PIP VECBI001
Selection and Purchase of
Bulk Solids Product Containers
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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# Selection and Purchase of Bulk Solids Product Containers

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1. **Scope**

This Practice provides selection guidelines and configuration requirements for use by a Purchaser specifying cylindrical, atmospheric and low-pressure, welded, shop- and field-fabricated dry bulk solids bins, hoppers, silos, and gravity blenders.

This Practice describes selection guidelines and configuration requirements for cylindrical shell, single-wall containers for dry bulk solids (i.e., bins, hoppers, silos, and gravity blenders) having internal design pressures not exceeding 103 kPa (15 psig) and/or full vacuum external pressure at the top of the container in its normal operating position, and are welded, shop- and field-fabricated, and generally in accordance with the philosophy and requirements of the *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1, henceforth referred to as the *Code*.

**Comment:** For dry bulk solids containers having internal and/or external pressures exceeding the 103 kPa (15-psig) limit, this Practice may be used for solids-handling issues, and *PIP VECV1001, PIP VESV1002*, and *PIP VEDV1003* for pressure container issues.

This Practice provides guidelines for selecting the type of dry bulk solids container configuration based on solids flow properties and type of flow regime. Guidelines are provided for selecting the bottom hopper configuration and discharge aids (e.g., fluidization, agitation, vibration, etc.). Guidance is also provided for the application of bin inserts, blending methods, internals, supports, and materials.

This Practice provides configuration requirements for dry bulk solids containers based on geometry, product properties, pressure and temperature, venting and relief protection, loadings, support system, connections, internals, and materials of construction. Instructions are also provided for completing a *PIP VEDBI003-D* Data Sheet to specify options covered in this Practice and other specific requirements applicable to a particular container. Another data form may be used if the required information indicated on the *PIP VEDBI003-D* Data Sheet is shown.

The following are not covered by this Practice:

a. Containers with nominal diameters 0.6 m (2 ft) or less  
b. Containers with volumes less than 2.8 cu. m (100 cu. ft)  
c. Bolted containers and other containers operating at atmospheric conditions  
d. Mechanically fastened shell or head courses with or without seal welding  
e. Non-metallic material  
f. Fluidized beds  
g. Non-cylindrical shells  
h. Container requirements associated with mechanical agitation by motor-driven blade impellers  
i. Portable transport containers  
j. Lethal service issues
Comment: For containers classified for lethal service, as defined by Code paragraph UW-2, or for other highly hazardous chemical services, see PIP VECV1001, PIP VESV1002, and PIP VEDV1003. PIP VESBI002 may also be applied to lethal service applications, adding company addenda (i.e., supplemental specification) as required.

k. Agricultural containers for non-commercial applications

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 VECV1001 – Vessel Design Criteria ASME Code Section VIII, Divisions 1 and 2
- PIP VEDBI003 – Documentation Requirements for Bulk Solids Product Containers
- PIP VEDV1003 – Vessel Drawing/Data Sheet and Instructions
- PIP VEFV1100 – Vessel/S&T Heat Exchanger Standard Details (Applicable details are as follows:)
  - PIP VEFV1117 – Vessel Manway Vertical Davit
  - PIP VEFV1118 – Vessel Manway Horizontal Davit
  - PIP VEFV1128 – Skirt Attachment
  - PIP VEFV1130 – Solids Product Container Blend Tube and Shell Interface
- PIP VESBI002 – Design and Fabrication of Bulk Solids Product Containers
- PIP VESV1002 – Vessel Fabrication Specification ASME Code Section VIII, Divisions 1 and 2
- PIP STF05501 – Fixed Ladders and Cages Details
- PIP STF05520 – Pipe Railing for Walking and Working Surfaces Details
- PIP STF05521 – Details for Angle Railings for Walking and Working Surfaces Details
- PIP STF05535 – Vessel Circular Platform Details

2.2 Industry Codes and Standards

- American Petroleum Institute (API)
  - API 650 – Welded Steel Tanks for Oil Storage
- American Society of Mechanical Engineers (ASME)
  - ASME Boiler and Pressure Vessel Code
    - Section II – Materials Part A
    - SA-414 – Specification for Steel, Sheet, Carbon, for Pressure Vessels
2.3 Government Regulations

- U.S. Environmental Protection Agency (EPA)
  - Clean Air Act Amendments of 1990
- U.S. Department of Labor, Occupational Safety and Health Administration (OSHA)

3. Definitions

angle of repose (poured): The slope of the surface of bulk solids when formed as a pile by pouring solids onto a horizontal plane. The angle is measured from the horizontal plane. This angle is not a flow property.

angle of repose (drained): The slope of the top surface of bulk solids when formed by discharging a container that holds the bulk solid. This angle is not a flow property.
arching: A no-flow condition in which the bulk solid forms a stable arch across a container. Typically, this arch forms at the bottom outlet opening, but can form at a higher location in the container. At a sufficiently large discharge opening, a stable arch cannot be sustained. The terms “bridge” and “dome” are also used to describe this condition.

bulk density: Weight per unit volume of a material including voids within the particle structure and also including voids between individual particle masses. The bulk density of a material can vary, depending on over-pressurization, vibration, time consolidation, etc.

Code: The ASME Boiler and Pressure Vessel Code, Section VIII, Division 1

coloration: An all-inclusive term comprising materials, design, fabrication, examination, and testing

fabrication: The actual making and assembling of the container and container components from specified materials

fluidization: The use of gas flow to permeate the interstitial spaces in bulk solids, making bulk solids act more like a liquid

Manufacturer: The party entering into a contract with the Purchaser to construct a container in accordance with the Purchaser’s specified requirements

owner: The party who owns the facility wherein the container will be installed and used

Purchaser: The party responsible for the execution of the requirements in this Practice and establishing construction criteria (e.g., selection of the geometry, loads, etc.) consistent with the philosophy and service hazards, for defining and specifying the mechanical design requirements, and for contracting with the Manufacturer for the fabrication of the container or container components. The Purchaser is also required to assure that all owner requirements are fulfilled.

solids product container: A bulk solids bin, hopper, silo, or blender

4. Requirements

4.1 General

4.1.1 Overall Responsibilities

4.1.1.1 Solids product containers shall be configured and specified in accordance with the requirements of this Practice, the Code, other codes and standards as referenced in this Practice, local requirements, and the other contract documents furnished by the owner.

4.1.1.2 The intended operating conditions of the container shall be determined and specified to provide a basis for design and fabrication.

4.1.1.3 The external environment (wind, seismic, etc.) to which the container is exposed and the intended function of the container shall be determined to provide a basis for design.

4.1.1.4 The mechanical loads imposed on the container, the container geometry, the specific support requirements, and the specific codes and laws
applicable where the container is to be installed shall be determined to provide a basis for design and fabrication.

4.1.1.5 The minimum and maximum bulk densities of the solids product shall be determined to provide a basis for design.

4.1.1.6 The flow properties of the contained solids product shall be determined to provide a basis for design.

4.1.2 Jurisdictional Compliance

4.1.2.1 The requirements in this Practice and the Code may be substituted by other requirements only by written agreement with the owner.

4.1.2.2 All aspects of the work shall be in accordance with the applicable local, county, state, and federal rules and regulations, including but not limited to the rules and standards established by EPA and OSHA, if applicable.

4.1.2.3 All applicable jurisdictional requirements, including those that are site-specific, shall be identified and specified on the PIP VEDBI003-D Data Sheet.

4.1.2.4 All references to EPA and OSHA may be replaced with national equivalent references that apply at the container installation site.

4.1.3 Documentation Responsibilities

4.1.3.1 A package containing the following documentation shall be prepared:

a. Completed PIP VEDBI003-D Data Sheet

   1) When the proposals for detailed design and construction of the container are requested, the Data Sheet may not be entirely completed; some entries may be requested from the prospective Manufacturers.

   2) The data provided shall fully describe the container configuration and dimensions (except thicknesses and weld seam locations), the loads, materials of construction, and the code to be used by the Manufacturer in the detailed design and construction of the container.

   3) See PIP VEDBI003 for the Data Sheet form and the instructions for completing the Data Sheet.

b. PIP VESBI002 with company addenda if any

c. Additional drawings and/or details required to describe the container

d. Completed PIP VEDBI003-T Inspection and Testing Requirements Sheet (ITRS). See PIP VEDBI003 for the ITRS form and the instructions for completing the ITRS.

e. Completed PIP VEDBI003-R Documentation Requirements Sheet (DRS). See PIP VEDBI003 for the DRS form and the instructions for completing the DRS. Requirements for providing the fabrication data package in electronic form, if applicable, shall be specified on the DRS.
4.1.3.2 The system of measurement units, whether U.S. customary units, metric units or both, to be used in all documentation including drawings and calculations shall be shown on the PIP VEDBI003-D Data Sheet.

4.1.3.3 All documents to be transmitted to the Manufacturer shall either be in English or shall show the English translation.

4.2 Container Selection Parameters

Comment: This Section provides information intended to assist with selecting the configuration and design loads for bulk solids containers. Also included are specific requirements pertaining to specifying the selection requirements to the Manufacturer.

4.2.1 Solids Flow Properties

4.2.1.1 For the design of a container for solids product, the following solids flow properties shall be considered. The properties shall be determined by performing the types of tests listed:

a. Arching and rat-hole critical dimensions – Cohesive Strength Test in accordance with ASTM D6128
b. Mass flow critical wall angle – Wall Friction Test in accordance with ASTM D6128
c. Bulk density variation – Compressibility Test
d. Flow rate limitations – Permeability Test
e. Minimum angle of chute for reliable flow – Chute Test
f. Gas quantity and pressure for effective fluidization – Fluidization Test
g. Minimum outlet diameter for conical bottoms or minimum width for slotted or oval bottoms to promote mass flow

4.2.1.2 Certain material and/or environmental conditions can affect results from solids flow properties tests. Properties tests shall be performed over the complete range of parameter values that are expected in the solids-handling process.

4.2.1.3 Properties testing shall consider the following parameters:

a. Temperature
b. Pressure
c. Mechanical overpressure
d. Moisture
e. Consolidation (storage) time
f. Particle size
g. Particle size distribution
h. Particle shape
i. Pattern of material structure (e.g., crystallinity, etc.)

j. Container wall material of construction

k. Reactivity with other chemicals that may be present

l. Surface finish of container

4.2.2 Flow Regimes

4.2.2.1 Symmetrical and Eccentric Flow Patterns

1. If obstructions do not exist that can cause preferential flow from one side of the outlet or from one side of the container, symmetrical flow is the flow pattern that results from a center-discharge nozzle. This Practice provides requirements for designing containers that have only symmetrical flow of solids.

2. Graphical representations of the four major symmetrical flow regimes are shown in Figure 1.

3. Off-center or side-discharge outlets can cause eccentric flow patterns. Eccentric flow patterns can also be caused by improper discharge methods. For example, eccentric flow patterns may be induced by improperly designed discharge equipment, such as non-mass flow screw feeders, and by partly opened discharge valves. The effects of eccentric flow patterns on structural loads necessitate implementation of proper discharge practices to ensure symmetric flow. If eccentric flow is required, describe the eccentric flow conditions on the PIP VEDBI003-D Data Sheet.

4.2.2.2 Mass Flow

1. A graphical representation of mass flow is shown in Figure 1, Type 1.

2. Mass Flow Characteristics

   a. Mass flow does not have stagnant regions in the solids product as it discharges from the container. Theoretically, a mass flow pattern provides first-in, first-out flow from the container. Actually, some product flows slower at the wall and can hinder the ability to obtain ideal mass flow. Typically, if the solids products have more consistent bulk densities, mass flow bins can have uniform discharge rates.

   b. Mass flow ensures uniform residence time in a container and promotes de-aeration of the solids product.

   c. Mass flow is facilitated by container designs that have a combination of a steep hopper angle and smooth walls. Marginal designs can cause slip-stick (i.e., unsteady) flow. Slip-stick flow can cause induced vibrations, which can be severe.

3. Mass Flow Requirements

   a. Discharge outlets for mass flow hoppers shall be configured to avoid arching.
b. The geometry of the hopper shall create stresses in the solids product that overcomes the strength of the product, thus breaking potential arches.

c. Minimum outlet diameters for prevention of arching vary with product and shall be determined by testing the product in a shear cell tester in accordance with ASTM D6128.
Flow Zone

Type 1
Mass Flow

Type 2
Funnel Flow

Flow Along Walls

Secondary Flow Zones

Primary Flow Zone

Figure 1 – Types of Symmetrical Flow Regimes
4.2.2.3 Funnel Flow

1. A graphical representation of funnel flow is shown in Figure 1, Type 2.

2. Funnel Flow Characteristics
   a. Funnel flow is characterized by a dynamic product flow channel surrounded by stagnant product. This flow pattern can be caused by one of the following conditions:
      1) A combination of an insufficient hopper angle and insufficient surface smoothness
      2) A discharge outlet that is not fully effective. This can be caused by improper placement of components in the discharge line, partly closed valves, poorly designed discharge equipment, etc.
   b. Typically, funnel flow design is acceptable for coarse, free-flowing materials that do not require first-in, first-out flow. Funnel flow design can be problematic for the following types of solids products and conditions:
      1) Fluidizable products where preferential flow channels can form
      2) Products where segregation can occur
      3) Cohesive products where arching and rat-holing can occur
      4) Products that require first-in, first-out flow
      5) Products that degrade over time
      6) Operations that require dependable control over the product discharge rate

3. Funnel Flow Requirements
   a. If a container will experience funnel flow, the discharge outlet diameter shall be designed to prevent rat-holing.
   b. The outlet shall be sufficiently large to prevent rat-holes from stabilizing.
   c. Minimum outlet diameters for prevention of rat-holing vary with product and shall be determined only by testing the product in a shear cell tester in accordance with ASTM D6128.

4.2.2.4 Rat-hole (Pipe Flow)

1. A graphical representation of rat-hole flow is shown in Figure 1, Type 3.

2. Large amounts of solids product could be static within a container if the flow is not properly considered. Typically, a hole (i.e., rat-hole) forms in this stagnant product from the discharge up to the top of the
container through which new product placed in the container can flow.

3. Stagnant solids product can significantly reduce the effective inventory of a container.

4. Rat-holes can be avoided by providing a container outlet large enough to overcome the internal strength of the solids product.

4.2.5 Expanded Flow

1. A graphical representation of expanded flow is shown in Figure 1, Type 4.

2. Expanded flow is characterized by mass flow in the hopper section and funnel flow in the upper section. This situation helps to prevent rat-hole development in funnel flow bins by allowing for a switch to a mass flow hopper at diameters less than the minimum rat-hole diameter for the solids product.

3. Expanded flow shall be considered for containers with multiple hopper outlets, where mass flow hoppers are placed next to one another to create a combined flow channel that is larger than the minimum rat-hole diameter.

4.2.3 Cylindrical Versus Polygonal Shell Configurations

4.2.3.1 Typically, cylindrical shell container shapes are preferred over polygonal because of the following characteristics:

a. A higher pressure rating can be achieved at a lower cost than polygonal shapes, which require extra reinforcement for corners and flat sides.

b. Mass flow can be more easily achieved because of the lack of flow restrictions.

4.2.3.2 Polygonal shapes are typically selected if all of the following apply:

a. Funnel flow is preferred

b. Headroom is a concern

c. Low operating pressures exist

4.2.3.3 This practice provides guidance and requirements for cylindrical shell shapes only.

4.2.4 Bottom Hopper Configurations

4.2.4.1 Various types of bottom hoppers may be used on cylindrical shell containers. The type of bottom hopper selected shall fit the application.

4.2.4.2 Conical Center-Discharge

1. A conical hopper with a center discharge is a standard, single outlet, cone hopper design to which many types of feeders are easily adapted.
2. Conical hoppers may also be configured with dual angles (angle from the hopper outlet to inlet varies) and with eccentric outlets.

3. To achieve mass flow, a conical hopper design shall include the following:
   a. Sufficiently smooth walls
   b. Hopper angle that is steeper than the critical hopper angle for mass flow for the application
   c. Discharge from the outlet that is uniform across the width of the outlet
   d. An outlet diameter that is greater than the minimum arching diameter for the application

4.2.4.3 Flat Bottom
   1. Typically, flat bottom hoppers are used for the following operating configurations:
      a. Containers with fully fluidized blending and/or discharging
      b. Large-quantity storage containers if complete emptying is not required

   2. The use of a flat bottom container for mass flow applications is typically not practical because of the size of the feeder required.

   3. To achieve mass flow, a flat bottom hopper shall include the following:
      a. Sufficiently smooth walls
      b. An outlet diameter that is equal to the cylinder shell diameter
      c. Discharge from the outlet that is uniform across the width of the outlet
      d. An outlet diameter and cylinder shell diameter that is greater than the minimum arching diameter for the application

4.2.4.4 Chisel (Wedge)
   1. A chisel hopper has a slotted discharge outlet with a length equal to the diameter of the cylindrical shell. The slotted outlet is suitable for use with feeders (e.g., auger, screw, and belt).

   2. Chisel hoppers and transition hoppers (see Section 4.2.4.5) may be preferred to the standard conical hopper for the following reasons:
      a. Less steep hopper angles (i.e., 10° to 12°) and still provide mass flow
      b. Smaller outlet sizes. Typically the width of wedge necessary for flow is one-half the diameter of a comparable cone; therefore, cones typically require larger, more expensive feeders.
      c. Higher flow rates
d. Less headroom required. This can be important for retrofits.

e. Capital cost can favor a chisel or transition hopper, depending on the situation (e.g., consider less expensive headroom requirements versus more expensive feeder and gate)

3. Chisel hoppers and transition hoppers can require more in-depth load analysis than a standard cone.

4. To achieve mass flow, a chisel hopper shall include the following:

   a. Sufficiently smooth walls
   b. Hopper angle that is steeper than the critical cone hopper angle for mass flow for the application
   c. Discharge from the outlet that is uniform across the width of the outlet
   d. Discharge outlet width that is greater than the minimum arching width for the application
   e. Discharge outlet length that is a minimum of three times the width of the discharge outlet

4.2.4.5 Transition Hoppers

   1. A transition hopper provides a transition from a cylindrical shell to a slotted discharge outlet. The slotted outlet is suitable for use with feeders (e.g., auger, screw, and belt).

   2. See Sections 4.2.4.4.2 and 4.2.4.4.3 for comparisons of wedge and transition hoppers to conical hoppers.

   3. To achieve mass flow, a transition hopper shall include the following:

      a. Sufficiently smooth walls
      b. Hopper end-wall angle that is steeper than the critical cone hopper angle for mass flow for the application
      c. Hopper side-wall angle that is steeper than the chisel (wedge) angle for mass flow for the application
      d. Discharge from the outlet that is uniform across the width of the outlet
      e. Discharge outlet width that is greater than the minimum arching width for the application
      f. Discharge outlet length that is a minimum of three times the width of the discharge outlet

4.2.4.6 Multiple Dischargers

   1. The configuration of hoppers with more than one outlet shall comply with the requirements of the particular application.
2. To achieve mass flow, a multiple discharge hopper shall include the following:
   a. Sufficiently smooth walls
   b. Hopper end-wall angle that is steeper than the critical cone hopper angle for mass flow for the application
   c. Hopper side-wall angle that is steeper than the chisel (wedge) angle for mass flow for the application
   d. Discharge from the outlets that is uniform across the width of chisel outlets, and product is drawn from all outlets simultaneously
   e. Discharge outlet width that is greater than the minimum arching width for the application
   f. For chisel discharge outlets, outlet width that is greater than the minimum arching width for the application
   g. For conical discharge outlets, outlet diameter that is greater than the minimum arching diameter for the application
   h. For chisel discharge outlets, outlet length that is a minimum of three times the width of the discharge outlet

4.2.5 Discharge Aids

4.2.5.1 Definition
Discharge aids are devices that are used to promote flow of bulk solids from containers with no flow or flows less than required.

4.2.5.2 Fluidization and Aeration Devices
1. Fluidization and aeration devices shall be considered if gas easily permeates interstitial spaces in the bulk solid, thus reducing internal cohesive forces and wall friction forces and aiding flow.
2. Fluidization is effective in promoting flow and in increasing flow rates from a container holding fluidizable solids product.
3. Fluidization devices can be provided with a new container or can often be retrofitted into an existing container.
4. Fluidization or aeration may be introduced through nozzles or pads in the container or through internal fluidizing media (e.g., perforated or sintered metal).

4.2.5.3 Agitation Devices
1. Agitation devices are effective on many types of bulk solids and can be used to mechanically assist solids flow.
2. Some agitation devices (e.g., screws and augers) can be used to promote and meter flow simultaneously. If discharging from a mass flow bin, proper design of screws and augers is critical for ensuring uniform solids flow.
3. Agitation devices may be used but can be problematic for the following types of solids:
   a. Solids that fluidize easily. The solids may flush through the screw or auger.
   b. Solids that cake
   c. Solids that have a low melting temperature. Heat may build up at motors, bearings, etc.

4. The use of agitation devices can also result in wear, maintenance, and power consumption problems.

4.2.5.4 Compressed Gas Devices

1. Compressed gas (i.e., air or nitrogen) is typically used as a means to create a shock wave in a container. The shock wave acts over a localized area and is intended to overcome the stresses that enable a stable arch or rat-hole to form.

2. Limited effectiveness may be seen when using compressed gas devices (i.e., air cannons or air blasters) on rat-holes or caked material because only localized areas can be cleared. Best results are achieved if the size, number, and placement of air cannons are properly determined.

3. The reaction forces and localized pressure zones created in the container wall as the device discharges compressed gas shall be considered. Fatigue effects in the container wall shall also be considered, especially for aluminum containers.

4.2.5.5 Sonic Horns

Similar to compressed gas devices, sonic horns use sound waves to promote material movement.

4.2.5.6 Vibration Devices

1. Air-driven or electric-driven vibrators use high-amplitude, low-frequency vibrations or low-amplitude, high-frequency vibrations to promote flow.

2. Externally mounted vibrators are typically easy to retrofit by means of a mounting bracket that shall be full-penetration welded onto a container.

3. Because maintenance and contamination issues have been problematic with internal vibration devices, these issues shall be evaluated. Vibration device manufacturer’s instructions shall be followed.

4. Fatigue effects in the container wall, use of the devices with pressure-sensitive materials, and the number and location of vibrators used shall be considered.
4.2.5.7 Vibrating and Oscillating Dischargers

1. Vibrating dischargers (i.e., live bottoms) use vibration in either a vertical or horizontal direction to initiate flow from a container. Oscillating dischargers move either internal cones or internal plates or screens to initiate flow.

2. Typically, dischargers are not appropriate for the following applications:
   a. Pressure-sensitive materials are used
   b. Mass flow is required
   c. Segregation is not permitted

3. Dead load weights and fatigue effects on the container at discharger interface shall be considered.

4. Because the container has to be emptied to replace some discharger components, effects of maintenance of vibrating and oscillating dischargers shall be considered.

4.2.5.8 Forced Extraction

1. Forced extraction devices are mechanical devices used to move solids product, typically along a container wall or bottom, toward the discharge of a container.

2. The device is inside a container and may or may not be covered by a head of solids product during operation.

3. Maintenance requirements, power consumption, and deformation and wear of the device shall be considered.

4.2.5.9 Flexible Walls

1. Flexible walls in a hopper can promote flow by permitting the stresses to be relieved in solids product that can build within the container.

2. Flexible walls may be used in conjunction with external mechanical devices that massage the flexible wall, thus agitating the solids product; however, the possibility of overly compacting the product shall be considered.

3. Because of wear on the liner, maintaining a flexible wall hopper can be difficult. Inaccessibility of the liner if the liner fails during operation shall be considered.

4.2.5.10 Chemical Flow Aids

Chemical flow aids may be added to a solids product to enhance flow properties. Typically, chemical flow aids promote product flow by one of the following methods:

a. Physically separating particles
b. Competing for adsorbed water
c. Canceling electrostatic charges/molecular forces
d. Modifying crystalline lattices

4.2.6 Fluidized Solids Product

If the solids product is to be fluidized, the following shall be considered:

a. Permeability of the solid to be fluidized (i.e., fluidization appropriate for the material of concern)
b. Stresses on a container from both fluidized and non-fluidized solids product during storage and discharge
c. Design of a container and/or container relief devices to contain available maximum pressure from the gas header
d. Design of a container, and/or container discharge devices, and/or container relief devices to accommodate required gas flow and gas discharge from the container

4.2.7 Bin Inserts

4.2.7.1 Flow, mass flow, or blending of certain solids products can require bin inserts (e.g., internal cones or other internal flow aids). Typically, bin inserts are used to expand the flow channel in a funnel flow bin or to convert a funnel flow bin to mass flow. Typically, these types of inserts are inverted cones, pyramids, or “hopper-inside-a-hopper” designs.

4.2.7.2 The design of the bin insert shall consider the stresses created by the solids product that the insert can experience in both static and discharging modes.

4.2.7.3 Bin inserts shall be configured to avoid ledges and other obstructions that can hinder or block product flow.

4.2.7.4 All parts of an insert that contact solids product shall be compatible with the product.

4.2.7.5 The dead load of the bin insert and live loads or fatigue loads created by use of the insert (e.g., vibrating bottoms) shall be specified on the PIP VEDBI003-D Data Sheet.

4.2.8 Blenders

4.2.8.1 General

1. Many types of blenders are available for various applications, from large-scale, continuous blending to small-scale, batch blending.
2. This Practice provides guidance for blending applications that use containers in the blending process.
3. This Practice does not cover blending design considerations related to some blenders, such as static mixers, mechanical blenders (e.g., tumble blenders, ribbon blenders, paddle mixers, etc.), and fluidized blenders.
4.2.8.2 Gravity Tube Blenders

1. Gravity Tube Blenders Characteristics
   a. For a gravity tube blend container, solids product is sampled at various heights within the container bed using internal or external tubes. Product from each tube is mixed in a blend chamber at the bottom of the container, and blended product is discharged from the blend chamber.
   b. If internal tubes are used, the tubes are run vertically along the inside of the container. The tubes may penetrate the container wall and enter the blend chamber externally. Each tube has inlets (typically multiple inlets at varying heights along the tube length) through which product enters and is carried to the blending chamber at the bottom of the blend container.
   c. Typically, gravity tube blend containers are used for granular and pelletized product.

2. Gravity Tube Blenders Requirements
   a. Adequacy of the cleaning of the tubes shall be considered.
   b. The container wall thickness and blend tube piping and supports shall be designed by the Manufacturer to resist the eccentric loads created by discharging solids product into the blend tubes. Alternatively, these loads may be furnished to the Manufacturer to check these components.
   c. For the connecting tubing for blend tubes for a gravity tube blender, the diameter of the lower section of tubing in a joint shall be specified to be larger in diameter than the upper section of tubing. This prevents material from collecting on ledges in the joint.

4.2.8.3 Velocity Gradient Gravity Blenders

1. For a velocity gradient gravity blender, solids product is mixed by inducing different velocities within the flow channel. In simple terms, material with less residence time in the blender flows at a faster velocity and blends with material having a longer residence time that flows at a slower velocity.

2. This velocity gradient gravity blending method reduces some of the fabrication complexity required for the internals in some gravity tube blenders.

4.2.9 General Internals Configuration

4.2.9.1 Areas on internal components where product build-up or hang-up can occur shall be avoided. Specifically, top edges of supports shall be sloped to promote free flow of solids product around supports. Also, areas where blend tubes penetrate the cone shall have a sloped deflector on the upstream side between the tube and the cone. See PIP VEFV1130 (Figure F-1).
4.2.9.2 Moving parts or other maintenance items within a container shall be avoided because these parts can require repair at inopportune times (e.g., when the container is full of solids).

4.2.9.3 The configuration of internals shall consider cleaning requirements (e.g., provide adequate access to blend tube interior walls).

4.2.10 Configuration of Supports

4.2.10.1 Smaller containers (i.e., less than 90,700 kg (200,000 lbs) operating weight) may be supported from three or four support points.

4.2.10.2 Because three to four support points may be impractical, larger containers (i.e., greater than 90,700 kg (200,000 lbs) operating weight), may be supported using multiple support points, skirts, or double rings.

4.2.11 Container Materials

Materials, coatings, liners, and surface finishes shall be selected based on performance tests with the contained product to determine which is most favorable.

4.2.12 Preliminary Layout

Straight side height-to-diameter ratios of 2:1 for silos and 3.5:1 for blenders are recommended for preliminary layouts.

4.2.13 Container Design Pressure and Temperature

4.2.13.1 The design pressure (i.e., internal and external) and coincident maximum temperature shall be determined. All operating phases that the container can experience during the specified project life shall be considered including the following:
   a. Initial startup
   b. Normal operations
   c. Temporary operations
   d. Emergency shutdown
   e. Emergency operations
   f. Normal shutdown
   g. Startup following a turnaround or emergency shutdown
   h. Cleaning, steam out, and decontamination
   i. Upset conditions
   j. Environmental restraints on relief venting

4.2.13.2 If fluidization can occur, the container shall resist the hydrostatic pressures caused by the contained product. The specified design pressure shall include the effective hydrostatic head of the product.

4.2.14 Pressure Venting and Relief

4.2.14.1 A means for venting gas (i.e., into and out of the container) under normal operating conditions and a means for relieving pressure under
abnormal operating conditions shall be developed and specified to the Manufacturer.

4.2.14.2 Various means may be used for venting gases during normal operating conditions depending on the application. Whether intentional or induced, situations that can require gas flow into or out of the container shall be considered including the following situations as applicable:

a. Gas displaced while filling a container
b. Gas required to fill void spaces when discharging from a container
c. Gas introduced into a container by gas cannons, aeration pads, aeration cones, bin vents, fluidization media, gas purges, etc.
d. Gas introduced and gas displaced when pneumatically conveying material into a container
e. Leakage gas on valves attached to the container (especially rotary airlocks)
f. Gas flow induced by temperature changes inside or outside the container
g. Condensation of vapor or vaporization of liquids, whether during operation or during cleaning

4.2.14.3 For information on venting for deflagrations (relief devices) and for explosion prevention systems, see NFPA 68 and NFPA 69, respectively.

4.3 Container Design

4.3.1 Geometric Configurations

4.3.1.1 If the contained solids product is a well-known commodity, having well-known flow characteristics, the selection of the geometric configuration and critical dimensions may be made on the basis of previous experience with that product.

4.3.1.2 If the discharge opening is required to be much larger (to avoid arching or rat-holing) than required to attain the desired discharge rate, the use of a feeder to control flow without affecting the desired flow pattern is normally required. A hopper configuration and corresponding discharge shape and dimensions shall be selected in conjunction with a practical discharge device.

4.3.2 Product Properties and Other Design Criteria

All of the design requirements determined in accordance with Section 4.2 shall be specified on the PIP VEDBI003-D Data Sheet for use by the Manufacturer in his design. Design requirements include the following data:

a. Product properties
b. Flow regime
c. Design volume
d. Dimensions of appurtenances
4.3.3 Pressures and Temperatures

The operating pressure and temperature and design pressure and temperatures shall be specified on the PIP VEDBI003-D Data Sheet.

4.3.4 Minimum Design Metal Temperature (MDMT) and Coincident Pressure

4.3.4.1 The minimum design metal temperature shall be shown on the PIP VEDBI003-D Data Sheet.

4.3.4.2 The MDMT and coincident pressure to be shown on the container nameplate shall be determined considering the operating phases such as those listed in Section 4.2.13.1 of this Practice and of the Code rules in paragraph UG-20(b).

4.3.4.3 If ambient temperatures govern the temperature during startup or normal operations, the lowest 1-day mean ambient temperature at the installation site shall be the MDMT value provided that temperature is not greater than 30°F (-1°C). API 650, Figure 4-2 shall be used to establish the lowest 1-day mean temperature insofar as applicable.

4.3.5 Venting and Relief Protection

4.3.5.1 Container vent systems shall be sized such that the design pressure, both internal and vacuum (i.e., external pressure), and the relief protection pressure setting are not exceeded.

4.3.5.2 All containers shall be provided with relief protection for both internal pressure and vacuum.

4.3.5.3 Actions of the relief device shall not exceed the design pressure (i.e., internal pressure and vacuum) rating of the container.

4.3.5.4 NFPA 68 and NFPA 69 shall be used for sizing deflagration venting systems and for selecting explosion prevention systems as applicable.

4.3.5.5 If deflagration is possible, deflagration shall be incorporated in the design pressure. See Code paragraph UG-22(i).

4.3.5.6 The nozzle schedule, attached equipment, and any nozzle loads shall be shown on the PIP VEDBI003-D Data Sheet.
4.3.6 Design Loads and Load Combinations

4.3.6.1 Wind Load

The classification category, basic wind speed, exposure category, and topographic factor shall be selected in accordance with ASCE 7, and specified on the PIP VEDBI003-D Data Sheet. If required by local regulations, an alternate wind design basis in lieu of ASCE 7 shall be specified on the PIP VEDBI003-D Data Sheet.

4.3.6.2 Seismic Loads (L6)

1. Unless otherwise specified, the seismic design requirements and data shall be in accordance with ASCE 7.

Comment: Local codes or regulations may require compliance with UBC or other rules for seismic design.

2. The seismic design requirements and the site-specific design values shall be determined and specified on the PIP VEDBI003-D Data Sheet.

4.3.6.3 Test Load (L7)

1. Test load (i.e., weight of the test medium) shall be determined and specified on the PIP VEDBI003-D Data Sheet.

2. Design basis shall consider that the container shall be tested in its normal operating position.

4.3.6.4 Piping and Superimposed Equipment Loads (L8)

1. Loads caused by piping (e.g., pneumatic conveying and other piping) other than the dead load and those caused by superimposed equipment shall be considered as applicable.

2. The effect of these loads on all container components shall be considered.

3. These loads shall be determined and specified on the PIP VEDBI003-D Data Sheet.

4.3.6.5 Mechanical Loads (L9)

Mechanical loads (i.e., loads caused by vibrators, air pulsation, agitators, flow aids, dischargers, etc.) shall be determined and specified on the PIP VEDBI003-D Data Sheet.

4.3.6.6 Lift Condition

1. If the default impact factor of 2.0 is not adequate, the required impact factor for the design for the lift condition shall be determined and specified on the PIP VEDBI003-D Data Sheet.

2. Components and accessories that are to be included in the lift condition design (e.g., trays, ladders/platforms, insulation, and additional piping with insulation) shall also be specified.
4.3.7 Container Support Systems

4.3.7.1 The type and quantity of container support (e.g., skirt, legs, lugs, rings) and the details necessary for design and construction shall be shown on the PIP VECDI003-D Data Sheet, and in sketches and/or drawings.

4.3.7.2 Skirts

1. Support skirts attached to the bottom head shall have the skirt butted to the outer portion of the head such that the outer diameter (OD) of the shell and the OD of the skirt coincide.

2. Support skirts fabricated by extending the shell below the bottom-head-to-shell weld joint shall be in accordance with PIP VEFV1128.

3. Skirt supports shall be provided with a minimum of two DIN 50 (NPS 2) vent openings.

4. If skirt diameter and height permit, one or more 0.6 m (24 inches) diameter or larger openings shall be provided to permit free access for inspection and/or maintenance work inside the skirt.

5. If a supporting skirt encloses auxiliary running equipment, the minimum opening shall be a door having dimensions in accordance with site requirements.

6. Opening configurations shall be shown on the PIP VECDI003-D Data Sheet and in sketches and/or drawings.

4.3.7.3 Legs

Leg supports shall be limited to containers that meet the following criteria:

a. Service is non-cyclic and non-pulsating

b. Container height-to-diameter ratio (h/D) does not exceed 5, where height is the distance from base of support to top tangent line of the container

Comment: Caution is advised for leg-supported containers that may be within h/D ≤ 5 but may have excessive axial and/or bending loads on the legs or an overstress condition in the container wall.

4.3.7.4 Load Cells

1. For containers supported by lugs, a load cell system shall provide support using all the support lugs.

2. Containers shall be adequately guided to limit lateral movement in accordance with the load cell system performance requirements.

3. Load cell installation requirements that affect the design of the container support system shall be indicated on the PIP VECDI003-D Data Sheet.

4. Piping attached to a container shall be designed with sufficient flexibility to permit required performance of the load cell system.
4.3.8 Top Head

4.3.8.1 Top head shape (e.g., flanged, dished, torispherical, or other) shall be specified on the PIP VEDBI003-D Data Sheet.

4.3.8.2 Additional concentrated roof loads resulting from top-mounted equipment (e.g., bin vents, cyclones, relief devices, etc.) shall be specified on the PIP VEDBI003-D Data Sheet.

4.3.8.3 Standard flanged and dished heads may be provided.

4.3.8.4 Torispherical heads may be provided; however, a torispherical head can be susceptible to internal pressure-induced buckling.

4.3.8.5 Overfilling

1. Solids product can exert upward forces on the top head of a container if overfilled and one of the following situations exists:
   a. Solids product is fluidized
   b. Top head has an angle with the horizontal plane that is greater than the minimum angle of repose for the product

2. The problems resulting from upward forces on the top head described in Section 4.3.8.5.1 can be avoided by the following actions:
   a. Eliminating overfill excursions through tighter control schemes and other such measures
   b. Designing the top head to withstand the forces exerted by the product. The Australian Code AS 3774 may be used for determination of forces on the top head due to product loading. If this design option is required, the option shall be specified on the PIP VEDBI003-D Data Sheet.
   c. Configuring the head to incorporate an angle that is less than the minimum angle of repose for the given material

4.3.9 Bottom

4.3.9.1 The selected internal weld surface finish shall be specified on the PIP VEDBI003-D Data Sheet.

4.3.9.2 For mass flow operation, all internal weld surfaces shall be specified as ground-flush or ground-flush-and-smooth finish.

4.3.9.3 The angle of friction of the selected hopper material affects the slopes of the selected hopper wall slopes. See Section 4.2.1.1.

4.3.10 Container Connections

4.3.10.1 Nozzles and Manways

1. Dimensional data for all nozzles, including diameter, flange type, flange class, type of cover, nozzle function, projection from container, gasket seal finish, etc., shall be shown on the Nozzle Schedule in the PIP VEDBI003-D Data Sheet.
2. Special nozzle loads (e.g., dynamic and thermal) which require a high level of analysis shall be described on the PIP VEB01003-D Data Sheet.

3. Minimum nozzle projections shall be as follows:
   a. For DIN 150 (NPS 6) nozzles and smaller, 150 mm (6 inches)
   b. For DIN 200 (NPS 8) nozzles and larger, 200 mm (8 inches)
   c. Nozzle projection measured from container outside diameter
   d. If insulation is required, a minimum of 50 mm (2 inches) between the outside of the insulation and the end of the flange studs shall be provided for wrench clearance.

4. Minimum connection size shall be DIN 40 (NPS 1.5).

5. All mechanical loads on nozzles if any shall be specified on the PIP VEB01003-D Data Sheet.

   Comment: Service requirements can cause the application of significant mechanical loads other than pressure on container flanges. The pressure-temperature ratings of ASME B16.5 and ASME B16.47 are based primarily on pressure loads; therefore, the flanges may not be suitably designed for externally applied moment or axial thrust loads. These loads can cause leak-tightness problems.

6. Minimum manway size shall be a nominal DIN 600 (NPS 24), with finished inside diameter not less than 584 mm (23 inches).

7. Larger diameter manways may be provided to satisfy additional requirements (e.g., installation of internal parts, maintenance requirements, etc.).

8. Manway sizes and quantity shall be specified on the PIP VEB01003-D Data Sheet.

9. To facilitate ventilation and heat curing of lined or coated containers, containers shall have a minimum of one DIN 300 (NPS 12) minimum nozzle or manway in the top head, and a shell manway. If two man-ways are located on the shell, they shall be 180 degrees apart and at the top and bottom of the shell.

4.3.10.2 Flanges

1. Carbon or low-alloy steel lap joint-type flanges may be used for flanged joints of stainless steel and nonferrous components.

2. Standard flanges and factory-made stub ends shall have a surface finish in accordance with ASME B16.5 or ASME B16.47, as applicable.

3. For services requiring special consideration, custom flanges, and shop-fabricated lap-joint stub ends, standard flanges with the following finish shall be provided. If required, these flanges shall be specified on the PIP VEB01003-D Data Sheet:
a. Gasket-bearing surfaces serrated concentric or serrated spiral
b. Surface finish of 3.2-6.4μm (125–250 Ra) (roughness average, MSS SP-6) is the default surface finish but different finishes may be specified to meet the gasket manufacturer’s recommendations. The finish shall be judged by visual comparison with Ra standards in accordance with ASME B46.1 and not by instruments having stylus tracers and electronic amplification.
c. Radial tool marks or scratches shall not be permitted

4. Studding pads (i.e., pad flanges) shall have standard bolting dimensions as follows:
   a. For DIN 600 (NPS 24) and smaller, ASME B16.5
   b. For greater than DIN 600 (NPS 24), ASME B16.47 Series B

4.3.10.3 Davits
   1. For nozzles DIN 450 (NPS 18) and larger and manways DIN 600 (NPS 24) and larger with blind covers, requirements for a davit or hinge if required to facilitate handling of the blind flange shall be specified on the PIP VEDBI003-D Data Sheet.
   2. Nozzles and manways on top of containers oriented with a vertical nozzle neck axis shall be equipped with a davit.

4.3.11 Gaskets and Seals
   4.3.11.1 The following gasket information shall be specified on the PIP VEDBI003-D Data Sheet:
      a. Number of spare gaskets to be provided by Manufacturer
      b. Gasket types, ratings, and “m” and “y” design factors
      c. If a joint-sealing compound or lubricant shall be used
   4.3.11.2 Consideration shall be given to the design of non-metallic seals at wall penetration points. It is especially important to consider limited seal life applications such as seals where movable internal components are actuated externally. Provide design details to the Manufacturer.

4.3.12 Corrosion Allowance
   Corrosion allowances, if any, for all parts of a container that contact the contained solids product shall be determined and specified on the PIP VEDBI003-D Data Sheet.

4.3.13 Compartment Containers
   4.3.13.1 For containers having more than one compartment, the most severe combinations of pressure, vacuum, temperature, and other loads on common components of containers that can occur during operation and test conditions shall be determined.
   4.3.13.2 The loading combinations shall be specified on the PIP VEDBI003-D Data Sheet in a special note.
4.3.13.3 Specifying simultaneous loading of internal pressure in adjacent compartments shall not be permitted.

**4.3.14 Anchor Bolting**

4.3.14.1 Anchor bolting orientation shall be specified on the *PIP VEDBI003-D* Data Sheet or drawings.

4.3.14.2 Anchor bolts for vertical containers shall be specified in multiples of four bolts.

**4.3.15 Lifting Lugs, Davits, and Platforms**

4.3.15.1 Special requirements for lifting lugs, if required, shall be specified on the *PIP VEDBI003-D* Data Sheet in a special note.

4.3.15.2 Davit requirements for removable container covers and manway covers shall be specified on the *PIP VEDBI003-D* Data Sheet, sketches, and/or drawings. See *PIP VEFV1117* and *PIP VEFV1118* for davit details.

4.3.15.3 Platform details (e.g., design loads, type, size, location, materials) shall be provided to the Manufacturer, using *PIP STF05501*, *PIP STF05520*, *PIP STF05521*, and *PIP STF05535*.

**4.4 Container Materials**

4.4.1 All container materials shall be in accordance with the *Code*.

4.4.2 All container materials, coatings, linings, and surface finishes, as determined in Section 4.2, shall be listed on the *PIP VEDBI003-D* Data Sheet or in a separate specification attached to the Data Sheet.

4.4.3 The following container materials shall not be specified for use:

   a. Mercury-containing products
   b. Cadmium-plated products
   c. SA-515 and SA-414 (B-G) carbon steels unless toughness requirements are in accordance with a recognized industry standard

**4.5 Fabrication**

4.5.1 If any of the following normally-prohibited designs are permitted, the design details shall be specified on the *PIP VEDBI003-D* Data Sheet in a special note:

   a. Nozzle openings in weld seams
   b. Pinch rings (i.e., outer flange face rings) in flanged connections
   c. Nozzles attached in accordance with *Code*, Figures UW-16.1 (a), (a-1), (a-2), (a-3) and (b)
   d. Weld joints covered by attachments (e.g., reinforcement pads)

4.5.2 Manufacturing tolerances not covered by the *Code* or the PIP Standard Details (e.g., *PIP VEFV1102*) shall be specified on the *PIP VEDBI003-D* Data Sheet in a special note.
4.5.3 Linings

4.5.3.1 If the container is required to be lined, the type of lining (i.e., elastomeric, thermoplastic, reinforced thermoset plastic, phenolic, or cured polymer system) shall be specified on the PIP VEDBI003-D Data Sheet.

4.5.3.2 If internal components of lined containers cannot be lined, the components shall be made of a corrosion resistant material.

4.5.3.3 If a lining system is required, it shall be specified on the PIP VEDBI003-D Data Sheet and a supplemental specification shall be provided to indicate the Manufacturer’s scope of work.

4.5.4 Weld Acceptance Standards

4.5.4.1 After evaluation of the weld samples required in accordance with Section 4.5.6.4 of PIP VESBI002, which refers to PIP VESV1003, one set of samples shall be returned to the Manufacturer for Manufacturer’s use. The other set shall be given to the Purchaser’s inspector for use as an inspection standard.

4.5.4.2 If the weld samples cannot be approved, a detailed explanation shall be provided to the Manufacturer and new samples shall be obtained from the Manufacturer for approval.

4.6 Inspection and Testing

4.6.1 Inspection

4.6.1.1 Container inspection shall be performed at the Manufacturer’s shop and at the plant site for field-erected containers.

4.6.1.2 Inspection witness points shall be established before fabrication.

4.6.2 Testing

4.6.2.1 Test procedures proposed by the Manufacturer shall be reviewed and approved.

4.6.2.2 Exceptions to the type of test or test location specified in PIP VESBI002 shall be agreed with the Manufacturer.

4.6.2.3 Any flanged joint for which the Manufacturer provides the service gasket, and disassembly does not occur after testing, shall be specified on the PIP VEDBI003-D Data Sheet to be tested with the specified service gasket.

4.6.2.4 If a flanged joint is to be disassembled after test, employs non-standard flanges (i.e., other than ASME B16.5), and/or if the service gasket is not specified, the test gasket shall be reviewed and approved.

4.7 Cleaning and Painting

Any cleaning and painting requirements not covered in PIP VESBI002 shall be specified on the PIP VEDBI003-D Data Sheet.

4.8 Instrumentation

Instrumentation requirements (e.g., pressure, temperature, level, and weight indicators) shall be determined and specified on the PIP VEDBI003-D Data Sheet.