this process is completely removed.
- e. The Gas Metal Arc Welding process in the globular transfer mode (GMAW-G) shall not be used.
- f. The Gas Metal Arc Welding (GMAW) process in the spray transfer mode shall not be used for the root pass.
- g. Covered welding electrodes (i.e., shielded metal arc welding – SMAW) for carbon steel welding shall be of the low hydrogen coating type and shall be in accordance with ASME Section II, Part C, SFA-5.1. Rod ovens, and other means as necessary, shall be used to ensure that the rods remain dry.
- h. Electrodes with a “G” (General) designation shall not be used unless a PQR is performed for each batch and lot used for production welds.
- i. Bare electrodes for inert gas and submerged arc welding shall be in accordance with ASME Section II, Part C, and the following electrode specifications:

Welding Process	Electrode Specification
Submerged Arc Welding	SFA-5.17
Gas Shielded Arc Welding	SFA-5.18
Flux Cored Arc Welding	SFA-5.20

- j. Submerged Arc (SAW) production welds shall be made with the same flux and filler wire combinations and of the same type and brand used for the Procedure Qualification Record (PQR).
- k. Backing strips, if used, shall be removed.

5.3 Postweld Heat Treatment

- a. Welding directly to the base metal shall be completed prior to final heat treatment unless welding after heat treatment is specifically permitted by ASME Section VIII Division 1. All welding to alloy lining shall also be completed prior to the final heat treatment unless a two layer weld overlay is used and the requirements of Paragraph 5.4c.(1) are met.
- b. Welded joints requiring post weld heat treatment shall be heat treated immediately upon completion of welding. The joint shall not be allowed to cool below 300°F (150°C) prior to heat treatment. Alternately, the weld and adjacent metal may be



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heated to 600°F (315°C), wrapped with insulation, and allowed to cool. Heat treatment may then be performed later.

- c. Vessels in HF acid service shall be postweld heat treated (PWHT) at a minimum temperature of 1150°F (620°C) $\pm$ 25°F (14°C).
- d. The alternate postweld heat treatment procedures permitted by ASME Section VIII, Division 1, Table UCS-56.1 (i.e., a reduced hold temperature for a greater time) shall not be used.
- g. Thermocouples shall be located on the inside and outside of the vessel surface, and placed to ensure that that all portions of the vessel are properly and uniformly heat treated, without the presence of detrimental thermal gradients.
- f. During heat treatment the vessel shall be supported and stiffened to prevent distortions.
- g. Flange facings shall be protected against oxidation during heat treatment.
- h. Flame impingement is prohibited at all times.
- i. When postweld heat treatment is required, one Brinell hardness reading shall be taken on the inside (except in lined portions of the vessel) and on the outside of each shell section, head, and nozzle, and each longitudinal, girth and nozzle weld. The readings shall be taken after final postweld heat treatment. No reading shall exceed a value of 200 Brinell. Readings shall be taken with a portable hardness tester, calibrated at 200 Brinell.

5.4 Alloy Lining**a. General**

- (1) The term "Alloy Lining" is a general term that does not imply a specific fabrication or manufacturing process.
- (2) Alloy lining for shells and heads shall be integrally bonded cladding or weld deposit overlay. The required alloy and thickness are specified on the UOP Project Specifications.
- (3) Strip lining is not permitted.
- (4) Rings, lugs, brackets, and other attachments in the lined portion of the vessel shall be weld deposit overlayed unless they are fabricated from an alloy corresponding to the lining.
- (5) Tubular liners are not acceptable in nozzles greater than 1½ inch NPS or nozzles of any size in HF acid service. Tubular liners may be used for smaller nozzles. The liner shall be welded to the alloy facing at the flange end. Attachment of the liner at the inside surface of the vessel shall be by an expansion/contraction collar. When differential thermal expansion/contraction between the liner and the nozzle is not a concern, the liner may be welded flush with the vessel's inside surface. The final details shall account for the sustained, transient, thermal (expansion/contraction), and cyclic stresses due to the operation of the vessel.

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- (6) In hydrogen service, nozzles with tubular liners welded on both ends shall be vented with a 1/8 inch NPS hole, drilled from the outside of the nozzle to the OD of the liner. The vent hole shall be tapped for future plugging with a material adequate for the operating temperature but incapable of retaining the operating pressure.

b. Cladding

- (1) Integrally bonded clad plate shall be fabricated in accordance with SA-263 for corrosion resistant chromium stainless steel cladding, SA-264 for chromium-nickel stainless steel cladding, or SA-265 for nickel and nickel based cladding.
- (2) The bond between the cladding and the base metal shall be tested by and comply with the requirement of the "shear strength" test as described in the applicable cladding specification.
- (3) When integrally bonded clad plate is used, the lining shall be cut back at all seams a minimum of 3/4 inch (19mm) from the edge of the weld bevel to permit welding of the base metal. Complete removal of the cladding shall be verified before proceeding with welding of the base metal. The weld metal shall be ground flush and fully covered with the applicable weld deposit overlay per Paragraph 5.4b.(4). of this Standard Specification. The weld deposit overlay shall be at least as thick as the cladding but no greater than twice its thickness.
- (4) Welding in conjunction with a clad lining shall be done with covered electrodes in accordance with ASME Section II, Part C and the following electrode specifications:

ASME Specification		Electrodes	
Cladding	Applied Lining	Alloy To Carbon or Killed Carbon Steel	Alloy to Alloy
SA-263	SA-240, Types 405 or 410S	SFA-5.4 E309L	SFA-5.4 E309L
SA-264	SA-240, Type 304	SFA-5.4 E309	SFA-5.4 E308
SA-264	SA-240, Type 304L	SFA-5.4 E309L	SFA-5.4 E308L
SA-264	SA-240, Type 316	SFA-5.4 E309Mo	SFA-5.4 E316
SA-264	SA-240, Type 316L	SFA-5.4 E309MoL	SFA-5.4 E316L
SA-264	SA-240, Types 321 or 347	SFA-5.4 E309Cb	SFA-5.4 E347
SA-265	SB-127	SFA-5.11 ENiCu-7	SFA-5.11 ENiCu-7

Note: When inert gas shielded or submerged arc processes are used, stainless steel welding shall be in accordance with ASME Section II, Part C, SFA-5.9, with composition similar to those listed above. Nickel-Copper alloy (Monel) welding shall be in accordance with ASME Section II, Part C, SFA-5.14 with a composition similar to that noted above.

- (5) ASME Section VIII, Division 1, Part UNF, Appendix NF, Paragraphs NF-7 and NF-14 are mandatory for nonferrous types of cladding or weld overlay.

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- (6) Internals may be attached directly to the cladding if the stress at the attachment under the design loads is less than one quarter of the allowable stress for the lug, ring, or bracket material. Otherwise, the cladding shall be cut back at least $\frac{3}{4}$ inch (19mm) beyond the toe of the attachment weld and the lug, ring, or bracket shall be attached directly to the base metal. After the attachment is completed, the exposed area shall be completely covered with weld overlay as described in Paragraph 5.4b.(4) of this Standard Specification. The weld deposit overlay shall be at least as thick as the cladding, but no greater than twice its thickness.
- (7) Large nozzles and manways utilizing built-up construction may use integrally bonded cladding for the nozzle neck if the nozzle neck is fabricated from rolled plate.

c. Weld Deposit Overlay

- (1) Weld deposit overlay may be applied by a single or multi-pass procedure and shall comply with the requirements of API RP 582 except as modified or amended by the UOP Specifications. The first pass of multipass austenitic stainless steel weld overlays shall be applied prior to postweld heat treatment when it is required and shall be made with an electrode complying with the requirements of Paragraph 5.4b.(4). The remaining passes shall be made with an electrode of the required lining alloy. Where internals will be attached to the lining, the second layer shall be applied after completion of the final post weld heat treatment. When the second layer is applied after postweld heat treatment, the thickness of the first layer and the heat input of the second pass welding procedure shall be such that the base metal is not affected by the heat and additional heat treatment of the base metal after the second layer is not required.
- (2) The ferrite content of austenitic stainless steel weld deposits shall be controlled to a WRC (Welding Research Council) Ferrite Number (FN) of 3 (5 for Type 347) minimum to 8 maximum. FN control shall be by reference to the DeLong Constitution Diagram for stainless steel weld metals. The limit defined above shall be confirmed by thoroughly checking the final deposits prior to postweld heat treatment with a magnetic instrument calibrated in accordance with the standard procedure defined in AWS A4.2. Readings shall be taken from at least ten randomly selected locations on each shell course and head, and at least one location from each nozzle girth weld, vessel seam overlayed separately (e.g., between clad sections), overlayed support ring, bracket, or lug, and strength weld. At least 6 readings shall be taken at each location.
- (3) Weld deposit overlay shall be applied circumferentially to the vessel and shall be smooth with no notches or undercuts that would act as stress intensifiers. If necessary, longitudinal application in nozzles up to 8 inch NPS is acceptable. Flaws on the surface of the base metal that would interfere with bonding of the overlay shall be removed by grinding.
- (4) The weld deposit overlay procedure shall be qualified on base metal of the same composition as the vessel and thickness of at least one-half of the vessel thickness or 2 inches (50 mm), whichever is less.



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- (5) Nozzles and manways in alloy lined portions of vessels shall be alloy lined and faced. The nozzle facing shall be made with a minimum of a two layer weld deposit in accordance with Paragraph 5.4b.(4). The surface layer shall be weld deposit of the same alloy as the vessel lining and shall be at least as thick as the vessel lining when properly machined. The first pass shall be applied before postweld heat treatment (PWHT) when it is required. When nozzles are lined with ferritic Type 405 or 410S stainless steel, the facing weld deposit shall be made with Type 309L welding electrode. For ring joint flanges with an austenitic stainless steel overlay, the second pass shall be applied after completion of PWHT. The thickness of the first pass and the heat input of the second pass welding procedure shall be such that the base metal is not affected by the heat and additional PWHT of the base metal is not required after the second pass.
- (6) When austenitic stainless steel weld deposit overlay is used in an elevated operating temperature {over 700°F (370°C)} hydrogen service the fabricator shall demonstrate that their procedures and materials provide immunity to lining disbonding. Testing shall be per ASTM G 146. As a minimum, the tests shall be representative of the actual operating conditions (e.g., hydrogen partial pressure, materials and material thicknesses, temperatures, and heating/cooling rates).
- (7) Weld deposit overlay cracks and fissures, and volumetric defects that penetrate through the overlay or are greater than 1/16 inch (1.6 mm) diameter shall be removed. Repaired areas shall be 100% re-inspected by liquid penetrant.
- (8) The weld deposit overlay of each overlaid shell section and head shall be examined in at least two separate, randomly selected, locations to confirm the required chemical analysis of the specified overlay material. Each manual weld overlay, such as those on girth seams, nozzles, and flange facings, shall also be examined in the same manner. After machining, analysis at a depth equal to the specified overlay thickness from the surface exposed to the process environment shall conform to the chemistry requirements (e.g., C, Cr, Ni, Nb (Cb), Mo, V, Ti, and Cu as applicable) for the alloy specified on the UOP Project Specifications. Where weld deposit overlay is applied by more than one welder/welding operator and/or procedure, examination shall include at least 2 samples of deposits made by each welder/welding operator for each procedure.

5.5 Tolerances

- a. Vertical vessels shall be checked for plumbness. The outside surface of the cylinder shall not vary from a straight vertical line by more than 1/4 inch (6 mm) in any 20 feet (6000 mm), nor more than 3/4 inch (19 mm) between any two points in the total length of the vessel. The vertical reference line shall be perpendicular to the vessel's cross section. When the shell thickness is 4 inches (100 mm) or more the variation from a straight line shall not exceed 1-1/4 inches (30 mm) between any two points in the total length of the vessel.
- b. Horizontal vessels shall comply with the criteria of Paragraph 5.5a. of this Standard Specification except that the reference line shall be horizontal and perpendicular to the vessel's cross section.

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- c. The maximum offset (misalignment) for longitudinal joints shall be 1/4 inch (6 mm) and for circumferential joints, 1/2 inch (13 mm).
- d. Vessels with internal trays or grids shall not vary more than plus or minus 1/2 percent from the nominal diameter specified in the UOP Project Specifications, with a maximum variation in diameter from nominal of 1/2 inch (13 mm). Vessels without trays or grids shall not vary more than plus or minus 1 percent from the nominal diameter specified in the UOP Project Specifications, with a maximum variation from nominal diameter of 1 inch (25 mm).
- e. The overall length of the vessel, not including the skirt, shall be within plus or minus the greater of 1/2 inch (13 mm) or 1/64 inch (0.4 mm) per foot (300 mm) of length specified in the UOP Project Specifications, up to a maximum of plus or minus 3/4 inch (19 mm).
- f. The length of skirt shall be within plus or minus 1/4 inch (6 mm) of the specified length.
- g. Nozzle elevations shall be within plus or minus 3/8 inch (10 mm) and orientations shall be within plus or minus 1/4 inch (6 mm) of the specified location. The nozzle projection shall be within plus or minus 1/8 inch (3 mm) of the specified value.
- h. The maximum horizontal or vertical deflection of the machined faces of nozzles from the design plane shall be 1/2 degree or 1/32 inch (0.8 mm), whichever is greater.
- i. Manway elevation, orientation, and projection shall be within plus or minus 1/2 inch (13 mm) from the specified values. Tilt shall be within plus or minus 1/4 inch (6 mm) of perpendicular to the nozzle axis.
- j. The maximum deviation of internal tray supports from a level (horizontal) reference plane shall be plus or minus 3/8 inch (10 mm).
- k. The maximum variation in spacing between supports for adjacent trays shall not exceed 1/16 inch (1.6 mm) per foot (300 mm), with a maximum of 1/8-inch (3 mm).
- l. The maximum variance (distance between high and low points) in individual tray supports with respect to the level plane shall be 0.3 percent of the nominal inside diameter of the vessel, with a maximum of 1/4 inch (6 mm).
- m. The tray support plane shall not vary more than 1 degree from normal to the vessel centerline.

6. NONDESTRUCTIVE EXAMINATION
6.1 Shells, Heads, and Nozzles

- a. Each category A or B pressure containing weld shall be spot radiographed in accordance with ASME Section VIII, Division 1, Paragraph UW-52 as a minimum requirement. Each spot radiograph shall be a minimum of six inches (150 mm) in length. Welds from each welding procedure, welder/welding operator, and shift shall be examined. All welds to be covered by nozzle reinforcing pads and at least one weld



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intersection shall be 100 percent examined (see Paragraph 5.1b.). Nozzle welds shall be spot radiographed or ultrasonically examined when possible. Nozzle welds shall be examined by magnetic particle or liquid penetrant as a minimum requirement.

- b. When the design pressure exceeds 1000 psig {70 kg/cm²(g)} or the vessel is in HF acid service, all pressure containing welds, including nozzle to vessel welds, shall be 100% radiographed.
- c. The use of ultrasonic examination (UT) in accordance with the provisions of ASME Code Case 2235 in place of radiographic examination (RT) is permitted when acceptable to the Owner, Contractor, Authorized (Code) Inspector (AI) and the governing authorities.
- d. When forming occurs after completion of welding, the specified radiography or other nondestructive examination may occur after welding but prior to forming. If so, an additional liquid penetrant or magnetic particle examination of all surfaces is required after forming.
- e. The specified radiography of welds may be performed before or after postweld heat treatment (PWHT). If performed before PWHT, an additional radiographic or, alternatively, ultrasonic examination shall be performed after PWHT.
- f. Welds joining non-pressure containing components to pressure containing components shall be 100% liquid penetrant or magnetic particle examined (after postweld heat treatment. when PWHT is required) This applies to permanent and non-permanent (e.g., lifting lugs, trunions, etc) attachments on the inside and outside of the vessel.
- g. When temporary attachments are removed, the area shall be ground flush with the surrounding shell surface and liquid penetrant or magnetic particle examined.
- h. When the design pressure exceeds 1000 psig {70 kg/cm²(g)} or the shell thickness exceeds 2 inches (50mm), all welded joints in shells and heads, all nozzle joints, and all repair welds shall be 100 percent ultrasonically examined after the final postweld heat treatment.
- i. When the shell thickness exceeds 2 inches (50mm) or a lining is present, ultrasonic calibration shall utilize the calibration block provided with the vessel (see Paragraph 4.2d).
- j. When the design pressure exceeds 1000 psig {70 kg/cm²(g)} or the shell thickness exceeds 2 inches (50mm), magnetic particle examination shall be performed in accordance with the following:
 - (1) Examination shall be in accordance with ASME Section VIII, Division 1, Appendix 6. If prods are used, the tips shall be carbon steel, not lead or copper.
 - (2) Plate edges shall be examined for laminations and injurious flaws after trimming and prior to welding. Laminations and injurious flaws shall be removed by chipping or grinding and the plate re-examined.

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- (3) The initial root pass of double butt welds, including root tack welds, shall be chipped, ground, and/or gouged to sound metal. The back-chipped welds, welding groove, and plate edges shall be examined to ensure that all cracks, pin holes, porosity, and other defects have been removed prior to commencing welding on the second side.
- (4) Root weld areas shall be examined before and after removal of defects.
- (5) Attachments to the vessel, including nozzle and support attachment welds, shall be examined.

6.2 Alloy Lining

- a. Weld deposit overlay, whether by manual or automatic procedures, shall be 100% liquid penetrant (PT) examined prior to postweld heat treatment in accordance with the methods described in ASTM E 165. When the overlay involves two passes (layers) and the procedure uses an intermediate heat treatment with cooling to room temperature prior to applying the second layer, each layer shall be 100% PT examined. Weld deposit overlay shall also be spot PT examined {a minimum of 10% of the surface, including no less than 1 square foot (0.1 square meter) in each 10 square feet (1 square meter) or fraction thereof} after final heat treatment and pressure testing. Weld deposit overlay machined surfaces shall be 100% PT examined after final heat treatment. Flange facings need not be included in the spot examination after hydrotest. In areas where attachments will be welded directly to the overlay, the overlay within 2 inches (50mm) of the attachment weld shall be 100% ultrasonically examined from the inside after postweld heat treatment. All unbonded areas at attachments shall be repaired and re-examined. The final PT at attachments shall be performed after final postweld heat treatment and pressure testing.
- b. In addition to the requirements of Paragraph 6.2a, when the hydrogen partial pressure exceeds 50 psia {3.5 kg/cm²(a)}, the design temperature exceeds 600°F (315°C), and an austenitic stainless steel weld deposit overlay is used, the overlay shall be 100 percent ultrasonically examined for lack of bond. The examination shall occur after the final postweld heat treatment and shall be from the outside. Examination shall be in accordance with ASME Section II, Part A, SA-578. The acceptance level shall be S7. Indications of a lack of bond shall be recorded and re-examined from the inside. Indications of an unbonded area that exceed the acceptance criteria shall be repaired by weld deposit overlay and re-examined.
- c. When integrally bonded cladding is used, a minimum of 10% of the clad surface, including no less than 1 square foot (0.1 square meter) in each 10 square feet (1 square meter) or fraction thereof, shall be ultrasonic examined from the exterior for lack of bond after forming and before the final postweld heat treatment. Ultrasonic examination shall be in accordance with ASME Section II, Part A, SA-578. The acceptance level shall be S6. In areas where attachments are to be welded directly to the cladding, the cladding within 2 inches (50mm) of the attachment weld shall be 100% ultrasonically examined from the inside. All unbonded areas where attachments will be welded directly to the cladding and other areas that exceed the acceptance criteria shall be repaired. Repairs shall be performed by weld deposit overlay in accordance with Paragraph 5.4b.(4) of this Standard Specification. When repairs in excess of 5 percent of the total examined area are required, the entire clad surface of



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the vessel shall be 100 percent ultrasonic examined. Ultrasonic examination shall be in accordance with ASME Section II, Part A, SA-578. The acceptance level shall be S7. Repaired areas and weld deposit overlay at weld seams shall be 100% liquid penetrant (PT) examined in accordance with ASTM E 165. At attachments, the final PT shall be performed after final postweld heat treatment and pressure testing.

- d. When the hydrogen partial pressure exceeds 50 psia {3.5 kg/cm²(a)}, the design temperature exceeds 600°F (315°C), and an austenitic stainless steel cladding is used, clad surfaces shall be 100 percent ultrasonically examined for lack of bond. The examination shall occur from the outside after forming and before the final postweld heat treatment. The ultrasonic examination shall be in accordance with ASME Section II, Part A, SA-578. The acceptance level shall be S7. Suspected unbonded areas shall be recorded and reexamined from the inside surface. Indications of unbonded areas that cannot be encompassed within a 3-inch (75 mm) diameter circle shall be recorded, repaired by weld deposit overlay in accordance with Paragraph 5.4b.(4) of this Standard Specification, and re-examined. All unbonded areas within 2 inches (50mm) of where attachments will be welded directly to the cladding shall also be repaired and reexamined. In addition, the lining shall be spot ultrasonically examined in accordance with Paragraph 6.2c. of this Standard Specification after final postweld heat treatment. The acceptance level shall be S6. Repaired areas and weld deposit overlay at weld seams shall be 100% liquid dye penetrant (PT) examined in accordance with ASTM E 165. At attachments, the final PT shall be performed after final postweld heat treatment and pressure testing.
- e. Alloy lining on support rings, lugs, and brackets shall be 100 percent ultrasonically examined from the inside after final postweld heat treatment. Unbonded areas shall be repaired and re-examined.

7. TESTING
7.1 Testing Medium and Conditions

- a. Hydrostatic test methods shall be used for pressure testing. Pneumatic testing may be used only when hydrostatic testing is not feasible and the owner, contractor, and fabricator concur. When pneumatic testing is performed, appropriate safety measures shall be taken, considering the danger presented by the stored energy of the compressed gas.
- b. The minimum METAL temperature during pressure testing shall be at least 30°F (17°C) above the brittle-ductile transition temperature of all pressure containing components at the time of pressure testing. The brittle-ductile transition temperature shall be determined by Charpy V-notch impact testing. If the required impact test data is not available, the pressure test temperature shall be in accordance with either (1) or (2) below.
 - (1) 30°F (17°C) above the minimum design metal temperature (MDMT) or the temperature at which impact testing was performed, if lower than the MDMT.



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(2) 30°F (17°C) above the temperature for which impact testing is not required for any of the vessel's components in accordance with ASME Section VIII, Division 1, Figure UCS-66 (not the exemption temperatures listed for carbon steels in ASME Section VIII, Division 1, Section UG-20).

- c. The hydrostatic test medium shall be clean, fresh, potable water. The water used for hydrostatic testing of austenitic stainless steel lined vessels shall have a chloride content less than 50 ppm (parts per million). If the chloride content is greater than 50 ppm and less than 250 ppm, a sufficient quantity of sodium nitrate shall be added to provide a 0.5% by weight sodium nitrate solution. Water with a chloride content of greater than 250 ppm shall not be used for hydrotesting vessels containing austenitic stainless steel. Vessel(s) shall be thoroughly dried immediately after draining to prevent the possibility of evaporation and concentration of chlorides. Heat drying is not permitted.
- d. The temperature of the test water at all locations shall be at least 50°F (10°C) at all times during hydrostatic testing. Other test mediums shall be at least 20°F (11°C) above their freezing or, for pneumatic testing, dew point temperature.

7.2 Procedure

- a. Pressure testing shall be performed after the completion of postweld heat treatment.
- b. Pressure testing shall be completed before primers, paint, or other coatings are applied
- c. Hydrostatic testing shall be completed before the installation of internal refractory linings. Pneumatic testing may take place with refractory linings present, however the weld seams shall not be covered with refractory.
- d. The welds of welded attachments provided with vent holes (e.g., reinforcing pads, slip-on flanges) shall be leak tested using 15psig {1 kg/cm² (g)} pneumatic pressure and a bubble forming solution prior to postweld heat treatment and final hydrostatic test.
- e. Sleeve linings for nozzles shall be pneumatically leak tested as described in Paragraph 7.2d to prove the soundness of the welds. In lieu of this, the welds may be inspected by liquid penetrant. Cracks and porosity shall be repaired and the liner re-tested and inspected.
- f. Test holes in sleeves shall not be seal welded until all trapped moisture is removed.
- g. Horizontal vessels shall be supported only by their permanent saddles during hydrotest, i.e., temporary supports are not permitted.
- h. The stress in any pressure containing component shall not exceed 90% of the material's minimum yield strength multiplied by the applicable joint efficiency at any time during pressure testing.
- i. Vertical vessels that are to be pressure tested in the horizontal position shall be supported so that local stresses in the shell do not exceed 90% of the minimum yield strength of the material multiplied by the applicable joint efficiency at any time.



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- j. The procedure for filling the vessel shall prevent the formation of air pockets or damage/dislocation of internals during liquid filling.
- k. The temperature of the test medium and the vessel shall be equalized prior to the commencement of pressure testing.
- l. The vessel shall be drained and thoroughly dried immediately upon the completion of pressure testing. The procedure for draining the test fluid shall prevent development of vacuum pressure within the vessel or its internals. The procedure shall prevent damage to or dislocation of the internals.

8. ADDITIONAL REQUIREMENTS FOR STORAGE SPHERES AND BULLETS**8.1 General Requirements**

- a. Storage spheres shall be supported so that the bottom is no less than 3 feet (1000 mm) above finished grade.
- b. A 24 inch manway shall be provided at the top and bottom of each sphere. Provide a means to handle the blind flange.
- c. Provide a minimum corrosion allowance of 1/16 inch (1.6mm) on all storage spheres and bullets.

8.2 Capacity

- a. The nominal capacities given in the UOP Project Specifications include allowances for vapor space and inaccessible bottom space. No further allowance is required.
- b. Spheres shall be strapped over their full height before being placed into service. A gauge table shall be provided.