PIP VESIN001
Design and Fabrication Specification for
Pressure Vessel Internals
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.

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PUBLISHING HISTORY

February 2018 Issued

Not printed with State funds
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1. **Scope**

This Practice provides the mechanical design, fabrication, examination, inspection, testing, and documentation requirements for pressure vessel process trays, tower structured packing, tower random packing, distributors, and related components welded to the pressure boundary.

2. **References**

Applicable parts of the following Practices and industry codes and standards 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)**

- VEFV1100 - *Vessel/S&T Heat Exchanger Standard Details (U.S. Customary Units)*

2.2 **Industry Codes and Standards**

- American Institute of Steel Construction
  - AISC 360 - *Specification for Structural Steel Buildings*
- American Society of Mechanical Engineers (ASME)
  - ASME Boiler and Pressure Vessel Code (Code)
    - Section V - Nondestructive Examination
    - Section VIII - *Rules for Construction of Pressure Vessels, Division 1*
    - Section IX - *Welding, Brazing, and Fusing Qualifications*
  - ASME B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard
  - ASME B16.47 - Large Diameter Steel Flanges: NPS 26 through NPS 60 Metric/Inch Standard

3. **Definitions**

*Code*: The ASME Boiler and Pressure Vessel Code, Section VIII Division 1 (or 2), its references and any Code Cases permitted by the User and authorizing agencies.

*construction*: An all-inclusive term comprising materials, mechanical design, fabrication, examination, inspection, testing, and certification

*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 supplier. The purchaser may also be the owner, user, or the owner’s or user’s designated agent (e.g., engineering contractor).

*supplier*: The party entering into a contract with the purchaser for the mechanical design and construction of vessel internals

*user*: The operator of the facility wherein the vessel will be installed. See *owner*. 
vessel fabricator: The party responsible for the fabrication of the pressure vessel in which the internals will be installed, or the party responsible for welding the internals attachments to the vessel wall

purchaser’s inspector: The person or company authorized by the purchaser, owner, and/or user to inspect pressure vessel internals to the requirements of this Practice and other purchaser contract requirements

4. Requirements

4.1 General

4.1.1 Overall Requirements

4.1.1.1 Internals shall be provided in accordance with this Practice and the following:

a. General internals design and operation (i.e., process) requirements provided by the purchaser

b. Codes and standards referenced in this Practice

c. Contract requirements furnished by the purchaser

4.1.1.2 It is the sole responsibility of the supplier to comply with the contract documents.

4.1.2 Components Welded to Pressure Boundary

4.1.2.1 Internal attachments to be welded to a vessel shall be designed by the supplier for fabrication and installation by the vessel fabricator.

4.1.2.2 Applied loads, including location, transmitted to the vessel via a vessel attachment shall be provided by the purchaser.

4.1.2.3 Welding requirements for internal attachments to pressure boundaries that are in accordance with the Code shall be in accordance with ASME Section IX.

4.1.2.4 Design of internal attachments welded to the pressure boundary shall account for differential thermal expansion between the vessel attachment and internals.

4.1.2.5 The material for internal attachments welded to the pressure boundary shall be the same nominal composition as the cladding, weld overlay, or shell to which it is directly attached.

4.1.2.6 The minimum thickness of internal parts welded to the pressure boundary shall be 5 mm (3/16 inch) plus the corrosion allowance.

4.1.2.7 Corrosion allowance for internal parts welded to the pressure boundary shall be applied to each surface exposed to the process.

Comment: A corrosion allowance equal to the vessel corrosion allowance is typical.

4.1.2.8 If specified in the contract documents that the vessel is subject to vibration and/or fatigue, internal welded non-pressure parts (e.g., support
rings, lugs, and baffles that can be subject to vibration or cyclic loading) shall be full penetration welded.

4.1.3 Bolting for Internal Components

Internal bolting shall be in accordance with the following:

a. Bolts shall be minimum 10 mm (3/8 inch) diameter.

b. Bolts shall have heavy hex heads and nuts.

c. Bolting material shall be specified by the owner.

d. If material is not specified in the contract documents, bolting shall be of highly corrosion resistant material.

e. High alloy (e.g., stainless steel) bolts and nuts shall resist galling.

Comment: Typically this requires a substantial difference between the bolt and nut hardness.

4.1.4 Vessel Manway Access

4.1.4.1 The minimum vessel manway inside diameter shall be furnished in the contract documents.

Comment: The minimum manway is typically DN 600 (NPS 24). A larger manway may be required for trays and supports in large diameter columns.

4.1.4.2 All removable components and parts (e.g., trays, packing (structured), distributors supports) shall be designed to pass through the vessel manways.

4.1.4.3 For trayed towers, a vessel manway shall be located above the top tray, below the bottom tray, and at each inlet distributor.

4.1.4.4 For trayed towers, vessel manways shall be located equal to or less than 18 m (60 feet) apart.

4.1.4.4 Vessel manways shall also be provided in accordance with the following tray limits.

a. Vessels with less than 60 trays manways are required every 20 trays

b. Vessels with 60 to 120 trays manways are required every 30 trays

c. Vessels with greater than 120 trays manways are required every 40 trays

4.1.4.6 For vessels with packing manways shall be provided above and below each packed bed.

4.1.4.7 Vessels with internal compartments that prevent access shall have a manway on both sides of the compartment.

4.1.5 Recommended Spares

4.1.5.1 The following minimum spares shall be provided with the internals:

a. Hardware 5%
b. Gaskets 20%, minimum 1 per size and type
c. Random Packing 10%

4.1.6 Fabrication

4.1.6.1 Plate edges to be welded shall be uniform, smooth, and free of cracks, scale, slag, oil, or other foreign matter.

4.1.6.2 Surfaces of fabricated parts shall be smooth and free of dents, hammer marks, kinks, or other defects.

4.1.6.3 Edges of all surfaces shall be free of burrs.

4.1.6.4 Edges exposed to passage of personnel shall be rounded.

4.2 Process Trays

4.2.1 General

4.2.1.1 Minimum tray thickness shall be 14 gauge in the corroded condition.

4.2.1.2 The corrosion allowance for tray components not welded to the pressure boundary shall be as specified in the contract documents.

Comment: A typical value for carbon and low alloy trays is 1/16 inch total. High alloy (e.g., stainless steel) trays typically have a corrosion allowance of zero.

4.2.1.3 Tray dimensions shall accommodate the maximum and minimum vessel diameters permitted by the vessel tolerances and the tray fabrication tolerances.

4.2.1.4 Cartridge trays shall be considered for vessels 750 mm (30 in) or less.

4.2.2 Mechanical Loads

4.2.2.1 Process trays and supports shall be designed to withstand the following:

a. Maximum operating process load of 2.15kN/m² (45 lbs/sq ft) in an upward direction at design temperature, evenly distributed

b. Tray weight plus a single maintenance load of 1330N (300 lbs) concentrated at any point on the tray assembly, at ambient temperature, in the corroded state

c. Tray weight plus the process liquid weight at the weir height plus an additional 50 mm (2 inches) at design temperature, or the tray weight plus 575 N/m² (12 lbs/sq ft), whichever is greater

4.2.2.2 Operating loads shall be considered to act on components in both the new and corroded condition.

4.2.2.3 Areas of trays under downcomers shall be designed to support their own weight at the design temperature plus the pressure from a water column half the height of the downcomer.

4.2.2.4 Draw-off and accumulation pans shall be designed to support their own weight at design temperature plus the greater of a uniform live load equal to 6.9 kN/m² (144 lbs/sq ft) or the pressure from a water column at the maximum operating level of the pan.
4.2.2.5 The maximum deflection of trays during operation, either upward or downward, shall not be greater than D/800 or 3 mm (1/8 inch), whichever is less, where D is the tower inside diameter.

4.2.2.6 The maximum deflection of tray support beams during operation shall not be greater than the lesser of 3 mm (1/8 inch) or L/900, where L is the length of the support beam.

4.2.2.7 Process trays shall not be installed out of level by greater than the tolerance provided in PIP VEFV1100 (VEFV1102 - Vessel Tolerances).

4.2.3 Supports

4.2.3.1 Support beams shall be designed in accordance with AISC 360 and fabricated by the supplier.

4.2.3.2 Except for vibratory or hydrogen services, welding of supports shall be as follows:
   a. Support rings shall be continuously welded on the top, and intermittently welded on the bottom.
   b. Brackets shall be continuously welded on the top and sides only.

4.2.3.3 For vibratory or hydrogen services, all welding shall be full penetration. For Hydrogen service fillet welds can be use provided the bottom weld is vented.

4.2.3.4 A minimum overlap of 20 mm (3/4 inch) shall be provided between the tray support ring and outside diameter of the tray.

4.2.3.5 The depth of supporting members normal to the direction of liquid flow on the tray shall not be greater than 15% of the tray spacing.

4.2.3.6 Tray support members and stiffeners shall be provided as follows:
   a. Located on the underside of the tray
   b. Not greater than 75 mm (3 inches) in width
   c. Not greater than 5% of the vessel diameter in depth

4.2.4 Draining

4.2.4.1 All trays including seal pans shall have a 12 mm (1/2 inch) diameter drain hole.

4.2.4.2 Inlet weirs shall have a 12 mm (1/2 inch) drain hole.

4.2.4.3 Chimney trays shall be drained through draw-off nozzles in lieu of drain holes.

4.2.4.4 Side draw-off nozzles shall be located flush with the bottom of the draw-off sump.

4.2.5 Assembly

4.2.5.1 A minimum clearance of 12 mm (1/2 inch) shall be provided between the outside radius of the tray and the inside radius of the vessel.

4.2.5.2 All parts shall be individually marked for assembly.

4.2.5.3 Marking materials and method shall not be deleterious to tray material.
Comment: For example, markings of stainless steel parts shall be chloride free.

4.2.6 Access

4.2.6.1 Access to all trays shall be provided by means of bolted tray manways.

4.2.6.2 Minimum tray manway clear opening shall be 300 mm by 450 mm (12 inches by 18 inches).

4.2.6.3 Bolting of tray manways shall be accessible, and manway removal possible, from both sides (top and bottom) of the tray manway.

4.2.6.4 Trays smaller than 1060 mm (42 inches) diameter may be split in lieu of providing tray manways.

4.2.6.5 Tray manways shall not form a part of the downcomer seal pan.

4.2.6.6 Tray manways shall not weigh greater than 300 N (65 lbs).

4.3 Packing

4.3.1 General

4.3.1.1 The maximum packed bed height shall be 9 m (30 feet).

4.3.1.2 Packing and supports shall be designed in accordance with the following:

a. Maximum downward operating load equal to the weight of the packing, liquid hold-up, and any other internals (e.g., hold-down grids) at design temperature.

b. Support assembly weight plus a single maintenance load of 1330 N (300 lbs) concentrated at any point on the assembly, at ambient temperature, in the corroded state.

c. Maximum deflection in any direction not greater than 0.0035 times D, where D is the inside diameter of the column.

d. Support assembly shall not installed out of level by greater than 0.3% of D, where D is the inside diameter of the column.

4.3.2 Supports

4.3.2.1 For column diameters greater than 760 mm (30 inches), a self-supporting packing grid resting on a ring shall be provided.

4.3.2.2 The maximum distance between packing grid elements shall be 100 mm (4 inches).

4.3.2.3 Packing grid elements shall be bolted or clamped together.

4.3.2.4 Support beams shall be designed in accordance with AISC 360 and fabricated by the supplier.

4.3.2.5 Packing bed support beam shall be designed with a maximum deflection of L/300, where L is the length of the beam.

4.3.2.6 A bed limiter shall be provided to keep the packing in place.
### 4.3.3 Assembly and Installation

4.3.3.1 Beds of structured packing shall be designed for installation and removal from the top.

4.3.3.2 Beds of random packing shall be designed for installation from the top and removal from the side at the bottom of the bed.

4.3.3.3 All parts shall be individually marked for assembly.

4.3.3.4 Marking materials and method shall not be deleterious to packing or support material.

*Comment:* For example, markings of stainless steel parts shall be chloride free.

4.3.3.5 Manways shall not be provided in packing support/hold-down grids.

4.3.3.6 For inspection of the vessel shell the entire packed bed shall be removed.

4.3.3.7 Structured Packing

   a. All structured packing layers shall be provided with a wall wiper.

   b. The maximum gap between the vessel wall and structured packing shall be as follows:

      1. Vessel diameter less than 900 mm (3 feet) the gap shall be 10 mm (0.4 inch)
      2. Vessel diameter between 0.9 and 2.75 m (3 and 9 feet) the gap shall be 15 mm (0.6 inch)
      3. Vessel diameter greater than 2.75 m (9 feet) the gap shall be 25 mm (1 inch)

4.3.3.8 Structured packing dimensions shall accommodate the maximum and minimum vessel diameters permitted by the vessel tolerances, and the packing fabrication tolerances.

4.3.3.9 Different types of random packing shall be separated by a bed limiter.

### 4.4 Distributors

#### 4.4.1 General

4.4.1.1 Inlet distributors shall be able to withstand the weight of the feed pipe and the weight of its contents, liquid full, with a specific gravity of 1.0 or the specific gravity of the operating fluid, whichever is greater.

4.4.1.2 Thermal expansion shall be accounted for in the inlet distributors design, both during operation and transient conditions.

4.4.1.3 The supplier shall design and provide the inlets distributors.

4.4.1.4 The fluid from pipe distributors shall impinge on a smooth, unobstructed surface.

4.4.1.5 Unless trays are designed for the distributor load, distributors shall not be supported from trays.

4.4.1.6 Except in main headers of liquid distributors, drain holes shall not be provided.
4.4.1.7 Pipe distributors constructed of high alloy (e.g., stainless steel) pipe shall have the following minimum wall thicknesses.
   a. For pipe sizes less than or equal to DN 300 (NPS 12), Schedule 40S minimum
   b. For pipe larger than DN 300 (NPS 12), 5 mm (3/16 inch) minimum nominal wall pipe or fabricate from 5 mm (3/16 inch) plate

4.4.1.8 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.

4.4.2 Assembly and Installation

4.4.2.1 All parts shall be individually marked for assembly.

4.4.2.2 Marking materials and method shall not be deleterious to the distributor material.

   Comment: For example, markings of stainless steel parts shall be chloride free.

4.4.2.3 Inlet distributors and redistributors shall be directly accessible from a column manway.

4.4.2.4 Internal distribution pipes shall have internal flanged connections to permit removal through the vessel manway.

4.5 Examination and Inspection

4.5.1 Examination

4.5.1.1 The methods and extent of examination 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 ASME Section V.

4.5.1.3 All welds shall be 100% visually examined.

4.5.1.4 A minimum of one tray of each type and size shall be assembled in the supplier’s shop before shipment.

4.5.1.5 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.

4.5.2 Inspection

4.5.2.1 Fabrication inspection requirements shall be in accordance with the contract documents.

4.5.2.2 The purchaser’s inspection and notification requirements shall be included in all suborders.

4.5.2.3 Certified drawings shall be provided for use by the purchaser’s inspector at the supplier’s and any sub-supplier’s location.
4.5.2.4 Supplier shall ensure, either directly or through sub-suppliers, that the inspections specified in purchaser’s contract documents are performed.

4.5.2.5 The performance of inspection by the purchaser’s inspector shall not relieve the supplier or sub-suppliers of responsibility for meeting the requirements of the contract documents.

4.6 Documentation

4.6.1 The following information shall be provided:
   a. Design temperature and all design loads
   b. Extent and type of examination
   c. Heat treatment requirements
   d. All ASME or ASTM material specifications
   e. Design corrosion allowance for all internals
   f. Fabrication details for all internals, including attachments to the pressure boundary
   g. Assembly drawings and instructions
   h. All weld details

4.6.2 All structural design calculations shall be provided with the detailed fabrication drawings.