

SCOPE

- I 1.1 This practice covers the design, fabrication, inspection, and testing of unfired pressure vessels, including all unfired steam generators and non-refrigerated carbon steel pressure storage spheres except as modified by [IP 9-2-1](#).
- I 1.2 **Small commercial vessels** which are not part of process equipment (such as sandblast machines, paint sprayers, and gunite machines) are outside the scope of this practice.
- I 1.3 **An asterisk (*)** indicates that a decision by the Purchaser is required, or that additional information is furnished by the Purchaser.

SUMMARY OF ADDITIONAL REQUIREMENTS

- R 2.1 This practice requires design, fabrication, inspection, and testing of pressure vessels under the provisions of the **ASME Code Section VIII, Division 1 or Division 2**, plus the additional requirements of this practice, except as permitted below.
 - * **Alternatively**, pressure vessels may be totally designed, fabricated, inspected, and tested under the provisions of a **recognized code** which is accepted by the authorities where the vessel is located and by the Owner's Engineer, plus the additional requirements of this practice. Where specific references to ASME requirements are made in this practice, the Owner's Engineer may authorize use of equivalent or more stringent provisions of the applicable recognized code.
- I 2.2 **Table 1** lists the practices which shall be used with this practice.
- I * 2.3 **Table 2** lists the practices, codes, standards, specifications, and publication which shall be used with this practice **as specified** by the Purchaser.

TABLE 1

PRACTICES	
IP 3-16-1	Flanged Joints, Gaskets, and Bolting
IP 5-3-1	Pressure Testing of Unfired Pressure Vessels
IP 18-7-1	Welding Procedures
IP 18-10-1	Additional Requirements for Materials
IP 20-1-1	Inspection of Equipment and Materials
IP 20-1-3	Quality Programs

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TABLE 2

PRACTICES	
IP 3-18-1	Piping Fabrication Shop or Field
IP 4-1-3	Design Loads for Structures
IP 4-1-4	Surge Vibration Design Loads
IP 5-1-2	Additional Requirements for Heavy Wall Pressure Vessels, Thickness Over 2 Inches
IP 5-2-1	Internals for Towers, Drums, and Fixed Bed Reactors
IP 18-4-1	Postweld Heat Treatment of Equipment Handling Alkaline Solutions
IP 18-12-1	Positive Material Identification
IP 19-1-1	Paint and Protective Coatings
IP 19-2-1	Weld Overlay and Integrally Bonded Cladding
IP 19-3-2	Refractory Linings for Pressure Vessels and Piping
IP 19-4-1	Glass Reinforced Plastic Tank Bottom Linings
IP 19-4-2	Natural and Synthetic Rubber Linings
IP 19-6-1	Facilities for Corrosion Monitoring in Process Equipment
IP 19-7-1	Protection of Stainless Steel During Fabrication, Shipping, Storage, and Field Construction

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TABLE 2 (Cont)

CODES, STANDARDS, SPECIFICATIONS, AND PUBLICATION	
ASME Codes	
Section I	Power Boilers
Section II	Materials
Section VIII	Pressure Vessels, Division 1
Section VIII	Pressure Vessels, Alternative Rules, Division 2
ASME Publication	
Pressure Vessel and Piping	Stresses in Large Horizontal Pressure Vessels, Pressure Vessel and Piping: Design and Analysis, Vol. II, ASME copyright 1997
ASME Standards	
B1.20.1	Pipe Threads, General Purpose (Inch)
B16.5	Pipe Flanges and Flanged Fittings
B16.20	Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed
B16.47	Large Diameter Steel Flanges (NPS 26 through NPS 60)
ASTM Standards	
A 193 / A 193M	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194 / A 194M	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
A 320 / A 320M	Alloy Steel Bolting Materials for Low-Temperature Service
A 370	Mechanical Testing of Steel Products
A 453 / A 453M	Specification for Bolting Materials, High Temperature, 50 to 85 KSI Yield Strength With Expansion Coefficient Comparable to Austenitic Steel
D 2000	Rubber Products in Automotive Applications
E 21	Elevated Temperature Tension Tests of Metallic Materials
F 436 / F 436M	Hardened Steel Washers
ANSI / AWS Specifications	
A5.1	Covered Carbon Steel Arc Welding Electrodes
A5.17	Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
A5.18	Carbon Steel Filler Metals for Gas Shielded Arc Welding
NACE Standards	
TM-01-77	Testing of Metals for Resistance to Sulfide Stress Cracking at Ambient Temperatures
TM-02-84	Evaluation of Pipeline Steels for Resistance to Stepwise Cracking
Welding Research Council (WRC) Bulletins	
107	Local Stresses in Spherical and Cylindrical Shells Due to External Loadings
297	Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles - Supplement to WRC Bulletin No. 107

DOCUMENTATION

- I 3.1 **An outline drawing** shall be furnished for each vessel, and shall contain the data in [Table 3](#). The location of the vessel marking or nameplate, the size and orientation of all nozzles and connections, and the anchor bolt layout shall also be shown on this drawing.
- I 3.2 A separate outline drawing for each vessel shall be furnished with appropriate markings to cross-reference each component (shell plates, heads, nozzles, flanges, forgings, skirt plates, etc.) to the applicable mill test certificates for the steels used in the construction.
- I * 3.3 **A manufacturer's data report** shall be furnished and shall contain the same information as required by form U-1 of the **ASME Code, Section VIII, Division 1**. Certified material test reports shall be furnished, and they shall represent the properties in the as-fabricated condition. The data report shall be signed by the Manufacturer, by an Authorized Inspector as defined in Par. UG-91 of the ASME Code, or as otherwise required by the applicable code. Other documentation (code papers, etc.) covering the construction of vessels built to the code of another nation shall be signed by the Manufacturer and, where applicable, by others having authority to sign such documentation.
- * Six signed copies of data reports and other required documentation shall be submitted to the Inspector prior to shipment of the vessel.

- I 3.4 **Fabrication drawings** shall show weld details and reference applicable welding procedures. The drawings shall also include impact test requirements, showing (as applicable):
- Component
 - Thickness for impact purposes
 - Material specification
 - Critical Exposure Temperature or Minimum Design Metal Temperature
 - Appropriate Charpy impact requirements (average/minimum values)
- C 3.5 **Welding and weld repair procedures** shall be submitted to the Purchaser for review prior to the start of fabrication.
- I 3.6 **Two copies of design calculations** (including lifting attachments and supports) made by the fabricator shall be furnished prior to or with submission of prints for approval. When calculations are made using a computer, all input data, assumptions, computer program version used, and a summary of the results shall be furnished.

DEFINITIONS

- I 4.1 **Vessel thickness** is defined as the thickness required for strength of the pressure vessel shell, including corrosion allowance, but excluding weld overlay, lining, integral cladding or non-integral parts.
- I 4.2 Vessels are in **hydrogen service** when the hydrogen partial pressure exceeds 90 psi (620 kPa) and vessel design temperature is 500°F (260°C) or greater.

MATERIALS

- S * 5.1 **Proposals to use materials having a specified maximum tensile strength greater than 90,000 psi (620 MPa)** at room temperature shall be submitted to the Purchaser for approval by the Owner's Engineer.
- R * 5.2 **For vessels in hydrogen service**, external welded attachments, and at least an 18 in. (450 mm) course of all skirts, shall be of the same nominal chemistry as the material used for the vessel.
Proposals to use alternative materials shall be submitted to the Purchaser for approval by the Owner's Engineer.
- R * 5.3 **Unlined carbon and low alloy steel vessels in wet H₂S service** shall be **postweld heat treated**.

DESIGN

DESIGN REQUIREMENTS

- R * 6.1 Unless otherwise specified, **all vessels**, except spheres designed to API-620, **operating above 1 psig** (7.0 kPa) shall have a minimum design pressure of 16 psig (110 kPa).
- ✦ * The Owner's Engineer shall specify the design pressure, design liquid level (including fluidized and bulk solids), specific gravity and/or design pressure at various elevations. The manufacturer shall design the vessel for the specified design pressure, liquid level and temperature.
- S,R * 6.2 **Vessels for vacuum service**, including those in which a vacuum may be created inadvertently, shall be designed for an external pressure differential of 15 psi (103 kPa) or an external pressure differential 25% greater than the maximum operating value, whichever is less.
- I 6.3 **For purposes of determining the applicability of IP 5-1-2**, thickness is defined as the thickness "as ordered," provided the plates actually supplied meet the ASTM tolerances on thickness (weight). Vessel pressure components or sections which are greater than 2 in. (50 mm) in thickness shall meet the INSPECTION AND TESTING requirements of **IP 5-1-2**. In addition, nozzle forgings for insertion into shell plates greater than 2 in. (50 mm) thick shall also meet the NOZZLE AND CONNECTIONS design requirements of **IP 5-1-2**.
Weld overlay, lining, integral cladding, non-integral parts, flat heads and closures, tubesheets, flanges, nozzle/manway reinforcing pads, areas of reinforcement, and areas of over-thickness up to 12% in excess of the specified thickness provided for plate thinning during forming or scale losses during heating, need not be considered in determining the applicability of **IP 5-1-2**.

DESIGN LOADS

- R * 6.4 **Loadings** to be considered in designing a vessel shall be per the **ASME Code Section VIII** and shall include cyclic conditions and erection loadings. If the vessel will be subjected to more than 1000 cycles in which the pressure range is greater than 80 percent of the design pressure or the temperature range is greater than 350°F (195°C), an assessment of the need for a fatigue analysis shall be conducted per the **ASME Code, Section VIII, Division 2, Par. AD-160**, or with approval of the Owner's Engineer, per the recognized code used for design and fabrication.
- R * 6.5 **Additional loadings.** Vessels containing circulating suspensions of solids in fluids (fluid-solids processes) shall be subjected to additional horizontal loadings per **IP 4-1-4**.
- S * 6.6 **During erection, start-up, or operation**, all applicable loads shall be considered as acting simultaneously, including either wind or earthquake, whichever governs.
- S * 6.7 **During hydrostatic testing**, a minimum wind load (wind pressure) equivalent to a 35 mph (16 m/s) wind speed shall be considered acting simultaneously with the hydrostatic test load.

ALLOWABLE STRESSES

- R * 6.8 The alternative higher stresses at temperature for high alloy steels permitted by the ASME Code shall not be used for flanges of gasketed joints, or other applications where slight amounts of distortion can cause leakage or malfunction unless approved by the Owner's Engineer.
- R 6.9 **Vessel supporting skirts.** Allowable tensile and compressive stresses for vessel supporting skirts shall be per the code used for vessel design.

VESSEL THICKNESS

- R,M 6.10 The **following additional criteria** shall be considered in calculating the required **thickness of vessels and supports**:
- a. Horizontal drums on saddle supports shall be investigated for buckling, local circumferential bending, and shear stresses.
The method of L. P. Zick (see **Pressure Vessels and Piping: Design and Analysis**, Vol. II, ASME Copyright 1972) may be used for this investigation.
 - b. Vessels shall be designed for hydrostatic testing with water, with the vessel in the operating position. For this condition, the maximum membrane stress in the vessel shell in the corroded condition shall not exceed 90% of the specific minimum yield strength for ferritic steels, nor 100% of the specified minimum yield strength for austenitic steels or non-ferrous materials. The appropriate weld joint efficiency factor shall be used in these calculations. Integral cladding, weld overlay, or additional thickness provided in excess of thickness required for strength, may be considered effective in calculating hydrostatic test stresses only.
 - * c. The maximum deflection of vertical vessels for all loadings, except earthquake, shall not exceed H/100, except level-sensitive equipment such as fractionating columns shall be limited to H/200 under normal operating loads including wind load as specified by the Owner's Engineer. (H is the overall vessel height from the base of the support ring to the top of the vessel.)
 - d. The minimum thickness of shells and heads, exclusive of corrosion allowance, shall be as follows:

MATERIAL OF CONSTRUCTION	VESSEL DIAMETER	MINIMUM THICKNESS
Carbon and Low Alloy Steels	≤ 84 in. (2130 mm)	3/16 in. (5 mm) ⁽¹⁾
	> 275 in. (7000 mm)	3/8 in. (10 mm) ⁽¹⁾
High Alloy Steels	All	1/8 in. (3 mm)

Note:

(1) Thicknesses between values shown may be obtained by linear interpolation based on diameter.

- e. The minimum thickness of support skirts shall be 0.25 in. (6 mm) or the vessel wall thickness, whichever is less.

- R * 6.11 **Minimum corrosion allowances** shall be as follows:

MATERIALS OF CONSTRUCTION	MINIMUM CORROSION ALLOWANCE	
	in.	mm
Carbon, Low Alloy, and Intermediate Alloy Steels ⁽¹⁾	1/16	1.5
High Alloy Steels ⁽²⁾ and All Non-ferrous Materials	0.01	0.25
Vessels with Metal Lining or Cladding	0.01 (external allowance)	0.25

Notes:

- (1) Includes all steels with an alloy content not exceeding 9Cr 1Mo.
(2) Includes all steels with an alloy content of 12Cr or greater.

HEADS AND TRANSITION SECTIONS

- R 6.12 **Inside radius of knuckles** for torispherical heads, toriconical heads, or conical transition sections where knuckles are required, shall be as follows:
- a. For knuckles 3/4 in. (19 mm) thick or less, minimum inside radius shall be not less than 6% of the outside diameter of the adjoining cylindrical section.
 - b. For knuckles thicker than 3/4 in., minimum inside radius shall be not less than 10% of the outside diameter of the adjoining cylindrical section.
- R * 6.13 **Intermediate heads** shall be attached to the shell per the **ASME Code, Section VIII, Division 1, Figure UW13.1-(f)** with fillet welds, unless otherwise approved by the Owner's Engineer.

NOZZLES, MANWAYS, VENTS AND CONNECTIONS

- R * 6.14 **Nozzles NPS 2 (50 mm) and larger** shall be **flanged or studded**, and shall have the same P-number as the vessel shell. Corrosion protection equivalent to that of the vessel shall be provided. Use of studded nozzles shall be approved by the Owner's Engineer.
- R 6.15 **Connections NPS 1-1/2 (40 mm) and smaller** may be **threaded**, except for pressure relief valve connections. Couplings or integrally reinforced fittings shall be used for threaded connections. Additional thickness shall be provided for corrosion allowance, as required to provide corrosion protection equivalent to that of the vessel. All couplings or fittings shall be installed with complete penetration welds. Half couplings welded to the outer surface of the vessel may be used.
- Threaded connections** shall have tapered threads per **ASME B1.20.1**.
- * Connections NPS 1-1/2 (40 mm) and smaller shall be braced per **IP 3-18-1** when specified by the Owner's Engineer.
- R * 6.16 Unless otherwise specified, all **instrument connections** except thermowells shall be a minimum of NPS 2 (50 mm) flanged, and thermowells shall be NPS 1-1/2 (40 mm) flanged.
- O * 6.17 **Connections** shall not extend into the vessel beyond the interior surface except as required by **Par. 6.18**, when specified, or when approved by the Owner's Engineer.
- M 6.18 **Nozzles in portions of vessels with gunite** shall have internal projections such that the nozzle end is flush with the lining.
- R * 6.19 **Nozzles and manways** shall be attached to the vessel by full penetration welds. Unless otherwise approved by the Owner's Engineer, full penetration welds shall be used for attaching reinforcing pad plates to nozzle and manway necks.
- R 6.20 **Flanges larger than NPS 24 (600 mm)** shall be per **ASME B16.47 Series B** or designed per **ASME Code, Section VIII, Division 1**, with allowable stresses as determined per that Code.
- R * 6.21 When used with **spiral wound gaskets**, the ID of **forged nozzles** including **long weldneck** flanged nozzles shall be decreased as necessary to meet the requirements of Table 16 and Table 18 of **ASME B16.20**. When specified, the ID of the nozzles shall match the ID of mating pipe flanges.
- R * 6.22 **Flanges for nozzles with attached piping**. Flanges that are not per **ASME B16.5** or **ASME B16.47** shall be designed to include the applied bending moment from the attached piping.
- R 6.23 **Nozzles subjected to large forces and moments** shall be analyzed for additional shell and nozzle neck reinforcement requirements. Stresses shall be limited to values listed in Appendix 4, Figure 4-130.1 of the ASME Code, Section VIII, Division 2, with the value of S_m taken equal to the allowable stress listed for the appropriate Division of the ASME Code, Section VIII or the recognized code to which the vessel is designed.