



PRESSURE VESSEL SPECIFICATION

FOR THE

CARTAGENA REFINERY EXPANSION PROJECT

CB&I CONTRACT NO. 166000

Prepared by: David Came

CB&I

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1.0 GENERAL

- 1.1 This document, when accompanied by applicable supplements, vessel design drawings and typical details, constitutes a complete set of specifications outlining acceptable construction for pressure vessels. All requirements of the ASME Code, Section VIII, Division 1 or Division 2 (when specified), for Pressure Vessels shall be followed whether or not the vessel is to be Code stamped.
- 1.2 In case of conflict between this document and the individual vessel design drawing/data sheet, the vessel design drawing/data sheet shall govern.

2.0 REFERENCES

Applicable sections of the following standards and publications shall be considered as a part of this design standard. The latest edition or addenda of each document applies (unless otherwise specified):

American Society of Mechanical Engineers
 B16.5 - Steel Pipe Flanges and Flanged Fittings, NPS ½" - NPS 24"
 B16.47 - Large Diameter Steel Flanges
 Section II - Material Specifications
 Section V - Nondestructive Examination
 Section VIII Division I - Rules For Construction of Pressure Vessels
 Section VIII Division 2, 2004 Edition, 2006 Addenda - Alternative Rules For Construction of Pressure Vessels (with Code Case 2575)
 Section IX - Welding and Brazing Qualifications
 American Institute of steel construction
 Uniform Building Code 1997
 NSR-98 – Ley 400 de 1997, Decreto 33 de 1998, Decreto 34 de 1998 (Wind & Seismic)
 American Welding Society
 AWS A2.2 - Nondestructive Testing Symbols
 Steel Structures Painting Council
 Steel Structures Painting Manual
 Welding Research Council (WRC) 107/297

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3.0 VESSEL FABRICATOR RESPONSIBILITIES

3.1 General

- 3.1.1 Conformance to the latest national and local codes and legal requirements is the responsibility of the vessel fabricator.
- 3.1.2 The vessel fabricator shall transmit all vendor data electronically and shall include an appropriate transmittal cover letter which references the CONTACTOR's job number and purchase offer number. Vendor data posted on a vendor website for extraction by the CONTRACTOR's Vendor Data Department is not an acceptable substitute.

3.2 Scope of Work

- 3.2.1 The vessel fabricator shall perform all required design calculations and provide detailed fabrication drawings for each vessel.
- 3.2.2 The vessel fabricator shall perform vessel fabrication using approved weld procedures and qualified welders. Vessel fabrication may not be subcontracted to outside companies without written approval from Purchaser.
- 3.2.3 The vessel fabricator shall furnish and install the following clips and attachments when listed on the vessel design drawings:
- External clips for ladders, platforms, pipe supports and guides.
 - Internal baffles, vortex breakers, distributors and other welded in internals.
 - Internal supports for packed beds, trays or mist eliminators.
 - Manway and vessel davits.
 - Lifting devices for erection.
 - Insulation supports and welding studs or blank nuts for fireproofing.
 - Other special brackets as detailed on the vessel design drawings or purchase offer documents.
- 3.2.4 The vessel fabricator shall perform all NDE examination and testing as required by the ASME Code, the vessel design drawing, and the purchase offer documents using properly qualified personnel or subcontractors.
- 3.2.5 The vessel fabricator shall furnish gaskets and external bolting for all manways, handholes, and other openings with a blind flange or bolted covers. One spare service gasket shall be furnished for all blinded openings unless otherwise noted on vessel design drawings or purchase offer.

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3.2.6 The vessel fabricator shall perform all required surface preparation and painting of completed vessel as required on the vessel design drawings or purchase offer documents.

3.2.7 The vessel fabricator shall furnish anchor bolt layout templates. Bolt hole size to be 1/8" larger than anchor bolt diameter.

4.0 FABRICATION DRAWINGS

4.1 Vessel design drawings submitted to the fabricator are not intended to cover complete details. The fabricator shall make detailed calculations and shop drawings for each vessel.

4.2 The vessel fabricator shall submit for approval fabrication drawings, welding procedures weld maps, repair procedure &, NDE / testing procedures before starting fabrication. CONTRACTOR will not be responsible for costs incurred for materials ordered or work performed by the fabricator prior to receiving approval of these documents.

4.3 Fabrication drawings shall have the tray supports and nozzles numbered and lettered identically with the vessel design drawings.

4.4 Complete vessel details shall be submitted including complete weld details, all vessel internal or external attachments supplied by the fabricator, inspection requirements, painting, and required shipping preparations. Weld procedure identification numbers shall be clearly identified on a designated weld map or shown in the tail of all welding symbols.

4.5 The vessel fabricator shall show the location of all circumferential and longitudinal welded joints on the shop drawings submitted for approval.

4.6 If nondestructive testing symbols are used on the vessel fabrication drawings, the symbols shall be as specified in AWS A2.2.

4.7 The vessel fabricator shall show on the vessel fabrication drawings the fabrication data of the heads (i.e. hot or cold forming, heat treatment, etc.).

5.0 NAMEPLATE STAMPING

5.1 The vessel fabricator shall stamp the following information on a stainless steel nameplate that shall be affixed to a support bracket of the same material as the shell or head and welded to the vessel:

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- Required markings as defined by ASME Code Section VIII, Division 1 or 2
- Purchaser's Item Number
- Purchaser's Offer Number
- Shell Material Specification
- Shell Thickness (New)
- Head Material Specification
- Head Minimum Thickness (New)
- Corrosion Allowance
- Hydrostatic Test Pressure

5.2 The support bracket shall project from the vessel a distance equal to the thickness of the insulation shown plus one inch, or three inches minimum.

5.3 The bracket shall be seal welded inside and outside to the vessel shell or head.

5.4 The bracket shall normally be located on the shell just above the lowest manhole or inspection opening on vertical vessels and adjacent to the manhole or inspection opening on horizontal vessels.

6.0 MATERIALS

6.1 General Requirements

6.1.1 All material shall be new and conform to specifications listed on the vessel design drawings, with any deviations or alternates clearly indicated.

6.1.2 The material shall comply with the relevant certificates per European Standard EN 10204 3.1.B, for the following parts, unless otherwise required by MR or local Authority:

- All pressure retaining parts
- Skirts including anchor chairs and base ring
- All elements directly welded on pressure parts
- Trays from alloy steel and non ferrous material
- Loaded support beams and removable catalyst grids
- Support Brackets

For all others remaining parts certificate 2.2 is required.

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Only original Material Test Reports (MTR) from the source of supply shall be acceptable for plate, non-standard forgings supplied directly from the mill. For nonstandard forgings, the original MTR for the billet shall be accompany by the MTR for the processed forgings. For the components supplied from stock, MTRs shall be stamped "Certified True Copy" by the stockist as representing the MTRs from the source of supply.

6.1.3 Material Substitution

- The vessel fabricator must formally request in written format any request for material substitutions. The request for the material substitution must be accompanied by complete information including corrected thickness, and must state the complete ASME (or ASTM) designation including any applicable grade, type, quality, or finish. Any cost impact, material availability or delivery issues shall also be clearly stated in the request for material substitution.
- CONTRACTOR must formally approve in written format all material substitution requests before the material is utilized in fabrication.
- CONTRACTOR shall not be held responsible for increased costs arising from material substitution unless formally approved by CONTRACTOR.

6.1.4 Rolled plate nozzle necks and reinforcing pads shall be the same material as specified for the vessel shell or head to which they are attached.

6.1.5 Pipe or tubing for heating or cooling coils shall be seamless. They shall be of the same quality materials as specified for internal pipe and shall have bolting and gaskets conforming to ANSI Standards.

6.1.6 Internal flanges shall have commercial quality bolts and nuts made from the same type material as the flanges. Where dissimilar material flanges are joined, material for the bolts and nuts shall be the same type as the flange with the lower alloy content.

6.1.7 For internal flanges, stud bolts with hex nuts may be substituted in place of hex head bolts. Stud bolts, if used, require two hex nuts on each end or a single hex nut and tack weld.

6.1.8 External bolting for covered or blinded flanges shall be stud bolts with two hex nuts each, or studs with one hex nut each when required for pad-type openings.

6.1.9 External supports and clips attached to pressure retaining vessel components shall be the same type material as the vessel part to which they are attached. Alloy steel vessels shall have an isolation pad of the same alloy material as the vessel shell between carbon steel parts and the vessel. The isolation pad shall have a minimum thickness of 1/4".

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- 6.1.10 Skirt supports attached to alloy steel vessels, shall have as a minimum, a two foot section of alloy skirt material attached to the head.
- 6.1.11 Vessels fabricated from welded pipe shall be furnished with all necessary ASME code data including welding procedures, qualifications, mill test reports, etc.
- 6.1.12 Plate materials mechanical properties shall be verified using test coupons prepared from each heat of plate.
- 6.1.13 Forging materials mechanical properties shall be verified per ASTM material specification unless otherwise noted.
- 6.1.14 Positive Material Identification (PMI) shall be performed on materials at the source of supply according to the Specification 000-SP-MU10-0013.
- 6.1.15 Gaskets shall be asbestos free

6.2 Carbon Steel Vessels

- 6.2.1 The minimum acceptable quality for pressure retaining plate material is SA 516 unless otherwise noted on the vessel specification drawing.
- 6.2.2 The minimum acceptable quality for pressure retaining pipe material is SA 106 Grade B unless otherwise noted on the vessel specification drawing.
- 6.2.3 The minimum acceptable quality for pressure retaining flanges or forging material is SA 105 unless otherwise noted on the vessel specification drawing.
- 6.2.4 The use of Thermo-Mechanical Controlled Process (TMCP) steel shall be subject to CONTRACTORS review and approval.

6.3 Low Alloy Steel Vessels

- 6.3.1 The minimum acceptable quality for pressure retaining plate material is SA 387 Grade 11, class 2 unless otherwise noted on the vessel specification drawing.
- 6.3.2 The minimum acceptable quality for pressure retaining pipe material is SA 335 Grade P11 unless otherwise noted on the vessel specification drawing.

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6.3.3 The minimum acceptable quality for pressure retaining flanges or forging material is SA 182 Grade F11 normalized and tempered unless otherwise noted on the vessel specification drawings.

6.3.4 Equipment that has a maximum temperature within the range 800°F (425°C) – 1125°F (600°C) and fabricated from P-No. 4, P-No. 5A & 5C materials shall be of controlled purity and designed and fabricated to minimize in-service temper embrittlement and low ductility HAZ cracking. The following requirements shall be applied:

6.3.4.1 For Low Alloy, the base material shall be supplied in the normalized, normalized and tempered, accelerate cooling and tempered or quenched and tempered condition. Tempering shall be performed at a temperature at least 50°F (10°C) higher the upper limit of the temperature range for PWHT.

6.3.4.2 All non-standard forgings shall conform to ASTM A336.

6.3.4.3 The chemistry restriction on product analysis shall be specified for pressure retaining components, in addition to the requirements of material specification:

Element	P-No. 4	P-No.5A	P-No. 5C
C	0.05-0.14%	0.05-0.15%	0.05-0.15%
P	0.012% max.	0.012% max.	0.012% max.
Sn	0.015% max.	0.015% max.	0.015% max.
As		0.008% max.	0.008% max.
Sb		0.008% max.	0.008% max.
S	0.01% max.	0.007% max.	0.007% max.
Cu		0.2% max.	0.2% max.
Ni		0.3% max.	0.25% max.
(Si+Mn)x(P+Sn)x10 ⁴	150 max.	120 max.	100 max.

6.3.4.4 P-No. 5A and P-No. 5C base materials shall be vacuum carbon dioxides to minimize silicon content.

6.3.4.5 The tensile test shall be performed on coupon submitted to simulate maximum heat treatments provided in fabrication including any hot forming or intermediate heat treatments performed between 750°F (400 °C) and 1125°F (600 °C) plus two additional PWHT cycles.

6.3.4.6 The impact test shall be performed on plate, pipe, fittings, forging and welds with a minimum thickness greater than 1/2" (13 mm). The test shall be performed on coupons that have submitted to simulate minimum heat-treatments provided in fabrication. For nonstandard

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forging, to demonstrate isotropic toughness properties, the impact testing shall be performed in three directions (longitudinal, radial and tangential).

The acceptance limits of impact value are:

- P-No. 4: 34J ave. / 28J min. at 0°F (-18°C),
- P-No. 5: 54J ave. / 48J min. at -20°F (-29 °C).

6.3.4.7 The consumable material for welds shall meet the following requirements:

C 0,06-0,14%
P 0,010% max.
(10P+5Sb+4Sn+As)/100 15ppm max.
%Mn+%Si (P No. 5A & 5C) 1,2 wt% max. (1,4% max for GTAW solid wire).

Diffusible hydrogen content of deposited consumable material shall be maximum 4,0 mL(H₂)/100g.

6.3.5 The minimum tempering temperature for all 1 1/4 Cr -1/2Mo materials shall be 1300°F (705 °C).

6.3.6 Unless otherwise specified in the purchase offer, all 1 1/4 Cr -1/2 moly vessels to receive PWHT regardless of thickness @ 1225°F (649 °C) minimum, 1275°F (663°C) with holding times in accordance with UCS-56. Maximum weld and HAZ hardness after PWHT shall be limited to 225 BHN.

6.3.7 The deliberate addition of unspecified micro alloying elements such as columbium, vanadium, niobium, titanium or boron to enhance material properties is prohibited without prior approval.

6.3.8 Impact test coupons shall be tested at the minimum required fabrication PWHT cycles. Yield and Tensile properties shall be tested with maximum PWHT cycles.

6.3.9 All required NDE other than radiography shall be performed after vessel PWHT.

6.3.10 The use of Thermo-Mechanical Controlled Process (TMCP) steel shall be subject to CONTRACTORS review and approval.

6.3.11 For vessel with design temperature greater than 650°F (350°C) and is quenched and tempered, hot tensile test is required on coupons submitted to simulate maximum heat treatments provided in fabrication including all hot forming or intermediate heat treatments performed between 750°F(400°C) and 1100°F(600°C) plus two additional PWHT cycles.

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6.4 Alloy steel vessels

- 6.4.1 All pressure retaining alloy materials shall be as specified on the vessel specification drawings.
- 6.4.2 All austenitic alloy materials shall be confirmed by magnetic testing. Any materials with positive results shall be checked by methods outlined in Positive Material Identification (PMI) specification 000-SP-MU10-013 to ensure compliance with the required material specification.
- 6.4.3 L grade austenitic stainless steel is mandatory for welded equipment/components. Dual Certification is acceptable
- 6.4.4 For welded 400 series stainless steel the low carbon type shall be provided such as Type 405 (UNS S40500) or Type 410S (UNS S41008). For non-welded components the materials Type 410 (UNS S41000) are acceptable.
- 6.4.5 The random inspection shall be performed before the material shipment, in according to ASTM A380 specification to ensure no iron contamination is present.

6.5 Clad plate material

- 6.5.1 Hot Rolled bonding is the preferred manufacturing method. Other forms of bonding may be used with prior approval.
- 6.5.2 The material shall comply with requirements of ASME SA-263, SA-264 or SA-265.

6.6 Ni-base Alloy and Titanium

- 6.6.1 The components shall be cleaning to avoid any low melting point contamination.
- 6.6.2 The random inspection shall be performed before the material shipment, in according to ASTM A380 specification to ensure no iron contamination is present. The Ferroxyl Test is required for Titanium material.

6.7 Material Requirements for Polythionic Acid attack

- 6.7.1 Where austenitic stainless steel have been selected, chemically stabilized type (321 SS and 347 SS) are required for process in which the normal maximum sustained operating temperature exceeds 800°F (425°C), because of their higher resistance to intergranular

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corrosion and stress corrosion cracking caused by polythionic acid attack. This kind of attack, can occur, especially during the shutdown periods as a result of sensitization during service.

- 6.7.2 However for maximum resistance to sensitization, types 321 and 347 SS shall be subjected to a stabilizing heat treatment.

6.8 Test requirements

- 6.8.1 Material impact testing is required when specified by the ASME Code requirements or when specified on the vessel design drawing or purchase offer documents. Testing and acceptance shall be in accordance with ASME code requirements as a minimum.
- 6.8.2 For materials subjected to impact testing and post weld heat treatment, test specimens shall be subjected to the minimum expected fabrication heat treatment cycle.
- 6.8.3 Additional material testing shall be as specified on the vessel design drawings or purchase offer documents.
- 6.8.4 Unless otherwise specified in the purchase offer, all vessels shall be subjected to spot radiography per ASME Section VIII, Division 1, paragraph UW-52 as a minimum.

7.0 DESIGN

7.1 General

The vessel shall be designed and stamped with the Maximum Allowable Working Pressure (MAWP) as defined by the ASME code. The MAWP shall be limited only by the head, shell or flanges.

7.2 Design pressure

- 7.2.1 The design pressure shall be as specified on the vessel design drawing/data sheet.
- 7.2.2 The design pressure for each pressure retaining component shall include any static pressure from the maximum anticipated operating liquid level. The fluid specific gravity shall be 1.0 unless noted on the vessel design drawings.
- 7.2.3 For vessels without trays, the operating liquid level shall be equal to the inlet nozzle elevation unless noted on the vessel design drawings. For vessels with trays, the operating liquid level shall be one foot below the lowest tray unless noted otherwise on the vessel design drawing.

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7.3 Design temperature

- 7.3.1 The maximum design temperature shall be as specified on the vessel design drawings. The fabricator shall verify that the vessel materials and flange ratings specified on the vessel design drawing are acceptable per the applicable ASME code section for the specified design conditions.
- 7.3.2 The required minimum design metal temperature shall be as specified on the vessel design drawings. The fabricator shall verify that all impact testing requirements of the ASME code are met. All ASME code exemptions utilized to avoid charpy impact testing of material or welding operations shall be clearly indicated in the vessel calculations.

7.4 Corrosion allowance

- 7.4.1 Vessel corrosion allowances shall be as specified on the vessel design drawings. The stated corrosion allowance shall apply to all pressure retaining parts.
- 7.4.2 Claddings or other applied linings shall be considered as corrosion allowance only. Credit shall not be taken for the strength of cladding or lining when performing ASME Code pressure calculations.
- 7.4.3 Corrosion allowance on removable internal parts shall be half of the required vessel corrosion allowance.
- 7.4.4 Corrosion allowance on non-removable internal parts shall be the same as the vessel corrosion allowance applied to each exposed pipe and plate surfaces.
- 7.4.5 When a corrosion allowance greater than 1/8" (3 mm) is specified, the Supplier shall verify the thickness of standard blind flanges.

7.5 Vessel Heads

- 7.5.1 Vessel heads shall be the type specified on the vessel design drawings. All ellipsoidal heads shall be 2:1 ratio.
- 7.5.2 Vessel heads shall be of one-piece construction unless specifically approved by CB&I. If approved, weld seams in formed heads shall be 100% radiographically examined.

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- 7.5.3 When not specified on vessel design drawings or sketches, the minimum thickness of head material used in the construction of carbon steel vessels shall be the greater of 3/16" or the calculated minimum thickness, excluding corrosion and forming allowances.
- 7.5.4 When not specified on vessel design drawings or sketches, the minimum thickness of head materials used in construction of alloy steel vessels shall be the greater of 1/8" or the calculated minimum thickness, excluding corrosion and forming allowances.
- 7.5.5 When seamless pipe fittings are used for vessel heads, the minimum material thickness shall be the greater of 1/8" or the calculated minimum thickness, excluding corrosion and forming allowances.

7.6 Vessel shells

- 7.6.1 When not specified on vessel design drawings or sketches, the minimum thickness of shell material used in the construction of carbon steel vessels shall be the greater of 1/4" or the calculated minimum thickness, excluding corrosion allowance.
- 7.6.2 When not specified on vessel design drawings or sketches, the minimum thickness of shell materials used in construction of alloy steel vessels shall be the greater of 3/16" or the calculated minimum thickness, excluding corrosion allowance.
- 7.6.3 When vessels are constructed using seamless pipe, the minimum head and shell material thickness shall be the greater of 3/16" or the calculated minimum thickness, excluding corrosion and thinning allowances.
- 7.6.4 Circumferential and longitudinal weld seams shall be located such that visual inspection can be made with all internal equipment in place. All attempts shall be made to avoid intersection of shell welds and nozzles or other attachment welds. Any attachment weld that will fall within 6" of a pressure boundary weld requires prior engineering review and approval. Longitudinal seams for trayed vessels shall not be located behind downcomers. Circumferential seams shall clear tray support rings by 2" minimum. Longitudinal seams shall be spaced a minimum 12" apart.

7.7 Nozzles

- 7.7.1 All nozzles shall be flanged, unless otherwise noted. For carbon steel and low alloy vessels, weld neck flanges or long weld neck type nozzles are preferred. Nozzles 2" and smaller shall be long weld necks. If specified, slip-on flanges may be used in non-cyclic conditions for class 150 rating and when design temperature is between 32°F (0°C) and 500°F (260°C), if written

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approval is obtained. Slip-on flanges shall be welded both internally and externally and have a 1/8" vent hole drilled in the flange hub prior to welding.

- 7.7.2 Nozzles specified as butt weld for field connection shall be beveled for welding and details of bevel shall be shown on fabricator's drawings.
- 7.7.3 Couplings shall be 6000 lb. minimum for carbon steel and low alloy vessels and 3000 lb. minimum for stainless steel vessels. Couplings shall be screwed, forged steel, full couplings.
- 7.7.4 Flanges for external nozzles or other pressure flanges NPS 24 and smaller shall be in accordance with ASME B16.5. Flanges for external nozzles or other pressure flanges shall be in accordance with ASME B16.47 Series A. Flange sizes over NPS 60 and any special design flange require calculations for the design/test and gasket seating conditions in accordance with ASME Section VIII, Divisions 1 and 2, Appendices 2 and 3, respectively. Any flange over NPS 60 or special designed flange shall be detailed and shown on the Supplier's vessel drawings or data sheets. Special designed flange shall be in accordance with the ASME code. Flanges over NPS 60 shall be of the forged hub type with through bolting, unless noted otherwise.
- 7.7.5 The finish of the gasket contact surface of vessel nozzle flange facing shall conform to ASME B16.5 or ASME B16.47. The surface finish of raised face flanges shall be limited to 125 - 250 AARH.
- 7.7.6 Gaskets for raised face flanges shall have the O.D. and I.D. conforming to the dimensions specified by ASME B16.5, Annex "E". The O.D. of the gasket shall extend to the edge of the bolts or shall be provided with a centering ring to center the gasket.
- 7.7.7 Nozzles necks and their reinforcements shall be attached to the vessel with full penetration welds. Back-up strips, if used, shall be of the consumable type only.
- 7.7.8 The following connections shall be trimmed flush with the inside surface of the vessel (unless otherwise noted):
- Drain and vent connections.
 - Connections on bottom heads of vertical vessels and on bottom heads of boot legs on horizontal vessels.
 - Connections on the bottom of horizontal vessels that are located on the vertical centerline.
 - Connections on lined vessels.
 - Connections within trayed sections.

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- 7.7.9 Nozzles, on bottom heads, attached to internal pipe shall have a 1/4" drain hole drilled adjacent to the inside surface of the vessel, if necessary for draining.
- 7.7.10 The edge at the inside diameter of flush-trimmed openings, including manways, shall be rounded to a minimum of 1/8" radius.
- 7.7.11 The edges at the inside diameter and outside diameter of internally projecting nozzles, including manways, shall be rounded to a minimum of 1/8" radius except for pipe less than 1/4" thick, which shall be rounded to a radius equal to one-half the wall thickness.
- 7.7.12 Nozzle necks having a heavier thickness than the thickness of hub at the small end of welding neck flange shall have the inside diameter tapered at a 3:1 ratio by machining or grinding unless the thickness difference is 1/32" or less, in which case the sharp shoulder may be removed with a grinder after welding. This requirement is also applicable at the joint of welding fitting to pipe. When drawings or contract specifications require that all inside diameters match, special fittings with matched bores shall be used.
- 7.7.13 Vessel nozzle projections shall be in accordance with Standard Detail 000-SP-MV09-0001-55.
- 7.7.14 Nozzles (made by pipe) smaller or equal to 1½" NPS shall be braced as per CONTRACTOR standard.
- 7.7.15 Bolt holes of the nozzle and manhole flanges shall always straddle the principal centerlines of the vessel or their parallel lines.

7.8 Inspection Openings

- 7.8.1 Unless otherwise noted on the vessel design drawings or purchase offer documents, inspection openings shall be provided as follows:
- Vessels up to 3'-0" diameter – (2) 4" NPS inspection openings
 - Vessels 3' - 0" to 3'-6" diameter – (1) 18" nominal diameter manway
 - Vessels over 3'-6" diameter – (1) 24" nominal diameter manway
- 7.8.2 Flanged or threaded openings from which piping or attached instruments may be removed may be used in place of inspection openings with approval of CONTRACTOR.
- 7.8.3 Vessels with removable internals shall have a manway or flanged end opening sized and located to provide access to the internals.

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7.8.4 Vessels with internal trays shall have additional manways located at feed points.

7.8.5 All manways shall normally be provided with davits (preferred) or hinges.

7.9 Horizontal Vessels

7.9.1 Horizontal pressure vessels shall be supported on two (2) saddles. Stresses in shells of horizontal vessels shall be analyzed by the fabricator in accordance with "Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports" by L.P. Zick. Supports shall be designed to support the vessel when tested full of water.

7.9.2 Unless otherwise specified on the vessel design drawings/data sheet or purchase offer documents, wind and seismic loadings shall be included when designing saddle supports and shall be in accordance with UBC 1997 with reference to NSR-98.

7.9.3 Stresses due to thermal expansion and frictional forces due to sliding supports shall be considered in the design.

7.9.4 The transition plate, if required, for support saddles and brackets shall be made of the same material specification as the vessel.

7.10 Vertical Vessels

7.10.1 Seams in supporting skirts shall be double-butt welded. Connections between skirts and vessels shall be made with a smooth flat-faced fillet weld; width of weld to be equal to skirt thickness, and height of weld equal to twice the width. The outside diameter of the skirt shall be equal to the outside diameter of the bottom shell course.

7.10.2 Vertical vessels shall be designed to be self-supporting for wind and seismic conditions. Unless otherwise specified on the vessel design drawings/data sheet or purchase offer documents, wind and seismic loadings shall be in accordance with UBC 1997 with reference to NSR-98.

7.10.3 The maximum deflection for vertical vessels shall not exceed 6" per 100 feet of height.

7.10.4 Weight and wind loadings for access platforms and ladders shall be added to the vessel calculations as follows unless otherwise noted in the purchase offer documents or vessel design drawings/data sheet:

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- Include (1) 180 x 4' -0" wide platform below all manways or dump nozzles that are more than 12 foot above grade.
- Include a square platform across the top head of the vessel when relief nozzles or a manways are located in the top head. Platform size to be equal to the vessel insulated outside diameter as a minimum. The platform size shall be increased when required to provide a two foot clearance in any direction around the top head nozzle flanges.
- Include (1) 90 X 3' -0" wide platform when ladder spans would otherwise exceed 30' -0" in length.
- All platforms shall be calculated using a design weight of 18 PSF for the platform area plus 15 lb/ft for 42" handrailing at the perimeter of the platform. Ladders weight shall be calculated using a design weight of 25 lb/ft.

7.10.5 Weight shall be included for each service nozzle (inlets, outlets, etc) to account for attached piping. Piping shall be assumed full of water for liquid services and should extend from the nozzle elevation to the bottom head seam.

7.10.6 The projected area of the vessel shell shall be increased by the larger of 12 inches or the nominal diameter of the largest nozzle + two times insulation thickness to account for attached piping when calculating wind loadings.

7.10.7 In addition, the contribution of wind load on areas above the top tangent line of the vessel shall be included.

7.10.8 The transition plate, if required, for legs and brackets shall be made of the same material specification as the vessel.

7.11 Design Load Combinations

Loading					
Condition	Pressure	Temperature	Dead/Live Loads	Wind	Seismic
Transportation/Lifting	Atmospheric	Ambient	Dead Only/Transport Loads	-	-
Erection	Atmospheric	Ambient	Dead Only	Max {Wind; Seismic}	
Operating	Design	Design	All	Max {Wind; Seismic}	
Design	Design	Design	All	Max {Wind; Seismic}	
Test	Design	Test	Dead Only, Full of Water	-	-

7.11 Vessel Trays

7.11.1 Vessel trays shall normally be purchased and supplied by CONTRACTOR, all required welded in tray supports, baffles, and internal inlet piping shall be supplied and installed by the vessel

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fabricator. Trays shall be installed by the vessel fabricator when specified on the purchase offer documents.

- 7.11.1 Unless otherwise specified, tray design and materials shall be in accordance with Engineering Design Standard 000-SP-MV09-0005.

7.12 External Attachments

- 7.12.1 For external attachments requiring reinforcing plates with one dimension greater than 24" (600 mm), the necessary intermediate anchorages to the shell shall be provided by means of welding plugs (7/8" (20 mm) diameter) positioned on a square pitch.

8.0 FABRICATION

8.1 Tolerances

- 8.1.1 The allowable tolerances after fabrication are specified in CONTRACTOR standard, unless more stringent limitations are specified by the contractual Codes and Standards.

8.2 Welding

- 8.2.1 Vessels shall be of welded construction per General Welding Specification 000-SP-MU10-0001.
- 8.2.2 Fabrication involving welding shall not be sublet to others without the written approval of the purchaser.
- 8.2.3 Welding shall be done with procedures and operators, which have been qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. Weld procedure specifications and procedure qualification records must be submitted and approved prior to start of fabrication.

8.3 Alloy Lining

- 8.3.1 Alloy lining for shell and heads shall be made using integrally and continuously bonded, clad plate or weld overlay.

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- 8.3.2 Integrally clad linings shall be made of plate clad with the required lining material at the steel mill in accordance with the applicable material specifications. Explosion clad material shall not be used without the written consent of the Purchaser.
- 8.3.3 Nozzle necks in clad vessel sections shall be weld overlaid or rolled clad plate. Sleeve liners are not acceptable. The minimum size nozzle neck for clad vessel sections shall be 2" unless otherwise specified.
- 8.3.4 Weld overlay shall be applied circumferentially and it shall be relatively smooth with no notches, flaws, or undercuts that would act as stress risers. Elbows, tees, and small bore nozzles may be overlay welded longitudinally followed by grinding or machining to a smooth surface.
- 8.3.4 Lining/cladding/weld overlay shall be considered as corrosion allowance and not considered in strength calculations.
- 8.3.5 Clad plates shall be subjected to shear test, unless otherwise specified.
- 8.3.6 Moreover, within a 4"(100 mm) wide strip each side of the internal parts directly welded to the lining, a full UT shall be performed with the acceptance criteria of the contractual Code. Any lack of bond in the integral cladding and the base material or lack of fusion between the weld overlay and the base material shall be repaired and checked again.
- 8.3.7 The X-ray examination of welded seams shall be made before the alloy cover weld is deposited, provided that the requirements of ASME Section VIII div.1 par. UCL-35 are met.
- 8.3.8 Unless otherwise specified the nozzles of clad vessels shall be as follows:
- The method of lining of nozzles and manways shall be integrally bonded cladding or weld deposit overlay, unless otherwise agreed by the CONTRACTOR
 - Minimum nozzles nominal diameter for clad vessel shall be 2"
 - The weld overlay of nozzles shall be made of 2 passes minimum, unless otherwise agreed by CONTRACTOR.
- 8.3.9 Tray support material shall be the same as the lining and shall be continuously fillet welded to the lining on both sides.

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8.3.10 The use of solid alloy, instead of the specified clad or overlaid material, is not allowed, unless it is specifically accepted by this document or approved in writing by CONTRACTOR.

8.4 Vessel Post Weld Heat Treatment

8.4.1 Post weld heat treatment shall be in accordance with the ASME code requirements as a minimum or the Purchaser's vessel drawings/data sheet.

8.4.2 When heat treatment is specified by the material specification of the contractor's specification, this heat treatment shall be performed as a separate operation from any manufacturing, hot working or hot forming operation.

8.4.3 No weld may be executed directly to the pressure parts, subjected to the post-weld heat treatment (PWHT), after heat treatment has been carried out.

8.4.4 Where heat treatment is to be performed during manufacturing, forming and/or fabrication, mechanical test of the base metals, including the welds, shall be performed on test coupons subject to simulated heat treatments cycle(s) to represent the maximum anticipated heat treatment applied during the fabrication including after repair except carbon steel components where the nominal thickness does not exceed 2".

8.4.5 The heat treatment above 900°F (482 °C) (e.g.: hot forming, intermediate stress relief, PWHT) shall be considered for simulated heat treatment cycle(s). The holding time at temperature shall be checked in accordance with the Tempering Parameter.

8.4.6 Flange facings shall be protected from oxidation and pitting during heat treatment. Full size shell flanges shall be machined after PWHT.

8.4.7 The vent holes on reinforcing plates, pads, slip-on flanges, shall be open and dirt-free during heat treatment.

8.4.8 Post-weld heat treatment for welds between dissimilar metals shall conform to the requirements of the material having the more stringent requirements and shall be verified by the Welding Procedure Qualification Tests. The proposed post-weld heat treatment procedures for these welds shall be reviewed by the Purchaser.

8.4.9 Local post-weld heat treatment shall not be performed without written approval of the Purchaser.

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8.4.10 The post-weld heat treatment temperature shall not exceed the tempering temperature of normalized and tempered or quench and tempered materials.

9.0 EXAMINATION AND INSPECTION

- 9.1 All the materials used for vessel fabrication shall be new and of the type and grade specified in the contractual drawings, sketches and/or other specifications. They shall be properly stored and identified before their employment.
- 9.2 Each plate, pipe and forging shall be marked by the mill with a readable stamp showing the material type, grade number and heat number. 3.2.3. The stamp transfer before cutting shall be carried out under the supervision of the Manufacturer's quality controller and, if required, witnessed by inspectors of CONTRACTOR and/or of a named Independent Authority. A procedure of Manufacturer's quality control for material identification and the stamp transfers record may be requested, according to the contractual Codes, Standards and specifications.
- 9.3 The metal stamp on pipes and rolled surfaces shall be made by a low stress type.
- 9.4 All materials and work are subject to inspection by the purchaser and/or the purchaser's client, as well as any other state, local or insurance inspection required for Code stamping. Waiver of any phase of vessel inspection must be obtained from the purchaser. All forms examination of welded seams shall be performed strictly in compliance with the contractual Codes and Standards and according to the requirements specified in contractor documents.
- 9.5 The Supplier shall place at disposal of the inspectors all the means and the assistance required for the proper performance of their activities.
- 9.6 Before the final inspection of the equipment, all the slag, loose scale, dirt, grit, weld spatter, paint, oil and other foreign matter shall be removed in order to allow an easy, reliable and complete inspection.
- 9.7 Vessels that will contain cartridge trays assembly shall be checked with a template. The diameter of the template shall be no smaller than the I.D. of the vessel minus 1/4"(6 mm).
- 9.8 Each reinforcing pad or segment thereof, slip-on flanges and wherever welded pads and/or accessories interfere with the welded seam of the shell shall have one test hole, tapped 1/4" minimum pipe thread and located at the lowest point. The welds of each pad or segment shall be given an air-and-soap solution test 15 psig (104 kPa) before testing the vessel. Test holes shall be left open and be filled with corrosion inhibiting grease after hydrostatic test and prior to shipment.

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- 9.9 The hydrostatic test shall be performed strictly in compliance with the requirements of the contractual Codes.
- 9.10 The test pressure value shall be read at the top of the vessel, erected as for operation. For vertical vessels, the test can be performed in horizontal position, but in this case, the missing water head shall be taken into account, by increasing the test pressure value.
- 9.11 Vertical vessels tested in the horizontal position shall be supported by saddles, adequately designed to avoid local stress values in the shell exceeding 90% of the yield strength of the material.
- 9.12 The test pressure value shall be maintained for one hour at least, in the presence of the inspector.
- 9.13 The gaskets included in the scope of the supply shall not be utilized for performing the test. However the test shall be conducted with gaskets:
- of the same type and material of the installed ones during operation for body flanges and blind nozzles;
 - of compressed asbestos free material for all other connection types.
- 9.14 Jacketed vessels shall be hydrostatic tested before the jacket installation.
- 9.15 After completion of fabrication and testing, the vessels shall be thoroughly drained of water and dried
- 9.16 The temperature of the vessel wall during hydrostatic test shall be the greater of 60°F (15°C) or 30°F (17°C) above the vessel Minimum Design Metal Temperature (MDMT). If the operating fluid or vessel material would be adversely affected by water, a non-hazardous liquid shall be used with the purchaser's approval. Clean water shall be the hydrostatic test medium, unless another one is approved in writing by CONTRACTOR. The hydrostatic testing of vessels with internal surfaces in austenitic stainless steel material shall be carried out with potable quality water having a maximum chloride content of 30 ppm. If the chloride content is greater than 30 ppm, up to 250 ppm, a sufficient quantity of sodium-nitrate shall be added to provide a test medium of 0.5% by weight sodium-nitrate solution. Water with chloride content greater than 250 ppm shall not be used for testing.
- 9.17 When required by Contractor and/or Process Licensor, due to contamination or oxidation, the internal surface of stainless steel vessels shall be pickled and passivated.

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- 9.18 All welded vessels, regardless of whether or not they are ASME Code stamped, shall be, as a minimum, spot examined by radiography per Paragraph UW-52 of the ASME Code. Sectioning is not permitted. Spot re-examination per Paragraph UW-52 of the ASME Code shall be made, when required, at the fabricator's expense. When X-Ray spot examination is required, the points to be X-rayed shall at least include all the T crosses between circumferential and longitudinal joints, as well as the weld seams in the torical section of the formed heads.
- 9.19 Welded joints belonging to Categories A and B of Paragraph UW-3 of the ASME Code shall not be positioned to pass under a reinforcing pad where possible. If this is unavoidable, the joint under the pad shall be ground smooth and full radiographed for their entire hidden length plus 1" on each side of the pad.
- 9.20 When vessel design drawings or supplementary specifications call for magnetic particle or liquid penetrant inspection of welds, this procedure shall be applied to the back-chipped surface of root pass welds before proceeding to weld on the opposite side.
- 9.21 For all the welds on non-magnetic materials, including weld deposits, the MT examination shall be substituted by PT.
- 9.22 When magnetic particle or liquid penetrant inspection is specified, machining or grinding of the weld surface will not be required other than to remove excessive irregularities which would interfere with proper interpretation of results.
- 9.23 Rolled and welded nozzle necks shall have the long seam fully radiographed.
- 9.24 After removing parts temporarily welded to the shell, the involved area shall be ground flush and checked by MT for materials with ultimate tensile strength $\geq 70,000$ psi(490 MPa).
- 9.25 When PWHT is required the X-RAY examination (RT) and the Ultrasonic Examination (UT) shall be performed as detailed in the table.

Materials	Thickness	Before PWHT	After PWHT
Carbon Steel	$\leq 2"$ (50 mm)	RT (1)	-
Low Alloy Steel	$\leq 2"$ (50 mm)	(2)	RT (3)
All ferritic carbon steel materials	$> 2"$ (50 mm)	RT	UT (4)

(1): Unless otherwise specified by applicable code.

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- (2): For low alloy steel with thickness less or equal to 2" (50 mm) preliminary RT before PWHT remain Supplier's in house testing.
- (3): For thickness between 9/16" (15 mm) to 2" (50 mm), RT before PWHT followed by UT after PWHT is acceptable.
- (4): For thickness higher than 2" (50 mm) preliminary UT before PWHT remain Supplier's in house testing.

10.0 STANDARDS

The following standard drawings shall be used by the fabricator. These drawings shall not be used in lieu of shop drawings.

000-DG-MV09-0001	PRESSURE VESSEL TOLERANCES (EXTERNAL)
000-DG-MV09-0002	PRESSURE VESSEL TOLERANCES (INTERNAL)
000-DG-MV09-0003	SKIRT DETAILS FOR VERTICAL VESSELS
000-DG-MV09-0004	SUPPORT LEGS FOR VERTICAL VESSELS
000-DG-MV09-0005	STANDARD SADDLE DETAILS FOR HORIZONTAL VESSELS FOUNDATION MOUNTED
000-DG-MV09-0006	STANDARD SADDLE DETAILS FOR HORIZONTAL VESSELS SKID MOUNTED
000-DG-MV09-0007	BASE RING AND ANCHOR BOLT CHAIR DETAILS FOR VERTICAL VESSELS
000-DG-MV09-0008	INSULATION SUPPORTS FOR VERTICAL VESSELS
000-DG-MV09-0009	INSULATION SUPPORTS FOR HORIZONTAL VESSELS
000-DG-MV09-0010	PIPE SUPPORT TYPE 1 (FOR PIPE 2" AND SMALLER)
000-DG-MV09-0011	PIPE SUPPORT TYPE 2 (FOR PIPE 3" AND 4")
000-DG-MV09-0012	PIPE SUPPORT TYPE 3 (FOR PIPE 6" THRU 14")
000-DG-MV09-0013	PIPE SUPPORT TYPE 4 (FOR PIPE 6" AND LARGER)
000-DG-MV09-0014	PIPE GUIDES - TYPE 11 & 12 (FOR PIPE 4" AND SMALLER)
000-DG-MV09-0015	PIPE GUIDE TYPE 13 (FOR INSULATED LINES 6" AND LARGER)
000-DG-MV09-0016	PIPE GUIDE TYPE 14 (FOR INSULATED LINES 6" AND LARGER)
000-DG-MV09-0017	PIPE GUIDE TYPE 15 (FOR UNINSULATED LINES 6" AND LARGER)
000-DG-MV09-0018	TYPICAL PLATFORM SUPPORT CLIP
000-DG-MV09-0019	TYPICAL LADDER SUPPORT & GUIDE
000-DG-MV09-0020	VESSEL LIFTING LUG DETAIL (ERECTION WT. < 20 TONS)
000-DG-MV09-0021	VESSEL LIFTING LUG DETAIL (ERECTION WT. > 20 TONS)
000-DG-MV09-0022	VESSEL TAILING LUG DETAILS
000-DG-MV09-0023	TOWER DAVIT
000-DG-MV09-0024	DAVIT FOR HORIZONTAL MANWAY
000-DG-MV09-0025	DAVIT FOR VERTICAL MANWAY

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000-DG-MV09-0026	HINGE DETAILS FOR MANHOLE COVERS
000-DG-MV09-0027	INLET BAFFLE DETAIL
000-DG-MV09-0028	INLET NOZZLE WITH CIRCUMFERENTIAL FLOW BAFFLE
000-DG-MV09-0029	INLET NOZZLE WITH AXIAL FLOW BAFFLE
000-DG-MV09-0030	INLET DEFLECTORS FOR HORIZONTAL SEPARATORS
000-DG-MV09-0031	INLET NOZZLE OPENING LOOKING UP
000-DG-MV09-0032	INLET NOZZLE OPENING LOOKING DOWN
000-DG-MV09-0033	INLET TEE WITH WEAR PLATE
000-DG-MV09-0034	INLET DISTRIBUTOR TYPE 1
000-DG-MV09-0035	INLET DISTRIBUTOR TYPE 2
000-DG-MV09-0036	INLET DISTRIBUTOR TYPE 3
000-DG-MV09-0037	INLET DISTRIBUTOR TYPE 4
000-DG-MV09-0038	INLET DISTRIBUTOR TYPE 5 & TYPE 5A
000-DG-MV09-0039	INLET DISTRIBUTOR FOR CATALYST VESSELS
000-DG-MV09-0040	TANGENTIAL INLET BAFFLE
000-DG-MV09-0041	VAPOR DRAW-OFF NOZZLE
000-DG-MV09-0042	DEMISTER PAD SUPPORT TYPE 1
000-DG-MV09-0043	DEMISTER PAD SUPPORT TYPE 2
000-DG-MV09-0044	DEMISTER PAD SUPPORT TYPE 3
000-DG-MV09-0045	DEMISTER PAD SUPPORT TYPE 4
000-DG-MV09-0046	DEMISTER PAD SUPPORT TYPE 5
000-DG-MV09-0047	DEMISTER PAD SUPPORT TYPE 6
000-DG-MV09-0048	VORTEX BREAKER TYPE I & TYPE II
000-DG-MV09-0049	PLATE FLANGES FOR INTERNAL PIPING
000-DG-MV09-0050	INTERNAL GRAB RUNGS
000-DG-MV09-0051	REGENERATOR CHIMNEY TRAY DETAIL
000-DG-MV09-0052	CATALYST SUPPORT
000-DG-MV09-0053	TYPICAL EDGE PREPARATION FOR CLAD PLATE
000-DG-MV09-0054	CATALYST RETENTION PLATE
000-DG-MV09-0055	NOZZLE PROJECTIONS
000-DG-MV09-0056	DEMISTER SUPPORTS FOR VERTICAL VESSEL TYPE 7
000-DG-MV09-0057	SYNGAS PLANT REACTOR VESSEL OUTLET SCREEN
000-DG-MV09-0058	PSA ABSORBER OUTLET SCREEN
000-DG-MV09-0059	AMINE CARBON FILTER VESSEL OUTLET SCREEN
000-DG-MV09-0060	DEMISTER PAD SUPPORT TYPE 8
000-DG-MV09-0061	CO2 ABSORBER SPARGER FOR 24" I.D. THRU 72" I.D. VESSEL
000-DG-MV09-0062	CLAD OR OVERLAYED NOZZLE DETAILS 1 & 1A
000-DG-MV09-0063	CLAD OR OVERLAYED NOZZLE DETAILS 2 & 2A
000-DG-MV09-0064	CLAD OR OVERLAYED NOZZLE DETAILS 3 & 3A
000-DG-MV09-0065	CLAD OR OVERLAYED NOZZLE TYPICAL DETAILS

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