

Process Industry Practices  
Vessels

**PIP VESV1002**  
**Design and Fabrication Specification for Vessels**  
**ASME Code Section VIII, Divisions 1 and 2**

---

## PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

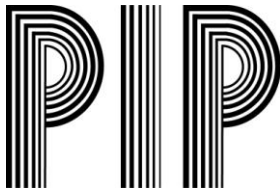
In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

© Process Industry Practices (PIP), Construction Industry Institute, The University of Texas at Austin, 3925 West Braker Lane (R4500), Austin, Texas 78759. PIP Member Companies and Subscribers may copy this Practice for their internal use. Changes or modifications of any kind are not permitted within any PIP Practice without the express written authorization of PIP. Authorized Users may attach addenda or overlays to clearly indicate modifications or exceptions to specific sections of PIP Practices. Authorized Users may provide their clients, suppliers and contractors with copies of the Practice solely for Authorized Users' purposes. These purposes include but are not limited to the procurement process (e.g., as attachments to requests for quotation/ purchase orders or requests for proposals/contracts) and preparation and issue of design engineering deliverables for use on a specific project by Authorized User's client. PIP's copyright notices must be clearly indicated and unequivocally incorporated in documents where an Authorized User desires to provide any third party with copies of the Practice.

### **PUBLISHING HISTORY**

<i>September 1997</i>	<i>Issued</i>
<i>December 1998</i>	<i>Technical Revision</i>
<i>February 2007</i>	<i>Complete Revision</i>
<i>May 2009</i>	<i>Editorial Revision</i>
<i>March 2012</i>	<i>Complete Revision</i>



Process Industry Practices  
Vessels

**PIP VESV1002**  
**Design and Fabrication Specification for Vessels**  
**ASME Code Section VIII, Divisions 1 and 2**

---

**Table of Contents**

<b>1. General Requirements .....</b>	<b>2</b>
1.1 Purpose .....	2
1.2 Scope.....	2
<b>2. References .....</b>	<b>2</b>
2.1 Process Industry Practices .....	2
2.2 Industry Codes and Standards .....	3
2.3 Government Regulations.....	4
2.4 Other References .....	4
<b>3. Definitions .....</b>	<b>4</b>
<b>4. Requirements.....</b>	<b>5</b>
4.1 General.....	5
4.2 Design.....	7
4.3 Materials .....	25
4.4 Fabrication .....	27
4.5 Examination, Inspection and Pressure Testing .....	36
4.6 Preparation for Shipment.....	42

**Appendix A**

Equivalent Pressure Formulas for Bending Moment and Axial Tensile Load

## 1. General Requirements

---

### 1.1 Purpose

This Practice provides design criteria and construction requirements for pressure vessels constructed in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1 or Division 2, henceforth referred to as the *Code*. Requirements that are specific to *Code*, Section VIII, Division 2 are shown in braces { }.

### 1.2 Scope

This Practice describes the design, fabrication, examination, inspection, testing, and documentation requirements for pressure vessels constructed in accordance with *Code*, Section VIII, Division 1 {or 2}.

Supplementary requirements for shell and tube heat exchangers are in *PIP VESST002*.

## 2. References

---

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

### 2.1 Process Industry Practices (PIP)

- PIP VESST002 - *Design and Fabrication Specification for Shell and Tube Heat Exchangers, ASME Code Section VIII, Divisions 1 and 2*
- PIP VEDV1003 - *Documentation Requirements for Vessels, ASME Code Section VIII, Divisions 1 and 2*
- PIP VEFV1100 - *Vessel/S&T Heat Exchanger Standard Details*
  - PIP VEFV1101 - *Vessel; Nameplate Bracket*
  - PIP VEFV1102 - *Vessel; Tolerances (Orientation)*
  - PIP VEFV1103 - *Vessel; Grounding Lug*
  - PIP VEFV1105 - *Vessel; Horizontal, Saddles Supported on Concrete*
  - PIP VEFV1106 - *Vessel; Horizontal, Saddles Supported on Steel*
  - PIP VEFV1116 - *Vessel; Manway Hinges*
  - PIP VEFV1117 - *Vessel; Manway Vertical Davit*
  - PIP VEFV1118 - *Vessel; Manway Horizontal Davit*
  - PIP VEFV1125 - *Vessel; Internal Ladders*

## 2.2 Industry Codes and Standards

For each of the following reference documents, if *Code* Table U-3 {1.1} lists an edition or addenda different than the edition listed in the reference, the edition listed in *Code*, Table U-3 {1.1} shall be used.

- American Institute of Steel Construction (AISC)
  - *Manual of Steel Construction*
- American Society of Mechanical Engineers (ASME)
  - *ASME Boiler and Pressure Vessel Code*
    - Section II, Part D - *Properties*
    - Section V - *Nondestructive Examination*
    - Section VIII - *Pressure Vessels, Divisions 1 and 2*
    - Section IX - *Welding and Brazing Qualifications*
    - Code Case 2260 - *Alternative Rules for Design of Ellipsoidal and Torispherical Formed Heads, Section VIII, Division 1*
  - *ASME B1.1 - Unified Inch Screw Threads (UN and UNR Thread Form)*
  - *ASME B16.5 - Pipe Flanges and Flange Fittings, Sizes NPS 1/2 through NPS 24*
  - *ASME B16.9 - Factory-Made Wrought Buttwelding Fittings*
  - *ASME B16.47 - Large Diameter Steel Flanges, NPS 26 through NPS 60*
  - *ASME PCC-1 - Guidelines for Pressure Boundary Bolted Flange Joint Assembly*
  - *ASME PCC-2 - Repair of Pressure Equipment and Piping*
  - *ASME SA-263 - Corrosion-Resisting Chromium, Steel-Clad Plate, Sheet and Strip*
  - *ASME SA-264 - Stainless Chromium-Nickel, Steel-Clad Plate, Sheet and Strip*
  - *ASME SA-265 - Nickel and Nickel-Based Alloy-Clad Steel Plate*
  - *ASME SA-578 - Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*
  - *ASME SA-745 - Ultrasonic Examination of Austenitic Steel Forgings*
- American Welding Society (AWS)
  - *AWS A2.4 - Standard Symbols for Welding, Brazing and Nondestructive Examination*
- American Society for Testing and Materials (ASTM)
  - *ASTM A-380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment and Systems*
- Welding Research Council (WRC)
  - *WRC Bulletin 107 - Local Stresses in Spherical and Cylindrical Shells Due to External Loadings*
  - *WRC Bulletin 297 - Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles*

- International Standards Organization
  - ISO 8573-1 - *Compressed Air - Part 1 Contaminants and Purity Classes*

### 2.3 Government Regulations

The following references are applicable to US installations or as specified by Purchaser.

- U. S. Department of Labor, Occupational Safety and Health Administration (OSHA)
  - OSHA 29 CFR 1910.146(k)(3)(ii) - *Permit-Required Confined Spaces for General Industry*

### 2.4 Other References

- “*Dynamic Response of Tall Flexible Structures to Wind Loading.*” Joseph Vellozzi, Ph.D., P.E. U.S. Department of Commerce, National Bureau of Standards, Building Science Series Number 32, 1966.
- “*Process Equipment Design.*” Brownell and Young. Wiley & Sons Publishers, 1959.
- “*Stresses in Large Cylindrical Pressure Vessels on Two Saddle Supports.*” L.P. Zick. *Pressure Vessels and Piping: Design and Analysis, A Decade of Progress.* Vol. 2, 1972.

## 3. Definitions

---

*approved equal:* A substitution to a specified product that has been approved in writing by the Purchaser

*Code:* The ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 {or 2} and its referenced Sections (e.g., Section II, Section V, and Section IX) and any Code Cases permitted by the *User*. References to Division 2 are identified in braces { }.

*construction:* An all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification (i.e., Code stamp and Manufacturer’s Data Report), {Manufacturer’s Design Report}, and pressure relief

*cyclic service:* A service that requires fatigue analysis in accordance with Code, Section VIII, Division 2, Section 5.5.2. This applies to Division 1 and Division 2 vessels.

*Manufacturer:* The party entering into a contract with the Purchaser to design and construct a vessel in accordance with the requirements in this Practice and the contract documents. In accordance with the Code definition, the *Manufacturer* is the party that possesses a valid Certificate of Authorization to manufacturer pressure vessels with the ASME Mark.

*Comment:* The Purchaser may duplicate portions or all of the vessel design.

*National Board:* The National Board of Boiler and Pressure Vessel Inspectors, an organization comprised of chief inspectors of various governmental jurisdictions in the United States and Canada.

*Owner:* The party who owns the facility wherein the vessel will be used. The owner is typically also the User.

*Purchaser:* The party who awards the contract to the Manufacturer. The Purchaser may also be the Owner, User, or the Owner's or User's Designated Agent (e.g., engineering contractor).

*User:* The party who establishes construction criteria in accordance with the *Code* philosophy and service hazards. The User is the operator of the facility wherein the vessel will be installed.

*Purchaser's Inspector:* The person or company authorized by the Purchaser, Owner, and/or User to inspect pressure vessels to the requirements of this Practice and other Purchaser contract requirements.

## 4. Requirements

---

### 4.1 General

#### 4.1.1 Overall Responsibilities

- 4.1.1.1 Vessels shall be provided in accordance with this Practice and the following:
- a. *PIP VEDV1003* including the following Purchaser's forms:
    - (1) *PIP VEDV1003-D* Data Sheet
    - (2) *PIP VEDV1003-T* Inspection and Testing Documentation Requirements Sheet or equivalent
    - (3) *PIP VEDV1003-R* Documentation Requirements Sheet
    - (4) *PIP VEDV1003-F* Welded Pressure Joint Requirements
  - b. The *Code*
  - c. Design criteria that may supersede the requirements of this Practice but not take exception to the requirements of the *Code*
  - d. PIP VEFV1100 details: VEFV1101, VEFV1102, VEFV1103, VEFV1105, VEFV1106, VEFV1116, VEFV1117, VEFV1118, VEFV1125
  - e. Other codes and standards referenced in this Practice
  - f. Local requirements
  - g. Other contract requirements furnished by the Purchaser
- 4.1.1.2 Vessels shall be in total compliance with the *Code*, including stamping.
- 4.1.1.3 Unless otherwise specified by the Purchaser, "U-" {U2-} stamped vessels shall also be National Board (NB) registered.
- 4.1.1.4 Deviations from this Practice shall be submitted in writing for approval by the Purchaser.

- 4.1.1.5 If a conflict is identified between this Practice, the design drawings, data sheets, referenced codes and standards, or any supplementary specification, written clarification shall be obtained from the Purchaser before proceeding with any work.
- 4.1.1.6 All aspects of the work shall be in accordance with applicable local, county, state, and federal rules, regulations and standards at installation site including but not limited to the rules and standards established by the EPA and OSHA, or equivalent national standards, if applicable, as designated by the Purchaser. See Purchaser's *PIP VEDV1003-D* Data Sheet.
- 4.1.1.7 Before any welding or preparation for welding is subcontracted to another shop or fabricator, approval for subcontracted fabrication work shall be obtained from Purchaser. The Manufacturer shall be responsible for assuring that subcontracted fabrication work is in accordance with this Practice and the contract documents.
- 4.1.1.8 Purchaser's review of Manufacturer's documentation (e.g., fabrication drawings, design calculations or weld procedures) shall not relieve the Manufacturer of his responsibility to comply with the requirements of this Practice and the contract documents.
- 4.1.1.9 If a vessel or vessel component design is furnished by the Purchaser, the Manufacturer shall not be relieved of his responsibility to comply with the requirements of this Practice and the contract documents.
- Comment:* Certain non-Code-design functions may be performed solely by the Purchaser (e.g., design of vessel internals).
- 4.1.1.10 Release for shipment by Purchaser Inspector shall not relieve the Manufacturer of his responsibility to comply with the requirements of this Practice and the contract documents.

#### **4.1.2 Alternative Design Proposals**

- 4.1.2.1 A base proposal for construction of the vessel shall be provided in full compliance with the Purchaser's request for quotation.
- 4.1.2.2 An alternative design proposal may be submitted if considered less costly and/or an improvement in the delivery schedule. However, the improvements in cost and schedule shall be realized without losing capability or shortening the anticipated life of the vessel.
- 4.1.2.3 Alternate design proposals shall be in accordance with the following:
- a. Shall be accompanied by the base proposal and be clearly identified as an alternate proposal.
  - b. Shall clearly state the intended use of *Code* cases.
  - c. Shall be fully and clearly described and substantiated by sketches or drawings.
  - d. Shall include a list of specific exceptions to Purchaser's request for quotation, this Practice, and the contract documents.



4.1.2.4 Unless approved in writing by the Purchaser, an alternative design including the use of *Code* cases shall not be used.

#### 4.1.3 Documentation Responsibilities

4.1.3.1 Vessel documentation shall be provided in accordance with Purchaser's *PIP VEDV1003-R* Documentation Requirements Sheet.

4.1.3.2 The data required for Part B of the *PIP VEDV1003-D* Data Sheet shall be provided with the approval drawings.

## 4.2 Design

### 4.2.1 General

4.2.1.1 Vessel design shall be in accordance with the applicable requirements of the *Code*, {User's Design Specification} this Practice, the Purchaser's *PIP VESV1003-D* Data Sheet, and all other requirements in the contract documents.

4.2.1.2 Minimum corroded shell and head thickness shall be 3/16 inch (5 mm).

4.2.1.3 If two allowable stress values are given in *Code* Section II Part D for a material, the greater value shall not be used in the design of flanges for gasketed joints or other applications if minimal amounts of distortion can cause leakage or malfunction.

4.2.1.4 Unless approved by the Purchaser, *Code Case 2260* shall not be permitted for use in the design.

4.2.1.5 Half-pipe or pipe section jackets shall be designed in accordance with *Code* Appendix EE {4.11.6}.

### 4.2.2 Pressure and Temperature

4.2.2.1 Unless otherwise specified, vessels shall be assumed to operate completely filled with operating fluid having a minimum specific gravity of 1.0.

4.2.2.2 Unless otherwise specified, Minimum Design Temperature shall not be warmer than 30°F (-1°C).

4.2.2.3 The maximum design temperature rating shall be increased to the highest temperature possible without affecting the minimum required thickness of the shell or heads and without changing the pressure class of nozzle flanges.

4.2.2.4 If appropriate, a vessel may be designed and *Code* stamped for more than one condition of pressure and coincident maximum metal temperature.

4.2.2.5 Unless otherwise specified, maximum design metal temperature shall not be colder than 150°F (65°C).

#### 4.2.2.6 Provisions for Future Field Hydrostatic Test

1. Unless provision for future field hydrostatic test is exempted, the vessel shall be designed to satisfy the load combination as specified in Section 4.2.3.2.d.
  2. The design shall verify that any component in the corroded condition can withstand the following loads, without exceeding 90% of the Specified Minimum Yield Strength at the coincident test temperature, in both circumferential and longitudinal directions:
    - a. Hydrostatic test pressure at the top of the vessel in accordance with *Code* Paragraph UG-99 {8.2.1}
    - b. Hydrostatic head of the vessel full of water when the vessel is in its operating position
  3. The stress level in Section 4.2.3.2.d shall not be permitted in those portions of the cylindrical shell within a meridional distance of  $2.5\sqrt{Rt}$ , where  $R$  is the mean radius of the shell and  $t$  is the thickness of the shell at the junction, from a gross structural discontinuity such as, but not limited to, the following:
    - a. Cone-to-cylinder junctions
    - b. Shell flange-to-cylinder junctions
    - c. Torispherical head (inside crown radius/head thickness  $L/t$  ratio greater than 500) -to-cylinder junctions
    - d. Openings in the shell that are larger than the dimensional limits given in *Code* Paragraph UG-36(b)(1) {4.5.2.1}
  4. See Section 4.2.3 for additional requirements.
- 4.2.2.7 Maximum Allowable Working Pressure (MAWP) shall not be limited by the nozzle reinforcement.
- 4.2.2.8 *Code* Paragraph UCS-66 {3.11.2.3} shall be used for determining the Minimum Design Metal Temperature (MDMT).
- 4.2.2.9 Carbon and low-alloy steel material for separate nozzle reinforcing pads, and stiffening rings and other attachments which are welded to pressure-retaining components, shall not limit the MDMT.
- 4.2.2.10 Jacketed or compartmented vessels that are designed for vacuum in the compartment under consideration shall have the common components designed for an external pressure equal to the sum of internal design pressure of the adjacent compartment plus the vacuum design pressure of the compartment under consideration.

### 4.2.3 Design Loads and Load Combinations

#### 4.2.3.1 Design Load Classifications and Definitions

1. Dead Load (L1)

Dead Load is the installed weight of the vessel, including internals, catalyst or packing, refractory lining, platforms, insulation fireproofing, piping, and other permanent attachments.

2. Operating Live Load (L2)

Operating Live Load is the weight of the liquid at the maximum operating level, including that on trays.

3. Pressure Load (L3)

Pressure Load is the MAWP (internal or external at the coincident temperature) considering the pressure variations through the vessel, if any. MAWP shall be calculated (not set equal to the design pressure) unless otherwise specified by the Purchaser. For vessels with more than one independent chamber, see *Code* Paragraph UG-19(a) {4.1.8}.

4. Thermal Load (L4)

Thermal Loads are caused by the restraint of thermal expansion/interaction of the vessel and/or its supports.

5. Test Load (L5)

Test Load is the weight of the test medium, usually water. Unless otherwise specified, design basis shall consider that the vessel shall be field tested in its normal operating position. See Section 4.2.2.6.

6. Wind Load (L6)

Wind Load shall be determined in accordance with Section 4.2.4.

7. Seismic Load (L7)

Seismic Load shall be determined in accordance with Section 4.2.5.

8. Piping and Superimposed Equipment Loads (L8)

Loads caused by piping (other than the Dead Load), and loads caused by superimposed equipment

#### 4.2.3.2 Load Conditions

Unless other conditions are specified by the Purchaser, vessels and their supports shall be designed to satisfy the most severe (i.e., controlling) of the following load conditions, and the controlling load condition shall be identified in the design calculations:

a. L1+L6

Erected Condition with full Wind Load

b.  $L1+L2+L3+L4+L6+L8$

Design Condition with full Wind Load. Both full and zero pressure loads (L3) shall be included for check of maximum longitudinal tensile and compressive stress.

c.  $L1+L2+L3+L4+L7+L8$

Design Condition with Seismic Load. Both full and zero pressure loads (L3) shall be included for check of maximum longitudinal tensile and compressive stress.

d.  $L1+(F)L3+L5+(0.25)L6$

If specified by Purchaser, initial (i.e., new uncorroded) hydrostatic test condition and future (i.e., corroded) hydrostatic test condition with vessel in normal operating position and with 50% of design wind velocity (i.e., 25% of wind load)

(1) Test factor F shall be in accordance with the *Code* for the test medium used {8.3.1}.

*Comment:* F is the *Code* test factor that, if multiplied by the lowest ratio (for the materials of which the vessel is constructed) of the stress value S for the test temperature of the vessel to the stress value {8.2.1} for the design temperature, establishes the minimum required test pressure at every point in the vessel.

(2) The general primary membrane tensile stress under this load condition, in the corroded condition or if a corrosion allowance is not specified, shall not be greater than either of the following:

(a) For hydrostatic testing, 90% of the Specified Minimum Yield Strength at 100°F (38°C) {that specified in 4.1.6.2(a)}

(b) For pneumatic testing, 80% of the Specified Minimum Yield Strength at 100°F (38°C) {4.1.6.2 b)}

e. Lift Condition

See Purchaser's *PIP VEDV1003-D* Data Sheet and Section 4.2.8.

#### 4.2.4 Wind

4.2.4.1 Unless specified otherwise, wind loads shall be determined in accordance with ASCE 7 design criteria using input data specified by the Purchaser.

4.2.4.2 The maximum allowable deflection at the top tangent line of a vessel in the corroded condition shall not be greater than 6 inches per 100 feet (150 mm per 30 m) of vessel height.

#### 4.2.4.3 Projected Area

1. The projected area of vessel accessories such as platforms, ladders, piping and other equipment attached to the vessel shall be considered in the wind load calculation.
2. If spoilers are to be added to a vessel, the column projected area normal to wind, and the corresponding force coefficient, for the column height where spoilers have been added, shall be used in the design of the vessel and supporting structure to calculate the overturning load.
3. The column projected area shall be calculated using the projected diameter taken at the outside edge of the spoilers multiplied by the height of the section under consideration.

#### 4.2.4.4 Wind-Induced Vibration of Vertical Vessels

1. Vessels with an h/D ratio of 15 or greater shall be evaluated for dynamic behavior from wind excitation as described in *Dynamic Response of Tall Flexible Structures to Wind Loading* or by other similar proven evaluation methodology.
2. Vessels shall be evaluated for wind-induced vibration considering vortex shedding ranges described as follows:
  - a. Lower Periodic Vortex Shedding Range  
If the Reynolds number is less than 300,000 and the Strouhal number is approximately 0.2, vibration because of periodic vortex shedding can occur with tall slender vessels that have very low fundamental frequencies.
  - b. Random Vortex Shedding Range  
If the Reynolds number is between 300,000 and 3,500,000, random vortex shedding can occur. If the Strouhal number is approximately 0.2, the random vortex oscillations can lock-in and become periodic, causing the vessel to vibrate.
  - c. Upper Periodic Vortex Shedding Range  
If the Reynolds number is above 3,500,000 and the Strouhal number is approximately 0.2, self-excited vibration can occur if the natural frequency of the vessel corresponds with the frequency of vortex shedding.
3. If it is determined that a vessel can vibrate and the attributes of the vessel (e.g., normal attachments) cannot be changed to put the vessel in a range where vibration cannot occur, wind spoilers shall be added to the vessel in accordance with one of the following methods. The method used to deter wind-induced vibration shall be provided to the Purchaser.
  - a. Helical Spoilers
    - (1) A three-start system of spoilers in a helical pattern shall be provided on the top third of the vessel.

- (2) The exposed width of the spoilers beyond insulation should be  $0.09D$  and a pitch of  $5D$ , where  $D$  is the diameter of the top third of the vessel.
  - (3) The spoiler system may be interrupted to provide clearance at vessel appendages.
- b. Short Vertical Spoilers
- (1) A three-start system of short vertical spoilers arranged in a helical pattern shall be provided on the top-third of the vessel.
  - (2) The exposed width beyond insulation of the spoilers should be  $0.09D$  and the pitch (i.e., height of one helical wrap) between  $5D$  and  $11D$ .
  - (3) A minimum of eight spoilers should be provided over the pitch distance (i.e., each complete helical wrap) and a minimum of 1.5 helical wraps over the top-third of the vessel.
  - (4) The spoiler system may be interrupted to provide clearance at vessel appendages.

#### **4.2.5 Seismic Loading**

Seismic loads shall be determined in accordance with *ASCE 7* using design parameters provided or otherwise defined by the Purchaser.

#### **4.2.6 Cyclic Loading**

##### **4.2.6.1 Fatigue Analysis**

1. If Purchaser specifies that the vessel is in cyclic service, the rules in *Code* Section VIII, Division 2, Paragraph 4.1.1.4, shall be used as a basis for establishing further action.
2. A fatigue analysis shall always be performed for agitator mounting nozzles and their attachment to the vessel.

##### **4.2.6.2 Agitator Installations on Formed Heads**

If an agitator is to be mounted on a nozzle or studding outlet in a formed head, the head design shall be sufficient to provide the rigidity and stress levels appropriate for the associated dynamic loadings. The head design shall be agreed with the agitator supplier and Purchaser before the head is ordered.

##### **4.2.6.3 Nozzle Reinforcement**

1. Nozzles supporting agitators, pumps, or other mechanical equipment shall be suitably reinforced to withstand the mechanical loadings specified by the equipment manufacturer and approved by Purchaser.

2. Dynamic loading shall be evaluated for an infinite number of stress reversals using the applicable stress concentration factor as follows:
  - a. 5 for as welded attachment welds
  - b. 3.5 for contoured and blend ground nozzle attachment welds  
*Comment:* Use of heavier nozzle necks, conventional reinforcing pads with properly contoured fillet welds, and formed heads of appropriate stiffness may result in a design suitable for an infinite number of cycles.
3. Nozzle reinforcement for pressure relief devices shall be designed and reinforced for thrust reaction.
4. Gussets shall not be used to strengthen, stiffen, or reinforce nozzles, unless demonstrated by calculations to be suitable for the specified cyclic life or thermal condition, and the dimensional requirements (e.g., tolerances) of the device as furnished by the device manufacturer are considered.

#### **4.2.7 Local Loading**

- 4.2.7.1 If external loads are furnished by the Purchaser, the local membrane and surface stresses caused by local loads (e.g., piping loads, platform loads, etc.) shall be determined using the *WRC Bulletin 107 and 297* procedures, or other local stress analysis procedures approved by the Purchaser.
- 4.2.7.2 For local loads and pressure, the allowable stresses {5.2.2.4} are 1.5S for local primary membrane stress and 3S for primary membrane plus secondary bending stress at nozzles, platform lugs, etc., where S is the *Code*-allowable stress at the design temperature.

#### **4.2.8 Shipping and Rigging Loadings**

##### **4.2.8.1 Transportation Loads**

1. Vessels subject to transportation loadings shall be analyzed for the following conditions:
  - a. Bending between supports
  - b. General primary membrane tensile stress
  - c. Compressive stress at supports and fixture attachment points
2. Calculated general primary membrane tensile stress shall not exceed that listed in Section 4.2.8.3.
3. Vessels shall be analyzed for actual vertical, lateral and longitudinal loadings as applicable.
4. Minimum acceleration loadings are shown in Table 1 for the various modes of transportation.

5. If erection loadings are greater than the transportation loadings, the vessel shall be designed for the most severe vertical, lateral and longitudinal loading condition.

**Table 1 - Minimum Transportation Acceleration Loadings**

Transportation Mode	Vertical Acceleration		Lateral Acceleration	Longitudinal Acceleration
	Downward	Upward		
Truck (Highway Speeds)	1.7g	0.5g	0.3g	1.8g
Truck (< 25 MPH or Multi-wheel Transporter)	1.3g	0.2g	0.2g	0.2g
Rail	2g	2g	2g	3g
Inland Barge	1g	0.2g	0.75g	0.4g
Oceangoing Ship or Barge	2g	2g	0.75g	0.4g
Notes: 1. If multiple modes of transportation are used, the most severe condition shall be used for evaluation. 2. 1.0g is a load equal to the weight of the vessel.				

#### 4.2.8.2 Impact Factor

1. A minimum impact factor of 2 shall be applied to the lift weight for the design of lifting devices.
2. The basis for the lift weight shall include all components to be included in the lift (e.g., trays, ladders/platforms, insulation, additional piping with insulation, etc.).

#### 4.2.8.3 Lifting Stresses

For vertical vessels having height-to-diameter ratios greater than 8 and weighing more than 25,000 pounds (11,300 kgf), the following lifting stress calculations shall be performed:

- a. Bending stresses in the vessel shell and skirt from the loadings imposed during the lift from the horizontal to vertical position shall be checked.
- b. Calculated general primary membrane tensile stress shall not be greater than 80% of the material's specified minimum yield strength at 100°F (38°C).
- c. Calculated compressive stress shall not be greater than 1.2 times the B factor specified by the *Code* {4.4.12}.



#### 4.2.8.4 Local Stresses

1. Local stresses in the vessel shell/head/skirt/base rings from lifting attachments (e.g., lugs, trunnions, etc.) shall be determined for the imposed loadings using *WRC Bulletins 107 or 297* procedures, or other accepted local stress analysis procedures (e.g., finite element analysis).
2. For the rigging condition, the allowable stresses specified in Section 4.2.7.2 {4.15.5} shall be used.

#### 4.2.8.5 Welds

Shear stresses for fillet welds on the lifting attachments to the vessel shell or head shall not be greater than 0.55 times the *Code*-allowable stress {design stress intensity} at 100°F (38°C) for the material selected.

#### 4.2.9 Nozzles and Manways

- 4.2.9.1 Nozzles and manways shall be integrally reinforced if any of the following conditions apply:
  - a. If located in vessel shell greater than 2 inches (50 mm) thick
  - b. Cyclic service is the controlling design consideration for the vessel
  - c. Maximum design metal temperature is warmer than 750°F (400°C)
  - d. Radial nozzles are within the scope of *Code* Paragraph 1-7(b)
  - e. Radiography is required on nozzles or manway connections to the shell or head
- 4.2.9.2 Minimum nozzle neck thickness for carbon steel and low alloy steel nozzles shall be in accordance with *Code* Paragraph UG-45 {4.5.4}, except that the nominal thickness selected for nozzle necks smaller than or equal to NPS 3 (DN 80) shall not be less than Schedule 80.
- 4.2.9.3 Minimum nozzle neck thickness for high-alloy and non-ferrous alloy nozzles shall be in accordance with *Code* Paragraph UG-45 {4.5.4}, except that the nominal thickness selected for nozzle necks smaller than or equal to NPS 3 (DN 80) shall not be less than Schedule 40S.
- 4.2.9.4 Surface-attached nozzles in accordance with *Code* Figures UW-16.1(a), (a-1), (a-2), (a-3), and (b) {Table 4.2.10, Detail 1 and 2}, and those with internal reinforcing pads, shall not be permitted.

#### 4.2.10 Custom-Designed Flanges

4.2.10.1 For recommended minimum gasket contact widths see Table 2.

**Table 2 - Recommended Minimum Gasket Contact Widths**

Flange ID inches (mm)	Gasket Contact Width inches (mm)
≤ 36 (900)	1 (25)
36 (900) < OD ≤ 60 (1500)	1-1/4 (32)
OD > 60 (1500)	1-1/2 (38)
Notes:	
1. Gasket Contact Width is the recommended minimum width of the gasket in contact with both flange faces.	
2. For 3-ply corrugated metal gaskets, the gasket OD shall be a minimum of 1/4 inch (6 mm) less than the raised face or lap ring OD.	
3. See Section 4.2.10.10.d.	

4.2.10.2 Flanges shall be designed not only for the design pressure, but also for other loadings specified by Purchaser in the contract documents, and applied to the joints during the project life (e.g., externally applied bending moment and axial thrust loadings).

4.2.10.3 Flange thickness shall be selected so that, considering all loadings that will be applied, the Rigidity Index as defined in *Code* paragraph 2-14 {Table 4.16.10} is less than or equal to 1.0, based on the recommended value of KL of 0.2 or K1 of 0.3, as applicable.

4.2.10.4 If specified by the Purchaser, flanges and their pressure-retaining covers for manways may be custom-designed, with consideration being given to providing a Rigidity Index in accordance with the recommendations in *Code* paragraph 2-14 {Table 4.16.10}.

4.2.10.5 Flange bolt diameters shall not be less than 3/4 inch (19 mm) nominal diameter.

4.2.10.6 Flange bolt hole diameters shall be 1/8 inch (3 mm) greater than the diameter of the bolts.

4.2.10.7 Unless otherwise approved by Purchaser, nubbins shall not be permitted.

4.2.10.8 The design of custom flanges shall include the effect of bolt spacing in accordance with the following:

$$1. \text{ Maximum bolt spacing} = 2a + \frac{6t}{m + 0.5}$$

2. If bolt spacing is greater than (2a + t), the design moment (M<sub>O</sub>)

acting on the flange shall be multiplied by  $\sqrt{\frac{B_s}{2a + t}}$

where:  $M_O$ , and  $m$  are as defined in *Code Appendix 2*,  
Paragraph 2-3;  
 $a$  = nominal bolt diameter, inches (mm)  
 $B_S$  = actual bolt spacing, inches (mm)  
 $t$  = minimum finished flange thickness, exclusive of  
corrosion allowance, inches (mm)

#### 4.2.10.9 Indicator-Type Bolting

1. If specified on Purchaser's *PIP VEDV1003-D* Data Sheet, Part D, line 23 for high bolt-load control accuracy during initial assembly and during operation at temperature, flanged joints with 2-inch (50 mm) diameter and greater bolting shall be provided with bolts having an indicator rod through the bolt center for measuring installed bolt elongation using a depth gauge.
2. Indicator-type bolts shall be purchased in accordance with *ASME PCC-1*, Figure 1 or Figure 2, as applicable.
3. Except as specified in Section 4.2.10.9.4, every bolt in the joint assembly shall be an indicator-type bolt.
4. If hydraulic tensioners are used, and unless otherwise specified on Purchaser's *PIP VEDV1003-D* Data Sheet, indicator-type bolts for every fourth bolt is recommended in the joint assembly for calibration purposes during initial assembly and for bolt-load control during operation at temperature.
5. The indicator rod material for low-alloy steel bolting shall be nickel alloy C-276.
6. The indicator rod for bolting materials other than low-alloy steel shall be the same as the bolts or a material having essentially the same coefficient of expansion and a composition suitable for welding to the bolts.
7. All bolts in the joint assembly shall have a through-hardened flat washer under each nut.

#### 4.2.10.10 Custom-Designed Lap Joint Flanges

Unless otherwise specified in the contract documents, custom-designed lap joint flanges shall be provided in accordance with the following:

- a. The minimum required radial lap width shall be in accordance with Table 3.

**Table 3 - Minimum Radial Lap Width**

Nozzle Vessel OD, inches (mm)	Radial Lap Width, inches (mm)
OD ≤ 18 (450)	1 (25)
18 (450) < OD ≤ 36 (900)	1-1/2 (38)
36 (900) < OD ≤ 60 (1500)	1-3/4 (44)
OD > 60 (1500)	2 (50)
Notes: 1. Radial lap width shall be measured from the toe of the lap-to-shell attachment weld to the outer edge of the lap ring. 2. See Section 4.2.10.10.d.	

- b. See Table 2 for the recommended minimum gasket contact width.
- c. Finished lap ring thickness shall be a minimum of 3/16 inch (5 mm) greater than the nominal wall thickness of the nozzle or shell to which the ring is attached.

*Comment:* This thickness permits possible future re-machining of the lap and is sufficient to permit the laps to be machined front and back, if necessary to maintain parallel surfaces after repair.

- d. If the values in the Table 2 and Table 3 are waived by the Purchaser, the gasket/lap/flange design shall be configured so that the gasket load reaction on the lap (defined as “G” in Code Appendix 2 {4.16.12}) is as close as practicable to being coincident with the reaction of the flange against the back of the lap, taken at the midpoint of contact between the flange and lap.

*Comment:* The Code does treat the gasket reaction and flange/lap reaction independently. See Code Figure 2-4(1) {Figure 4.16.6}. However, this configuration may promote improved joint performance because it minimizes the amount of bending in the lap ring resulting from applied forces.

- e. The difference between the lap joint flange inside diameter and the shell outside diameter shall not be greater than the following:
  - (1) 1/16 inch (1.5 mm) for nominal nozzle diameters less than or equal to NPS 12 (DN 300)
  - (2) 1/8 inch (3 mm) for nominal nozzle diameters greater than NPS 12 (DN 300) through 48 inches (1200 mm) outside diameter

- (3) 3/16 inch (5 mm) for nominal nozzle diameters greater than 48 inches (1200 mm) outside diameter
- f. The lap ring weld and flange bevel shall be configured as follows:
  - (1) The weld attaching the lap ring to the shell shall be an equal leg fillet weld. The fillet weld leg dimension shall be equal to the nominal shell thickness with a tolerance of +1/16 inch (+1.5 mm) and -0.
  - (2) The difference between the diameter of the flange bevel where the lap ring contacts the surface of the flange and the nominal diameter at the toe of the lap ring attachment weld at the back of the lap ring shall be 1/8 inch (3 mm) with a tolerance of +1/16 inch (+1.5 mm) and -0.
- g. The distance between the inside edge of the bolt hole in the lap joint flange and the outside diameter of the lap ring shall not be greater than 1/16 inch (1.5 mm).
- h. The nominal outside diameter of shop-fabricated laps shall be in accordance with *ASME B16.9* standard diameters if used with ASME standard flanges.

#### 4.2.10.11 Quick Opening Closures

Quick opening closures, if specified, shall be in accordance with the following:

- a. Swing bolts (i.e., eye bolts) shall be of one-piece construction without welding.
- b. Hinge pins shall be solid (i.e., not rolled) and of the same material as the swing bolts.
- c. See *Code* paragraph UG-35.2 and Appendix FF {4.8 and Annex 4.B}.

#### 4.2.11 Supports

##### 4.2.11.1 General

1. *Code*-allowable stresses {design stress intensity} shall be used for vessels and their supports. For combinations of earthquake or wind loadings with other loadings listed in *Code* Paragraph UG-22 {4.1.5.3}, the allowable stresses {design stress intensity} may be increased in accordance with *Code* Paragraph UG-23(d) {Table 4.1.2}. See Section 4.2.3.2 for load combinations to be considered. See also *Code* Appendix G {4.15}.
2. For structural-shape support members in compression, if slenderness ratio is a controlling design consideration, an increase in the allowable compressive stress shall not be applied.

3. For supports outside the scope of the *Code*, either *Code*-allowable stresses {design stress intensity} or, for structural shapes, those in the *AISC* Manual of Steel Construction may be used.
4. Localized shell and support stresses at all support-to-shell locations shall be considered, as applicable, for wind load, earthquake, and all other loadings in accordance with *Code* Paragraph UG-22 {4.1.5.3}. See Sections 4.2.4 and 4.2.5.
5. If reinforcing pads are used under supports, consideration shall be given to stresses caused by possible temperature differentials among the vessel, pads, and supports.
6. Unless otherwise specified, vertical vessels shall be designed as self-supporting units and shall resist overturning from wind or earthquake loadings (see Sections 4.2.4 and 4.2.5) and other applicable loadings in accordance with *Code* Paragraph UG-22 {4.1.5.3}.

#### 4.2.11.2 Skirt Supports

1. Vessel skirts shall have a minimum thickness of ¼ inch (6 mm).
2. Skirt Construction
  - a. See Purchaser's *PIP VESV1003-D* Data Sheet, Part C, for the required standard skirt attachment detail shown on *PIP VEFV1128*. Skirts shall be attached to the bottom head by a continuous weld sized so as to provide for the maximum imposed loadings.
  - b. See *Code* Division 2, Figure 4.15.7 for illustrative weld attachment details and associated minimum weld sizes.
  - c. All butt weld joints within the skirt shall be Type No. 1 in accordance with *Code* Table UW-12 {Table 4.2.2}.
  - d. Alignment tolerance at plate edges to be butt-welded shall be in accordance with *Code* Paragraph UW-33 {Paragraph 6.1.4.3}.
  - e. Skirt-to-base ring attachments in vessel skirts shall be two continuous fillet welds, one outside and one inside.
3. Skirts shall be vented with a minimum of two, 2-inch (50 mm) openings, located near the top of the skirt, but below the head insulation or fireproofing.
4. Skirt Sleeves
  - a. All skirt openings shall be provided with rings or collars, sized to provide 100% reinforcement of the opening.
  - b. If the skirt is to be provided with insulation or fireproofing, the projection of the rings or collars (i.e., sleeves) shall not be less than the insulation or fireproofing thickness.

- c. Sleeves shall be of sufficient size to provide clearance for painting, insulation, and expansion.
- d. Sleeve material shall be the same material composition as that portion of the skirt and shall be continuously fillet-welded inside and outside.

#### 4.2.11.3 Saddle Supports

1. Horizontal vessels shall be designed for two saddle supports attached by welding.
2. Saddles shall be designed in accordance with the applicable loadings, including those to be used in conjunction with weigh cells or slide plates.
3. If the operating temperature is greater than 250°F (120°C), or the calculated thermal expansion is greater than 1/4 inch (6 mm), or the Purchaser specifies that the saddles shall be designed to accommodate sliding, sliding saddles shall be provided.
4. Design of saddle supports and calculation of localized shell stress may be determined by the L. P. Zick method in accordance with *Stresses in Large Cylindrical Pressure Vessels on Two Saddle Supports*. See Code Appendix G {4.15.3}.
5. The minimum saddle support contact angle shall be 120 degrees.
6. Saddle Wear Plates
  - a. Saddle wear plates, if required, shall have the following proportions:
    - (1) Plate thickness shall be determined by design, but shall not be less than the smaller of vessel shell thickness or 3/8 inch (10 mm)
    - (2) Plate width shall be the width of the saddle plus 5t on each side of the saddle, where t equals the vessel shell thickness in the corroded condition
    - (3) Plate extension beyond the horn of the saddle shall be equal to r/10, where r equals the radius of the vessel shell in the corroded condition
  - b. Wear plates shall have a minimum radius of 2 inches (50 mm) on the corners.
  - c. Wear plates shall be continuously welded to the shell.
  - d. Wear plates shall be provided with one 1/4 inch (6 mm) drilled telltale hole (or equivalent venting) per segment, and shall be vented to the atmosphere.
  - e. Vent holes shall be located at the low point of the wear plate and shall not be plugged during hydrostatic testing.

7. Fixed Saddles

- a. The fixed saddle, as designated by the Purchaser in the contract documents, shall be provided with round holes for the anchor bolts.
- b. The anchor bolts are to be located at the center of the bolt holes.
- c. The diameter of the bolt holes shall be 1/4 inch (6 mm) greater than the bolt diameter.

8. Sliding Saddles

- a. The sliding saddle, as designated by the Purchaser in the contract documents, shall be provided with slotted holes for the anchor bolts.
- b. The anchor bolts are to be located in the slot to accommodate the calculated movements.
- c. The diameter of the bolt holes and width of the slot shall be 1/4 inch (6 mm) greater than the bolt diameter.
- d. The length of the slot shall be calculated using the following equation:

$$\text{Slot length} = 2.5\alpha(D_L)\Delta T$$

where:

$\alpha$  = Coefficient of thermal expansion of shell material,  
inch/inch/°F (mm/mm/°C)

$D_L$  = Length between saddle supports, measured to  
centerline of anchor bolts, inches (mm)

$\Delta T$  = Greatest absolute value of: ambient temperature at  
installation, but not warmer than 70°F (20°C), minus the  
maximum or minimum shell temperature to be stamped on  
the *Code* nameplate, °F (°C).

9. Slide Plates

Slide plates shall be furnished and installed by Purchaser.

*Comment:* Examples of standard details that may be used for  
slide plate applications are shown on *PIP*  
*VEFV1105* and *PIP VEFV1106*.



#### 4.2.12 Anchor Bolts

4.2.12.1 Anchor bolt loads, the size and quantity of anchor bolts, and base plate details shall be determined. The anchor bolt loads shall be provided to the Purchaser.

*Comment:* Anchor bolting shall be furnished and installed by others.

4.2.12.2 The allowable tensile design stress, as calculated using the tensile stress area of the threaded portion, shall not be greater than the following:

- a. For carbon steel or stainless steel, 20,000 psi (138 MPa)
- b. For low-alloy steel, 30,000 psi (207 MPa)

*Comment:* For vessels on concrete foundations, the allowable stress of anchor bolts may be limited by the strength and dimensions of the concrete for the bolt spacing selected.

4.2.12.3 Allowable stresses used in the final design for anchor bolts shall be approved by the Purchaser.

4.2.12.4 Anchor bolts shall be specified with the following threads and the tensile stress area shall be selected accordingly:

- a. For bolts 1 inch (25 mm) and less in diameter, coarse thread series, ASME B1.1
- b. For bolts greater than 1 inch (25 mm) in diameter, 8 thread series, ASME B1.1

4.2.12.5 Unless otherwise specified, for vessels on concrete foundations, the design concrete bearing stress used shall be 1658 psi (11.4 MPa).

*Comment:* This design bearing stress value is based on the use of concrete with an ultimate strength,  $f'_c$ , of 3000 psi (20.7 MPa) for which the minimum allowable bearing is  $(0.65)(0.85)f'_c$  [i.e., 1658 psi (11.4 MPa) for 3000 psi (20.7 MPa) concrete].

4.2.12.6 The design loadings for anchor bolts embedded in concrete shall be determined by either the simplified method (i.e., neutral axis of bolt pattern at centerline of vessel) or the shifted neutral axis method in accordance with *Process Equipment Design*. The method used shall be specified on the Purchaser's *PIP VEDV1003-D* Data Sheet.

*Comment:* The shifted-neutral-axis method does not apply for vessels supported by steel structures.

4.2.12.7 Anchor bolts for vessels shall not be less than 3/4 inch (19 mm).

4.2.12.8 Anchor bolts shall straddle normal centerlines.

4.2.12.9 If low-alloy steel bolting is required, the anchor bolt circle shall provide radial clearance for a bolt tensioning device.

#### 4.2.13 Internals

- 4.2.13.1 Vessel internals constructed of alloy pipe shall have the following minimum wall thicknesses:
  - a. For pipe sizes smaller than or equal to NPS 12 (DN 300), Schedule 10S minimum
  - b. For pipe larger than NPS 12 (DN 300), 3/16 inch (5 mm) minimum nominal wall pipe or fabricate from plate
- 4.2.13.2 Unless otherwise specified on Purchaser's *PIP VEDV1003-D* Data Sheet, the material for internal attachments shall be the same nominal composition as the cladding, weld overlay, or shell to which it is attached.
- 4.2.13.3 Verify that all removable internals can pass through designated vessel openings.
- 4.2.13.4 For vertical vessels with internals, if a vessel manway is not located in the top head, internal rigging clips shall be provided to facilitate handling of the internals.
- 4.2.13.5 Grab rungs, if specified on Purchaser's *PIP VEDV1003-D* Data Sheet, shall be in accordance with *PIP VEFV1125*.
- 4.2.13.6 Internal piping and baffles shall be mounted in a manner that cannot restrict thermal expansion.
- 4.2.13.7 If Purchaser's *PIP VEDV1003-D* Data Sheet specifies that the vessel is subject to vibration and/or fatigue, internal welded non-pressure parts (e.g., baffles that can be subject to vibration or cyclic loading) shall be continuously welded.
- 4.2.13.8 If specified on Purchaser's *PIP VEDV1003-D* Data Sheet, internal bolting in vessels, especially where vibration is expected (e.g., where agitators are installed), shall either be double-nutted, tack-welded to the clip or baffle, or have a lock wire placed in the nut/bolt or other supports.
- 4.2.13.9 Unless otherwise specified, flanges for internal non-pressure piping may be fabricated from plate but shall be in accordance with ASME B16.5 and B16.47 Class 150 bolting patterns.
- 4.2.13.10 Vessel internals and all portions of each vessel shall be self-draining to ensure complete elimination of liquid from the vessel when drained.
- 4.2.13.11 The minimum thickness of internal welded-in parts shall be 3/16 inch (5 mm) plus the corrosion allowance for each wetted side.
- 4.2.13.12 Internal support rings shall not be considered for vessel strength calculations.
- 4.2.13.13 All internal feed piping including piping supports shall be furnished and installed according to the tray manufacturer's designs and/or recommendations.

*Comment:* Process design of trays and other removable internals is outside the scope of this Practice.

#### **4.2.14 Attachments**

- 4.2.14.1 All attachments welded to pressure-retaining vessel components shall be considered critical to the structural integrity of the vessel for evaluation of impact test requirements. See *Code* Paragraph UCS-66(a) {3.11.2.3c}.
- 4.2.14.2 For the purpose of establishing impact test requirements for carbon and low-alloy steel attachments welded to pressure-retaining components, the level of applied general primary membrane stress shall be considered to be the same as the maximum level applied to the pressure boundary component to which they are attached.
- 4.2.14.3 Unless otherwise specified, all clips, brackets, and other items welded to the outside surface of the vessel or skirt shall be provided and installed, including the following:
- a. Manufacturer's nameplate configured as follows:
    - (1) Made either of 300 series stainless steel or of a nickel-copper alloy UNS N04400 or equivalent (i.e, Monel®)
    - (2) Attached securely using a nameplate support bracket in accordance with detail *PIP VEFV1101*.
  - b. Lifting attachments, as designed by the Manufacturer or as specified by Purchaser
  - c. For vessel shells under external pressure, *Code*-required stiffening rings placed on the outside of the vessel and configured as follows:
    - (1) Minimum thickness, 3/8 inch (10 mm)
    - (2) Maximum ring width-to-thickness ratio, 10
    - (3) Made from a structural form that cannot trap and hold water

*Comment:* Drains or gaps may be provided in the stiffener rings, if necessary to prevent water from collecting.
    - (4) Attached by continuous fillet welds on both sides of the ring
  - d. Grounding lug in accordance with detail *PIP VEFV1103*

### **4.3 Materials**

- 4.3.1 All impact test values shall be reported in the material supplier's certified test reports.
- 4.3.2 Except for flanges in accordance with *ASME B16.5* and *B16.47*, all carbon, low-alloy, and high-alloy steel forgings greater than 3 inches (75 mm) in

thickness shall be examined ultrasonically in accordance with *ASME SA-745* with the following requirements:

- a. Quality levels for straight beam examinations from flat surfaces shall be in accordance with Table 4.

**Table 4 - Quality Levels for Straight Beam Examinations from Flat Surfaces**

<b>FORGING THICKNESS (t)</b>	<b>QUALITY LEVEL</b>
Inches (mm)	
$3 (75) < t \leq 8 (200)$	QL-2
$8 (200) < t \leq 12 (300)$	QL-3
$t > 12 (300)$	QL-4

- b. Quality level for straight beam examinations from curved surfaces shall be QL-5.
  - c. Quality level for all angle beam examinations shall be QA-1. Notch depth shall be in accordance with QA-1 or 1/4 inch (6 mm), whichever is less.
- 4.3.3 Integrally clad plate for vessels designed for vacuum service and for vessels whose design calculations include the cladding shall be examined in accordance with *ASME SA-578* Acceptance Standard - Level B and Supplementary Requirement S6.
- 4.3.4 The heat treatment of integrally clad plate in accordance with *ASME SA-263*, *ASME SA-264*, and *ASME SA-265* shall be performed by the plate manufacturer.
- 4.3.5 All integrally clad plate, including explosion clad plate, in accordance with *ASME SA-263*, *ASME SA-264*, and *ASME SA-265* shall be cold flattened, if required, after final heat treatment and descaling.
- 4.3.6 For quick opening closures, swing bolts (i.e., eye bolts) shall be of one-piece construction without welding. Hinge pins shall be solid and of the same material as the swing bolts. See *Code* paragraph UG-35 and Appendix FF {4.8 and Annex 4.B}.
- 4.3.7 As an alternative to the materials specified by the Purchaser, other materials may be proposed for the attachments with consideration given to the following:
- a. Potential problems associated with welding dissimilar materials
  - b. Compatibility with the Code nameplate maximum and minimum design metal temperatures
  - c. Whether the attachment is essential to the structural integrity of the vessel. See Code Paragraph UCS-66(a) {3.11.2.3c}.
  - d. Differential thermal expansion characteristics and associated stresses
  - e. Corrosion resistance
  - f. Painting requirements
  - g. Suitability for the anticipated loadings

- 4.3.8 Gaskets specified by Purchaser shall be provided. For test gaskets, see Section 4.5.3.7. For spare gaskets, see Section 4.6.2.3.

## 4.4 Fabrication

### 4.4.1 General

- 4.4.1.1 All equipment shall be in accordance with the manufacturing tolerances shown in the contract documents.
- 4.4.1.2 Tolerances on fabricated equipment shown on detail *PIP VEFV1102* shall apply to the completed vessel after pressure test.
- 4.4.1.3 Machining shall be performed after welding or heat treatment if such operations change machined surface characteristics or geometry (e.g., flange face flatness).
- 4.4.1.4 When forming any austenitic stainless or nonferrous plate, care shall be taken to prevent carbon pickup or contamination of formed material.
- 4.4.1.5 Only stainless steel brushes and clean, iron-free sand, ceramic or stainless steel grit shall be used for cleaning stainless steel and non-ferrous surfaces. Cleaning tools or materials shall not have been previously used on carbon steel.
- 4.4.1.6 Unless otherwise specified, cutting stainless steel shall be performed by mechanical methods (i.e., shearing, sawing, or machining).
- 4.4.1.7 If cutting stainless steel by any thermal process (e.g., plasma arc or air arc) is specified and/or approved by Purchaser, an allowance shall be made for the removal of not less than 1/8 inch (3 mm) of metal [e.g., 1/4 inch (6 mm) in the diameter of an opening] by machining or grinding to the finished dimension.
- 4.4.1.8 Special care shall be taken to prevent stress raisers which can cause low impact strength because of notch effect or abrupt change in section.
- 4.4.1.9 Welder's and welding operator's symbols and reference lines may be stamped on the material in accordance with the provisions of *Code* Paragraph UW-37 {6.2.5.4}, provided that a round-nose stamp is employed and the symbol is located a minimum of 1 inch (25 mm) from the edge of the weld.
- 4.4.1.10 Materials that can cause corrosive attack when the vessel part is heated shall not be permitted. Such materials include the following:
- Marking inks that contain halogens
  - Lubricants
  - Crayons
  - Adhesives
  - Tapes (e.g., duct tape)
  - Coatings to prevent adhesion of weld spatter

- g. Paints containing sulfur
- h. Chlorine compounds that decompose to hydrogen chloride
- i. Carbon
- j. Harmful metal or metal salts (e.g., zinc, lead, or copper)

#### 4.4.2 Shells and Heads

- 4.4.2.1 Longitudinal joints of adjacent shell courses (including skirts) shall have a minimum offset of not less than 5 times the plate thickness or 6 inches (150 mm), whichever is greater.
- 4.4.2.2 Plate layouts shall be arranged so that longitudinal and circumferential weld seams clear all nozzles, manways, and their reinforcing pads by 2 inches (50 mm) minimum, measured from weld edge to weld edge.
- 4.4.2.3 If the requirement of Sections 4.4.2.1 and 4.4.2.2 cannot be met, the following shall apply:
  - a. Subject seam shall be ground flush and 100% radiographically examined before welding the nozzle.
  - b. Nozzles which intersect weld seams shall be located such that their centerline falls approximately on the centerline of the weld seam.
  - c. The seam shall be radiographed in accordance with *Code* Paragraph UW-51 {4.2.5, 7.5.3} in accordance with *Code* Paragraph UW-14 {7.4.3.5 a) 4}).
- 4.4.2.4 Unless otherwise approved by Purchaser, the longitudinal seams shall, if possible, not fall within the downcomer area of trays or behind any obstruction that prevents inspection of the welds.
- 4.4.2.5 Circumferential seams shall not fall on a tray ring, and shall be located not less than 2 inches (50 mm) above or below the tray ring.

#### 4.4.2.6 Saddles

- 1. Saddles shall be continuously welded to the shell.
- 2. Welded seams under the saddle or wear plate are not permitted.
- 3. Longitudinal weld seams in the shell shall not be located within 15 degrees of the horn of the saddle, because this is a location of high stress.

#### 4.4.2.7 Seams in Formed Heads

- 1. The flat plate from which formed heads are made shall be either seamless or made equivalent to seamless in which all Category A welds are Type (1) and fully radiographed in accordance with *Code* Paragraph UW-51 {7.5.3} before forming.
- 2. Before forming, welds shall be ground flush with the plate surfaces.

3. After forming, the spin hole, if it remains in the final construction, shall be repaired with a metal plug butt-welded in place. The weld shall be in accordance with the Category A weld joint requirements.

#### **4.4.2.8 Structural Attachment Welds**

1. Structural attachment welds (e.g., internal support rings or clips, external stiffening rings, insulation support rings, and ladder, platform or pipe support clips) shall clear weld seams by a minimum of 2 inches (50 mm).
2. If overlap of pad type structural attachments and weld seams is unavoidable, the portion of the seam to be covered shall be ground flush and radiographically examined before the attachment is welded on.
3. The seam shall be radiographed in accordance with *Code* Paragraph UW-51 {7.5.3} for a minimum distance of 2 inches (50 mm) beyond the edge of the overlapping attachment.
4. Radiographic examination of weld seams is not required if single-plate edge-type attachments (e.g., tray support rings, downcomer bolting bars, stiffening rings, insulation support rings, ladder, platform, or pipe support clips) cross weld seams.
5. Coping of external attachments to clear main seams shall be performed wherever possible.

#### **4.4.3 Nozzles, Manways, and Flanges**

- 4.4.3.1 Bolt holes in all fixed flanges and studding outlets shall straddle the natural centerlines.
- 4.4.3.2 For nozzles in heads, the bolt holes shall straddle centerlines parallel to or coincident with the natural vessel centerlines.
- 4.4.3.3 All inside nozzle neck edges shall be rounded to 1/8 inch (3 mm) minimum radius.
- 4.4.3.4 Nozzles for pressure relief devices and for drainage shall be flush with the inside wall of the shell or head.
- 4.4.3.5 Nozzle reinforcing pads shall be external.
- 4.4.3.6 If multi-segmental reinforcing pad elements are used, the weld shall be a Type 1 or Type 2 full penetration butt weld, and the joint efficiency of the pad as applied to the allowable stress of the pad material,  $S_p$ , shall be not be greater than one of the following as applicable:
  - a. If the weld is not radiographed or UT examined, 0.65
  - b. If the weld is 100% radiographed or alternatively UT examined, 0.90

- c. If the weld is not less than 60 degrees from the longitudinal axis of the vessel the following joint efficiencies may be used as applicable:
  - (1) For 100% radiography, 1.0
  - (2) For spot radiography, 0.85
  - (3) For no radiography, 0.70
- 4.4.3.7 Each pad segment shall have one American Standard Taper Pipe Thread (NPT) 1/4 inch (6 mm) telltale hole for testing purposes. See Section 4.5.3.4 for testing of reinforcing pads. Each hole shall be located near the lowest point of a pad with the vessel in its operating position to permit drainage.
- 4.4.3.8 If not circular, nozzle reinforcing pads and attachment pads shall have rounded corners of 2 inches (50 mm) minimum radius.
- 4.4.3.9 Nozzles in dished heads shall be positioned such that the nozzle, reinforcing pads, and attachment welds, if applicable, are within the spherical portion of the head.
- 4.4.3.10 Unless otherwise specified, for a vessel supported by a skirt, flanges of nozzles in the bottom head shall be located outside the skirt.
- 4.4.3.11 Unless projections are otherwise specified by Purchaser, when establishing nozzle and manway projections, the following shall apply:
  - a. Clearance shall be provided for removing flange stud bolts from between the flange and vessel and for accessing flange stud nuts.
  - b. Clearance shall be provided for flange studs and nuts if nozzles penetrate insulation or platforms.
  - c. Minimum projection from the outside of the vessel wall to the nozzle face shall be:
    - (1) For nozzles less than or equal to NPS 8 (DN 200), 8 inches (200 mm)
    - (2) For nozzles larger than NPS 8 (DN 200), 10 inches (250 mm)
  - d. The dimension from the face of the nozzle to the vessel centerline or reference line shall be rounded up to the next greater 1/2-inch (10 mm) increment.
- 4.4.3.12 For lap joint flanges NPS 4 (DN 100) and larger that face upward (i.e., the nozzle inclines from the horizontal at an angle of 30 degrees or greater.), safety retainer clips shall be provided as follows:
  - a. A minimum of three clips shall be welded to the nozzle neck at the back of the flanges.



- b. The spacing of the clips between the back of the lap and the face of the flange shall be one length-through-hub dimension (i.e., dimension Y in *ASME B16.5*).

4.4.3.13 For all flanges (except *ASME B16.5* and *ASME B16.47* flanges) and shop-fabricated lap rings, the gasket contact surface flatness tolerance shall be in accordance with the following:

- a. 0.006 inch (0.150 mm) total indicator reading in both the radial and circumferential directions.
- b. The total circumferential tolerance shall not occur in less than 20 degrees arc.
- c. Measurement shall be made using a dial indicator after all other operations (i.e., fabrication and heat treatment of the flange or lap ring, and attachment to the shell or nozzle neck) that can affect flatness tolerance have been completed.

#### 4.4.3.14 Flange Facing and Surface Finish

1. Except for lapped flanges, flanges shall have one of the following configurations:
  - a. Raised face
  - b. If required in accordance with Section 4.4.3.14.4, a construction that provides outer confinement to the gasket
2. The height of a raised face shall be one of the following as specified on Purchaser's *PIP VEDV1003-D* Data Sheet:
  - a. 1/16 inch (1.5 mm)
  - b. In accordance with *ASME B16.5*
  - c. In accordance with *ASME B16.47*
  - d. As specified by Purchaser

*Comment:* For some Purchaser-designated services, flat-face flanges or ring joint facings may be required.

3. For standard flanges, custom flanges, and shop-fabricated and manufactured lap joint stub ends, the gasket contact surface shall have either a serrated concentric or serrated spiral finish having a resultant surface finish from 125 - 250  $\mu$  inch (3.2 – 6.4  $\mu$  m) average roughness.
4. Gasketed flange joint designs (i.e., body flange and nozzle joints) larger than NPS 24 (DN 600) shall provide outer confinement of the gasket for any of the following conditions:
  - a. Design pressure is equal to or greater than 300 psi (2 MPa)
  - b. Design temperature is warmer than 500°F (260°C)
  - c. MDMT is colder than minus 20°F (-29°C)

- d. Cyclic pressure or temperature service
- e. Joint requires metallic gasket

*Comment:* Robust metal reinforced gaskets (e.g., spiral-wound with outer gauge ring, double-jacketed corrugated metal gaskets with a corrugated metal filler, etc.) do not require gasket confinement.

4.4.3.15 For corrosive service, the use of splice welds on gasket contact surfaces of a lap ring or flange shall be approved by Purchaser.

4.4.3.16 Joints shall be assembled in accordance with *ASME PCC-1*.

4.4.3.17 Hardened washers shall be provided under nuts for all bolts having diameters of 1-1/4 inches (32 mm) or larger to prevent damaging the back side of the flange. The washers shall be a minimum of 1/4 inch (6 mm) thick.

4.4.3.18 If studed connections are used, the following shall apply:

- a. The holes in a studed connection and the studs shall be machined in accordance with *PIP VEFV1129*.
- b. Indicator type studs for studed connections, if used, shall be in accordance with *ASME PCC-1* Figures 1 and 2.
- c. A spacer ring of the same material as the nozzle flange may be provided behind the flange to increase the effective stud length. See note on *PIP VEFV1129*.
- d. If a spacer ring is used, the thickness of the ring shall be equal to or greater than the mating flange thickness.
- e. Studs and spacer ring, if required, shall be provided for each studed connection on the vessel.
- f. Studed connections shall be checked to assure the remaining thickness of the drilled holes is in accordance with *Code* UG-43(d){4.5.3.1 b}).

#### **4.4.4 Vessel Attachments**

4.4.4.1 For services the Purchaser specifies as corrosive, the following shall apply:

1. Welding of vessel internals attached to a pressure boundary component shall be continuous on all surfaces to eliminate corrosion pockets.
2. All seams and corner joints shall be sealed.
3. If a vessel corrosion allowance is specified, the size of welds shall include allowance for corrosion.
4. Minimum weld size shall be 3/16 inch (5mm) in the corroded condition.

4.4.4.2 Except as permitted in Section 4.4.4.3, all external supports, support rings, pads, and structural brackets attached to the vessel shall be seal-welded all around to prevent corrosion between the vessel and attachments.

4.4.4.3 If seal welding all around an external attachment is not practical, provision for drainage shall be made (e.g., a gap in the low-point weld).

#### **4.4.4.4 Temporary Welded Attachments**

1. Attachment point of spiders, braces, or other temporary attachments shall be of the same material alloy as the point on the vessel to which it is attached.
2. All temporary attachments shall be removed before hydrostatic testing.
3. Temporary attachments shall be removed flush with the vessel shell and nondestructively examined [i.e., Magnetic Particle Examination (MT) or Dye Penetrant Examination (PT)], in addition to visual examination, to ensure no cracks have been generated.
4. Temporary welds shall be in accordance with Section 4.4.5.4.

4.4.4.5 Galvanized clips or attachments shall not be welded to a vessel.

4.4.4.6 For half-pipe jackets or pipe sections welded to shells and/or heads, jacket to shell welds shall be full penetration and full strength welds, and 100% liquid penetrant examination shall be performed.

4.4.4.7 For integrally clad and weld overlaid vessels, attachments shall be in accordance with the following:

- a. Lightly loaded supports in accordance with *Code* Section VIII, Division 2, Paragraph AD-912, footnote 4 (e.g., supports for trays, baffles, etc.) may be welded directly to the alloy clad or weld overlay.
- b. If an attachment (e.g., packing bed support rings) supports a significant load (e.g., greater than 25% of the allowable stress for fillet welds), the support shall be welded directly to the base metal.

#### **4.4.5 Welding**

4.4.5.1 Unless specified on Purchaser's *PIP VEDV1003-F* Welded Pressure Joint Requirements Form, minimum requirements for welded pressure joints shall be in accordance with Section 4.4.5.11.

4.4.5.2 The selected welded pressure joint requirements shall be consistent with service-specific needs; however, the following shall apply as a minimum:

- a. Welded joints of Categories A, B, and, if used, butt-type Categories C and D shall be Type No. 1 of *Code* Table UW-12 {Table 4.2.2}.

*Comment:* This requirement excludes the use of permanent weld joint backing strips, and butt welds with one plate offset. See *Code* Figure UW-13.1(i). Not applicable to *Code* Division 2.

- b. Non-butt joints that connect nozzles including manways and couplings to the vessel wall (i.e., *Code* Category D joints) shall be full penetration welds through the vessel wall and through the inside edge of reinforcing plates, if used.
- c. Nozzle necks that extend beyond the inside surface of the vessel wall shall have a fillet weld at the inside corner.
- d. For compartmented vessels having a flanged and dished intermediate head(s), the end of the intermediate head skirt(s) shall be seal-welded to the shell of the compartment. See *Code* Fig. UW-13.1 (e){Table 4.2.5 detail 6}.

4.4.5.3 The responsibility for welding shall be part of the overall construction responsibility of the Manufacturer.

4.4.5.4 All welds, including those for non-pressure parts and attachments, including temporary attachments and shipping attachments, shall be made by welders, welding operators, and welding procedures qualified under the provisions of *Code* Section IX.

4.4.5.5 Welds shall be in accordance with the supplementary provisions of the *Code*, and with recognized and generally accepted good welding practices including, but not limited to, the use of clean and dry materials, good techniques, and the proper chemistry.

4.4.5.6 Unless otherwise specified, the welding consumables used in the fabrication of the vessel and its components shall be of the same nominal chemistry as the base metal, and shall have material properties (e.g., tensile strength, yield strength, etc.) equal to or greater than the minimum requirements for the base metal at both ambient and design temperature.

4.4.5.7 Shielded metal arc electrodes used for pressure-retaining welds shall be of the low-hydrogen type.

4.4.5.8 Unless specifically approved in writing by Purchaser, use of weld materials with strengths higher than that of low-hydrogen weld materials for any welding processes is not permitted.

4.4.5.9 The following documents shall be provided to the Purchaser for review and approval before the start of fabrication:

- a. Welding Procedure Specification
- b. Procedure Qualification Record
- c. Welder Performance Qualification

- d. Detailed weld map
- e. Welding procedures
- f. Fabrication drawings

4.4.5.10 The detailed weld map shall include, as a minimum, a sketch of all weld joints, welding symbols used in accordance with AWS A2.4, and associated weld procedure numbers.

4.4.5.11 Pressure retaining butt-weld seams shall be in accordance with the following:

- a. Type No. 1 of *Code* Table UW-12 {Table 4.2.2} (i.e., butt joints as attained by double-welding or by other means that obtain the same quality of deposited weld metal on the inside and outside weld surfaces in accordance with *Code* Paragraph UW-35 {6.2.4.1}).
- b. Welds using permanent metal backing strips are not permitted.
- c. Butt-weld seams shall be accessible for examination, inspection, and/or repair with welded attachments in place.
- d. For joints inaccessible from the inside, an alternative method for obtaining a full penetration and full fusion weld from one side shall be submitted to Purchaser for review and approval.

4.4.5.12 Except as specified in Section 4.4.5.13, Gas Metal Arc Welding (GMAW) shall be used only in the spray transfer range.

*Comment:* Pulse arc is considered spray transfer.

4.4.5.13 The GMAW short arc transfer mode may be used for carbon steel materials less than or equal to 3/16 inch (5 mm) thick and for the root pass in carbon steel material of any thickness with the following provisions:

- a. Vertical welding is performed in the uphill progression
- b. The root pass is backgouged
- c. GMAW-S is not used on branch connections, o-let, socket-type welds, or pipe less than or equal to 3 inches (75 mm) outside diameter

4.4.5.14 If weld overlay is specified, the deposited weld overlay shall have a composition that corresponds to that of the composition and depth specified on the contract documents.

#### **4.4.6 Postweld Heat Treatment (PWHT)**

4.4.6.1 Vessels shall be postweld heat treated in accordance with applicable sections of the *Code* and the material specifications or as specified by the Purchaser because of service conditions.

4.4.6.2 Unless otherwise specified by the Purchaser, requirements for PWHT of carbon and low-alloy steels shall be in accordance with *Code* Table UCS-56 {Table 6.8 through 6.15}.

- 4.4.6.3 Unless otherwise approved by the purchaser, alternative PWHT requirements of *Code* Table UCS 56.1 {Table 6.16} shall not be used.
- 4.4.6.4 PWHT of test specimens shall be in accordance with *Code* requirements.
- 4.4.6.5 Unless otherwise specified on Purchaser's *PIP VEDV1003-D* Data Sheet, PWHT of test specimens shall include one extra PWHT cycle for potential future field repair.
- 4.4.6.6 PWHT shall be performed after all welding, weld repairs, and nondestructive examination is completed, but before any hydrostatic testing or other load testing.
- 4.4.6.7 Furnaces used for PWHT shall be constructed to prevent flame impingement on the work.
- 4.4.6.8 A sufficient number of thermocouples, attached directly to the unit being heat-treated, shall be used to accurately indicate the temperature of the work and detect uneven heating.
- 4.4.6.9 The equipment shall be adequately supported during the PWHT to avoid distortion.
- 4.4.6.10 Except as specified in Section 4.4.6.11, pressure parts made of austenitic stainless steel, if hot formed, shall be solution annealed between 1850°F (1010°C) and 2050°F (1120°C) followed by rapid cooling through the sensitization range.
- 4.4.6.11 Solution annealing of stabilized grades or "L" grades of austenitic stainless steel with 0.035% carbon max is not required.
- 4.4.6.12 Vessels shall not come into contact with galvanized components during PWHT.

## 4.5 Examination, Inspection and Pressure Testing

### 4.5.1 Examination

- 4.5.1.1 The extent of examination and special documentation, in addition to the minimum requirements of the *Code*, shall be as specified in the contract documents.
- 4.5.1.2 All specified nondestructive examination, including that for non-pressure parts and attachments, shall be performed in accordance with *Code* methods.
- 4.5.1.3 For specific welded pressure joint examination requirements, see the Purchaser's *PIP VEDV1003-F* Welded Pressure Joint Requirements Form. For *Code* Division 2 vessels, the form is not applicable.
- 4.5.1.4 The minimum degree of examination of welded butt joints shall be spot radiography in accordance with *Code* Paragraph UW-52 {7.4.3.1 and 7.4.3.5}. In applying the rules of *Code* Paragraph UW-52 {7.4.3.1 and 7.4.3.5}, the increments of weld shall be selected to include all Category A, B, and C butt welds, except for those

Category B or C butt welds in nozzles and communicating chambers that are less than or equal to NPS 10 (DN 250) or less than or equal to 1-1/8 inches (29 mm) wall thickness.

- 4.5.1.5 See the Purchaser's contract documents for requirements for examining the accessible surfaces of completed Category D corner joint welds by magnetic particle, liquid penetrant, ultrasonic, or other nondestructive methods.

*Comment:* For example, see optional Note E in the Nondestructive Examination Notes of the *PIP VEDV1003-F* Welded Pressure Joint Requirements Form.

- 4.5.1.6 Welded joints that are inaccessible after assembly shall be examined by PT or MT in accordance with the following instructions, and repaired as required before painting, assembly, and testing:

- a. After back-chipping to sound metal, the root pass and its opposite side shall be examined.
- b. After any required machining or grinding, the finished surfaces of the weld shall be examined, and all indications on the finished weld surfaces shall be repaired by grinding or welding before the pressure testing.

- 4.5.1.7 If an examination reveals an unacceptable imperfection, the imperfection shall be repaired, and as a minimum, the repair shall be examined by the same method, to the same extent, and by the same acceptance criteria that revealed the condition.

- 4.5.1.8 The following items shall be examined by magnetic particle or liquid penetrant examination:

- a. The following surfaces of Categories A and B, and Categories C and D butt-type joints greater than 2 inches (50 mm) thick:
  - (1) After back-chipping or gouging root pass to sound metal, the back-chipped or gouged surface
  - (2) All accessible surfaces of completed weld
- b. The following surfaces of Category C and D non-butt type joints, including those in nozzles and communicating chambers, if the vessel section and/or head is designed using a joint efficiency of 1.00:
  - (1) After back-chipping or gouging root pass to sound metal, the back-chipped or gouged surface
  - (2) All accessible surfaces of completed weld
- c. The cut edge of openings in vessel walls greater than 1/2-inch (13 mm) thick into which nozzles and communicating chambers are attached with a full penetration weld through the nozzle or communicating chamber wall. The examination shall be performed before nozzle attachment, and a re-examination performed after attachment if accessible.

- d. All accessible surfaces of completed welds for the following:
  - (1) Welds (i.e., internal and external) if the thickness of the pressure part is greater than 2 inches (50 mm)
  - (2) Welds attaching vertical vessel supports (e.g., skirts, lugs, legs, etc.)
  - (3) Welds attaching vessel lifting (i.e., erection) lugs
  - (4) Welds attaching manway davits

4.5.1.9 Except for blind flanges in accordance with *ASME B16.5* and *B16.47*, rolled carbon, low-alloy, and high-alloy steel plate for flat covers and blind flanges greater than 3 inches (75 mm) thick shall be examined in accordance with *ASME SA-578* Acceptance Standard - Level B after cutting to final size.

#### **4.5.2 Inspection**

- 4.5.2.1 Purchaser's inspection requirements (i.e., review, witness, inspection, hold points, and inspection documentation) are furnished on Purchaser's *PIP VEDV1003-T* Inspection and Testing Requirements Sheet.
- 4.5.2.2 If major components or services are obtained from sub-suppliers, the Purchaser's Inspector shall be notified and given the option of inspecting those items at their point of manufacture.
- 4.5.2.3 The Purchaser's quality surveillance and notification requirements shall be included in all suborders.
- 4.5.2.4 The Manufacturer shall arrange for certified drawings to be available for use by the Purchaser's Inspector at the sub-supplier's location.
- 4.5.2.5 The Manufacturer shall ensure, either directly or through sub-suppliers, that the inspections necessary for conformance to the Purchaser's contract documents are performed.
- 4.5.2.6 The performance of quality surveillance by the Purchaser's Inspector shall not relieve the Manufacturer or sub-suppliers of responsibility for meeting the requirements of the contract documents.

#### **4.5.3 Pressure Testing – General**

- 4.5.3.1 Vessels shall not be painted or controlled shot-peened before the *Code* pressure test, with the following exceptions:
  - a. Surfaces that are to be painted, but are inaccessible after assembly (e.g., mating surfaces of lap-joint stub ends, flanges and nozzle necks, flange bolt holes, welded joints, etc.) shall be painted before assembly and pressure testing.
  - b. Welded joints that are inaccessible after assembly (e.g., joints covered by lap-type flanges) shall be examined by PT or MT and repaired as required before painting, assembly, and pressure testing. See Section 4.5.1.6 for specific examination requirements.



- 4.5.3.2 The test pressure shall be measured at the high point of the vessel in the test position.
- 4.5.3.3 All welds shall be sufficiently cleaned and free of scale or paint before pressure testing to permit proper examination for defects.
- 4.5.3.4 Reinforcing pad attachment welds and accessible surfaces of inside nozzle to vessel wall welds shall be tested for the absence of leaks with a gauge pressure of 15 psig (100 kPa) dry air or nitrogen and bubble forming solution. This test shall be performed before the final hydrostatic or pneumatic test as applicable.
- 4.5.3.5 All facilities and materials (e.g., blinds, bolting, and gaskets) required for testing shall be provided.
- 4.5.3.6 The temperature of the pressure-retaining components during the pressure test, regardless of test media, shall be:
  - a. At least 60° F (15°C), but not warmer than 120°F (50°C) and
  - b. At least 30°F (17°C) warmer than the minimum design metal temperature of the vessel.
- 4.5.3.7 Gaskets shall be used for test purposes in accordance with the following:
  - a. If a flanged joint is not to be disassembled after testing, the specified service gasket shall be used. Service gaskets used for testing shall be left installed for shipment for all blind flanged connections.
  - b. If a joint is to be disassembled after testing and has flanges in accordance with *ASME B16.5* or *ASME B16.47*, the test gasket may be selected by Manufacturer.
  - c. If the joint is to be disassembled after testing, employs nonstandard flanges (i.e., other than *ASME B16.5* or *ASME B16.47*), and the service gasket is not specified, the test gasket description shall be submitted to Purchaser for approval.
- 4.5.3.8 Unless specified for the service condition, joint sealing compound or gasket lubricant shall not be used.
- 4.5.3.9 All bolting and washers, if used for testing, shall be properly lubricated for assembly before the initial hydrostatic test.
- 4.5.3.10 Except for leakage that can occur at temporary closures for those openings intended for welded connections, leakage shall not be permitted at the time of the required inspection.
- 4.5.3.11 Leakage from temporary seals shall be directed away to avoid masking leaks from other joints.
- 4.5.3.12 Sensitive leak tests, if specified, shall be performed before hydrostatic testing.
- 4.5.3.13 Flanged joint assemblies specified to be provided with service gaskets (e.g., main body flange joints, manways, blind flange

nozzles) and which are disassembled following tests shall be reassembled using new service gaskets. If the joints are shipped unassembled, new service gaskets for field installation shall be suitably packaged, marked, and shipped with the vessel. See Section 4.6.2.3.

- 4.5.3.14 Welding, burning or grinding, including cosmetic grinding of pressure retaining welds, shall not be performed on vessels that have been pressure tested unless approved by Purchaser. This includes but shall not be limited to welds for shipping attachments, refractory or insulation clips, stiffeners, spiders, or grinding for surface preparation.
- 4.5.3.15 If field assembly and erection is specified in the contract documents, the final pressure test shall be performed at the installation site. A detailed test procedure shall be provided to Purchaser for review before testing.
- 4.5.3.16 If hydrostatic testing at the installation site is specified in the contract documents, Purchaser shall furnish a fill line and a drain line for the test water at a location adjacent to the test site.

#### 4.5.4 Hydrostatic Test

- 4.5.4.1 Unless otherwise specified on Purchaser's *PIP VEDV1003-D* Data Sheet, *Code* paragraph UG-99(b) {8.2.1(d)}, including footnote 34 {2.2.2.1d 1)}, shall be regarded as the standard hydrostatic test. See the *PIP VEDV1003-D* Data Sheet for the test pressure or applicable *Code* paragraph number.
- 4.5.4.2 If specified on Purchaser's *PIP VEDV1003-D* Data Sheet, liquids other than water may be used for hydrostatic testing in accordance with the *Code*. A detailed test procedure shall be submitted to the Purchaser for approval.
- 4.5.4.3 Horizontal vessels designed to support a full weight load of water shall be tested resting on its support saddles, without additional supports or cribbing.
- 4.5.4.4 Vertical vessels being tested in the erected position, whether shop or field, shall have design consideration given to the additional pressure and weight from the fluid head. See Section 4.2.2.6.
- 4.5.4.5 Vessels shall be adequately supported during the pressure test to prevent damage.  
*Comment:* Unless otherwise specified, design shall be in accordance with Section 4.2.3.2.d regardless of test orientation.
- 4.5.4.6 Testing of vessels shall be performed with test water that is clean and free of debris. Except for applications specified in Section 4.5.4.7, potable water can be used. Brackish or untreated water shall not be used.

- 4.5.4.7 Except as permitted in Section 4.5.4.8, testing of vessels or components made of austenitic stainless steel materials shall be performed with water containing a maximum of 50 ppm chloride.
- 4.5.4.8 If the duration of the test procedure is 72 hours or less and the procedure includes rinsing with water containing less than 50 ppm chloride, testing of vessels or components made of austenitic stainless steel materials may be performed with water containing greater than 50 ppm chloride but less than 250 ppm chloride.
- 4.5.4.9 Test water shall not be in contact with austenitic stainless steel for greater than 72 hours unless treated with an appropriate biocide.
- 4.5.4.10 Before application of the test pressure, the test water and the vessel material shall be permitted to equalize to approximately the same temperature.
- 4.5.4.11 The final pressure test shall be held for a minimum of one hour, or as specified in writing by the Purchaser.
- 4.5.4.12 After completion of the hydrostatic test, the vessel shall be drained, dried including drying internals, and closed as quickly as practicable.

#### 4.5.5 Pneumatic Test

- 4.5.5.1 Pneumatic testing presents hazards that require strict attention as part of the design of the pressure vessel to ensure personnel safety. These considerations include, but shall not be limited to, the following:
  - a. Vessels shall be constructed of materials that ensure fracture toughness during the test.
  - b. Additional nondestructive examination of main seams, nozzle attachments, and some structural attachments in accordance with *Code UW-50* {not Div. 2 applicable}. All additional nondestructive examination shall be performed in accordance with *Code* methods and acceptance criteria. The requirements for the details of all additional examinations shall be furnished by Purchaser.
  - c. Clearance of non-essential personnel from the immediate area.
- 4.5.5.2 If specified in the Purchaser's *PIP VEDV1003-D* Data Sheet, pneumatic testing shall be performed in the field at the installation site.
- 4.5.5.3 Detailed written procedures shall be prepared for any pneumatic testing. The procedures shall be agreed with the Purchaser and the User.

*Comment:* Pneumatic testing can create extreme hazards to a facility and nearby personnel. See *ASME PCC-2* Article 5.1 for guidance on energy calculations for pneumatic tests and safe distances for personnel during the test. Pneumatic testing should not be permitted

unless hydrostatic testing is not reasonably feasible. See Code Paragraph UG-100 {8.3} and Code Paragraph UW-50 {Not Division 2 applicable}.

- 4.5.5.4 If acoustic emission monitoring of the pneumatic test is specified in the contract documents, procedures for the monitoring shall be submitted to Purchaser for approval before testing.
- 4.5.5.5 Except as permitted in Section 4.5.5.6, inert gas shall be used as the test medium for pneumatic testing because inert gas cannot support combustion.
- 4.5.5.6 Clean, dry, oil-free air in accordance with *ISO 8573-1* Class 1, 2 or 3 air, with a dew point ranging from +4°F to -94°F (-20°C to -70°C), may be used as the test medium.

## **4.6 Preparation for Shipment**

### **4.6.1 Cleaning, Painting, and Marking**

- 4.6.1.1 Before shipping or before leaving the installation site if field-erected, the vessel shall be thoroughly cleaned inside and outside. Grit, scale, oil, grease, weld rod stub ends, sand, water, free moisture, and all other foreign material shall be removed from the vessel.
- 4.6.1.2 If specified on the Purchaser's *PIP VEDV1003-D* Data Sheet, all or part of the following vessel cleaning procedure shall be performed before shipping:
  - a. Perform solvent or detergent wash
  - b. Rinse
  - c. Perform wet-dry test in accordance with *ASTM A 380*
  - d. If rust stains appear in wet-dry test, acid clean with passivation solution.  
*Comment:* The appropriate application method of hand wipe, spray, or circulating should be chosen based on the extent of rusting.
  - e. Repeat wet-dry test.
  - f. If rusting reappears, consider pickling solution.
  - g. Rinse
  - h. Dry
- 4.6.1.3 Before shipping, painting shall be completed in accordance with the contract documents. See Section 4.5.3.1.
- 4.6.1.4 All PWHT vessels shall have the following notice painted on two sides of the shell and insulation covering, if present, in three-inch high letters visible in the shipping position from grade. See Section 4.4.1.10:

**POSTWELD HEAT TREATED - DO NOT BURN OR WELD**

- 4.6.1.5 All vessels with non-metallic linings shall have the following notice painted on two sides of the shell and insulation covering, if present, in three-inch high letters visible in the shipping position from grade. See Section 4.4.1.10.

**LINED VESSEL - DO NOT BURN OR WELD**

**4.6.2 Preparation and Closure**

- 4.6.2.1 Machined surfaces, flange faces, threaded surfaces, and other finished or delicate parts shall be well-greased and protected against rusting and damage during shipment.
- 4.6.2.2 Holes in reinforcing pads (see Sections 4.2.11.3.4.d and 4.4.3.7) shall be plugged with Room Temperature Vulcanizing (RTV) silicone sealer or rust preventative grease that is compatible with the base material.
- 4.6.2.3 If flanged joints are specified to be provided with service gaskets, a spare gasket, in addition to any required for initial field assembly in accordance with Section 4.5.3.13, shall be provided and suitably packaged, marked, and shipped with the vessel for all joints except for flanged joints having standard ANSI flanges. See Section 4.5.3.7.a.
- 4.6.2.4 Blind flanged connections, including manways, shall have the blinds attached with a full complement of new bolts.

**4.6.2.5 Temporary Protective Covers**

1. Except for flanges with permanent blinds, each flange face shall be protected with 1/2 inch (13 mm) thick wood or 1/8 inch (3 mm) thick suitable metal plate and soft rubber gasket, not less than the flange outside diameter, and secured with a minimum of the greater number of bolts as follows:
    - a. 25% complement of total flange bolting
    - b. 4 bolts
  2. Welding stub ends shall be protected with bevel protecting caps.
  3. Threaded couplings shall be protected with bull plugs.
  4. Socket weld fittings shall be protected with plastic caps.
- 4.6.2.6 Internals which cannot be safely shipped in place shall be identified, tagged, and shipped separately.
- 4.6.2.7 For internals which have specified clearances or tolerances, a minimum of one of each type (e.g., tray type or distributor type) shall be trial assembled into the vessel to ensure proper fit before shipment.
- 4.6.2.8 All bolting and other loose parts shall be suitably packaged and identified with the purchase order number.

4.6.2.9 Uncoated bolts and nuts shall be coated with a suitable thread lubricant to prevent corrosion during transportation and storage. The lubricant shall be easily removable with mineral spirits or a solvent.

**4.6.2.10 Securing and Padding**

1. Ropes, chains and straps may be used to secure the vessel and associated equipment to the transporter deck.
2. Padding shall be placed between cables or chains and stainless steel or high alloy equipment to prevent discoloration of the vessel shell and/or contamination of the metal.
3. Cables and chains are not permitted even with padding used, unless attached to tie down clips provided on the vessel.
4. If carbon steel shipping saddles are used for stainless steel or high alloy vessels, the saddles shall be padded.

4.6.2.11 Nozzles, including attached piping, within or passing through vessel support skirts shall be adequately supported during shipping and handling.

4.6.2.12 Special provisions for shipping saddles shall be agreed with Purchaser.

4.6.2.13 If the permanent saddles of horizontal vessels are used for support during shipment, saddle extensions constructed of timber or other suitable materials shall be secured to the saddles to provide adequate ground clearance for boot or nozzle projections, if any, that extend below the permanent saddle base plate.

## **Appendix A**

### **Equivalent Pressure Formulas for Bending Moment and Axial Tensile Load**

### Equivalent Pressure Formulas for Bending Moment and Axial Tensile Load

When sustained bending moments or axial thrust loadings are applied to the flanged joint during operation in sufficient magnitude to warrant consideration in the flange design, the design pressure,  $P$ , used in the calculation of total hydrostatic end load,  $H$ , in the flange design calculations shall be replaced by the following design pressure:

$$P_{FLG} = P + P_{EQ}$$

The equivalent pressure  $P_{EQ}$  is determined as follows:

$$P_{EQ} = \frac{16M}{\pi G^3} + \frac{4F}{\pi G^2}$$

Where:

- $M$  = Sustained bending moment applied across full section at flange during the design condition, in-lb
- $F$  = Sustained axial tensile force applied at flange, lb
- $G$  = Diameter at location of gasket load reaction, in. (See Appendix 2 {4.16.12} of the *Code* for full definition.)

*Note:* Experience has shown that axial tensile forces resulting from a properly designed piping system have no significant effect on the flange design and hence are typically not included in the  $P_{EQ}$  determination.

Therefore, the hydrostatic end load,  $H$ , used in the flange calculations is determined as follows:

$$H = 0.785 G^2 P_{FLG}$$

Dynamic Bending Moment

$$P_{EQ} = \frac{8M}{\pi G^3}$$

Where:

- $M$  = Bending moment, as defined above, but including dynamic bending moment (e.g., seismic moment) applied across full section at flange during the design condition, in-lb

Other Terms = Same as above