PIP VEEVJ001
Gasket Guidelines
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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1. Introduction

1.1 Purpose

This Practice provides guidelines for specifying gaskets for circular flanges for pressurized equipment and piping.

1.2 Scope

This Practice describes guidelines for use of gaskets with the following types of flanges:

a. Standard flanges in accordance with ASME B16.1, B16.5, B16.42, or B16.47
b. Custom flanges designed in accordance with Code, Division 1 Appendix 2 or Division 2, Paragraph 4.16 or Part 5

This Practice applies to all of the following:

a. Common gasket styles contained between flat (planar) flange surfaces.
b. Corrugated metal, double jacketed, grooved metal with covering layer, sheet, and spiral wound gaskets.
c. Design conditions not greater than the standard flange rating or the manufacturer’s published gasket rating if more restrictive.

This Practice does not address the following:

a. Confined gaskets, i.e., gaskets contained in grooves (e.g., ring joint, tongue and groove, male-female, spiral wound without retaining rings, etc.)
b. Self-actuated gaskets (e.g., “o”-rings)
c. Proprietary gasket styles
d. Other types of gaskets not specifically covered in this Practice
e. Cyclic service as defined for vessels in accordance with ASME Section VIII, Division 2, paragraph 5.5.2, Screening Criteria for Fatigue Analysis (cyclic service is defined as requiring a fatigue analysis) and for piping by ASME B31.3 paragraph 300.2, Severe Cyclic Service definition.

The guidelines in this Practice are intended to:

a. Improve process containment
b. Reduce risk of personnel exposure
c. Enhance blowout prevention
d. Improve bolted joint reliability
e. Provide for gasket standardization

Specific services, environment, or situations may require considerations that take precedence over the guidelines of this Practice.

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)
   - PIP PNSM0105 - Purchasing Requirements for Gaskets
   - PIP VESPMI01 - Positive Material Identification Specification
   - PIP VESV1002 - Design and Fabrication Specification for Vessels

2.2 Industry Codes and Standards
   - American Society of Mechanical Engineers (ASME)
     - *ASME Boiler and Pressure Vessel Code*, Section VIII – Pressure Vessels (Code)
       - Division 1, Rules for Construction of Pressure Vessels
       - Division 2, Alternative Rules for Construction of Pressure Vessels
     - ASME B16.1 - Gray Iron Pipe Flanges and Flanged Fittings (Classes 25, 125 and 250)
     - ASME B16.5 - Pipe Flanges and Flanged Fittings NPS ½ Through NPS 24 Metric/Inch Standard
     - ASME B16.20 - Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral-Wound, and Jacketed
     - ASME B16.21 - Nonmetallic Flat Gaskets for Pipe Flanges
     - ASME B16.42 - Ductile Iron Pipe Flanges and Flanged Fittings Classes 150 and 300
     - ASME B16.47 - Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard
     - ASME B46.1 - Surface Texture (Surface Roughness, Waviness, and Lay)
     - ASME PCC-1 - Guidelines for Pressure Boundary Bolted Flange Joint Assembly
     - ASME PCC-2 - Repair of Pressure Equipment and Piping
   - American Petroleum Institute (API)
     - API 6FB - Specification for Fire Test for End Connections

3. Definitions

*alloy*: Non-ferrous metallic materials and ferrous metallic materials containing intentionally added alloying elements, other than carbon

corrugated metal gaskets (CMG):* Gaskets consisting of a corrugated metal core with compressible, non-metallic, sealing layers on both sides. See Figure 1.

![Figure 1 – Corrugated Metal Gaskets](image-url)
custom designed flanges: Flanges designed in accordance with Code, Division 1, Appendix 2 or Code, Division 2, Paragraph 4.16 or Part 5.

double jacketed gaskets (DJG): Gaskets with a metal sheathing totally encapsulating a compressible, non-metallic filler material. See Figure 2.

ePTFE: Expanded biaxial oriented filler, sheet and tape polytetrafluoroethylene (PTFE)

equipment: Pressure vessels, tanks, pumps, compressors, fired heaters, heat exchangers, etc.

full face gaskets: Gaskets that extend beyond the bolts to the outside diameter of a flange

grooved metal gaskets with covering layer (GMCL): Gaskets consisting of a solid metal core with concentric grooves and compressible, non-metallic, sealing layers on each face. Sometimes called kammprofile gaskets. See Figure 3.

“m” factor (maintenance factor): ASME Code gasket factor, defined as the ratio of gasket stress to internal pressure that is required to maintain a seal during operation. The “m” factor is used to evaluate the ability of the flange fastener’s preload to maintain sealing pressure on a gasket after the internal pressure is applied to the joint. This gasket factor is required for ASME custom flange design. The “m” factor is determined by the gasket manufacturer.

nubbin: A circumferential protrusion, typically 1/64 inch (0.4 mm) high and 1/8 inch (3.2 mm) wide, on a gasket sealing surface used as an intermediate seal. Nubbins are used only with double jacketed gaskets.

positive material identification (PMI): The procedure used to test and evaluate material to confirm that it is the specified material, typically by analyzing its elemental make-up.

rigidity index (J): A value calculated in accordance with Code, Division 1, Appendix 2 or Code, Division 2, Part 4.16 to check flange rigidity. This value is used as part of joint design and assembly requirements to ensure leak tightness. A rigidity index less than or equal to one minimizes potential dishing of the flanges and resultant leakage between the bolts.
**ring gaskets:** Gaskets with outside diameter bound by the flange bolting.

**seat:** Compressing a gasket so that it deforms or “flows” to conform tightly to the flange surface, forming a seal.

**sheet gaskets:** Flat gaskets typically cut from a single sheet (i.e., without joints) of compressible, non-metallic, material. The gasket covers the flange surface, extending to or beyond the bolt holes. Gaskets with a metallic or composite core and tanged (i.e., metal sheet with projections to anchor it into the surrounding compressible material) gaskets are included.

**spiral wound gaskets (SWG):** Gaskets made of spiral wound metal strip with compressible, non-metallic, sealing material between the windings. See Figure 4.

![Figure 4 – Spiral Wound Gaskets](image)

**standard flanges:** Flanges in accordance with ASME B16.1, B16.5, B16.42, or B16.47. The standard used for a flange should be in accordance with the code governing design of the associated equipment or piping. Use of standard flanges permits use of standard, commonly available, gaskets.

**“y” value:** ASME Code gasket value, defined as the pressure over the contact area of a gasket required to seat the gasket without internal pressure in the joint. This gasket factor is required for ASME custom flange design. The “y” value is determined by the gasket manufacturer.
4. General

4.1 Gasket Purpose

Gaskets are intended to prevent leakage of a pressurized fluid (vapor or liquid) contained by a flanged joint.

4.2 Gasket Styles

4.2.1 Double Jacketed Gaskets (DJG)

4.2.1.1 In the past, DJG was the most commonly used gasket style in the US process industry. DJGs have been replaced by other gasket styles for most applications, but remain common for the following applications:

a. Large diameter flanges, because a large spiral wound gasket could be hard to handle
b. If the sealing surfaces are other than circumferential (e.g., exchanger pass partitions)
c. If the sealing surfaces too narrow for other gasket styles (e.g., exchanger pass partitions)

4.2.1.2 DJGs should be of the corrugated double jacketed type because of high contact pressure at the peaks and improved sealing because of the series of peaks along the radial fluid leakage path.

4.2.1.3 DJGs can accommodate turndown conditions, variations in applied stress (including some overstress), and resist relaxation over time.

4.2.1.4 Non-corrugated DJGs may be used if corrugated DJGs are not feasible (e.g., if the sealing surface is too narrow to accommodate the corrugations of the corrugated style).

4.2.1.5 DJGs require a smoother flange surface finish than the other gasket styles covered by this Practice.

4.2.2 Spiral Wound Gaskets (SWG)

4.2.2.1 SWG is the most commonly used gasket style in the US process industry because of the following advantages:

a. Required flange surface finishes are easily provided
b. Seals well over a wide range of pressures and temperatures (e.g., turndown conditions) and a variety of liquid and vapor fluids
c. Accommodates limited flange surface imperfections, overstress, flanges out-of-parallel and fit-up issues
d. Maintains seal during limited radial axial thermal expansion and contraction at the gasket.

4.2.2.2 The high seating stress and radial series of peaks of an SWG creates a very tight seal, suitable for very high pressure service.
4.2.2.3 Low Seating Stress

1. A low seating stress version of SWG may be used if the flanges cannot accommodate the typically required seating stress, such as in the following cases:
   a. Class 150 flanges
   b. Retrofits on existing flanges designed for a more compressible gasket
   c. Large diameter (e.g., vessel body) flanges in low pressure service

2. Low pressure is typically defined as where Class 150 or Class 300 flanges are acceptable.

3. Use of low seating stress SWGs should be reviewed by an engineer experienced with gasket and flange joint design, evaluation, and behavior.

4.2.3 Grooved Metal Gaskets with Covering Layer (GMCL)

4.2.3.1 GMCLs are more commonly used than SWGs in Europe and other areas of the world. GMCLs have the advantages of SWGs, and may exceed SWGs in the following ways:
   a. Easier to handle than SWGs because of the presence of a solid metallic core which is stiffer and cannot unwind
   b. The metallic core may be reused with replacement of the sealing surface material on both sides
   c. The solid metal core provides additional blowout protection
   d. Require the same, easily provided, flange surface finish as SWGs
   e. Typically fit on the same standard flange raised face as SWGs
   f. Require a lower seating pressure than SWGs

4.2.3.2 GMCLs typically may be substituted for SWGs, though a check is necessary to confirm full contact with the flange sealing surface.

4.2.4 Corrugated Metal Gaskets (CMG)

4.2.4.1 CMGs have begun to replace SWGs and DJGs for use with flange Classes 150 and 300. CMGs have a simpler design with many of the same advantages in low pressure use. The seating stress of CMGs is low and the compressibility is high compared to SWGs and DJGs.

4.2.4.2 If the increased bending moment and stress imposed upon the flange is not a concern, CMGs are used in place of sheet gaskets because of superior “spring.”

4.2.4.3 CMGs are not suitable for high temperature (i.e., defined by the manufacturer, typically over 850 °F (455 °C)) or high pressure (i.e., greater than Class 300) services.

4.2.4.4 CMGs should not be used with potentially brittle flanges (e.g., iron or non-metallic).
4.2.5 Sheet Gaskets

4.2.5.1 Sheet gaskets are inexpensive and suitable for non-toxic, non-flammable, easily sealed fluids in low pressure and/or utility services if small amounts of leakage are tolerable.

4.2.5.2 Sheet gasket’s large area and soft, compressible material provides low gasket stress, and therefore these gaskets are not suitable for sealing high pressures, flammable or toxic fluids, etc.

4.2.5.3 Sheet gaskets are typically used for the following services:
   a. For brittle flange materials (e.g., iron or non-metallic) to reduce the bending moment and forces developed within the flange for gasket seating
   b. For flat faced plate flanges (such as may be used on storage tanks) to reduce internal flange stresses
   c. For flanges lined with brittle materials (e.g., glass) to minimize distortion, which could damage the lining.

4.2.5.4 The seating stresses for sheet gaskets are low, but since the gasket area is large the required bolt load is still moderate, and possibly large.

4.3 Gasket Suitability

4.3.1 Gaskets should be suitable for the applicable flange class, size, facing, surface finish, the process fluid, and the design conditions. Gaskets that are in accordance with the industry standards recommended in this Practice may be used without further review.

4.3.2 For flanged piping applications, gasket types specified in the applicable piping line class specifications should be used.

4.3.3 For flanged connections between equipment and piping, gasket types specified in the applicable piping line class specification should be used.

4.3.4 For equipment flanges that do not connect to piping (e.g., girth (body) flanges, manways, handholes, vents, instruments) and flanges that connect equipment directly without any piping in between, gasket types should be in accordance with the piping line class used for piping connected to the equipment except where additional design considerations (e.g., a specially designed flange) require a different, defined, gasket type.

4.4 Flat Faced Flanges

4.4.1 The entire mating surface of flat face flanges lies in one plane (i.e., no raised face). Cast iron, non-metallic, polymeric, elastomeric or glass-lined flat faced flanges, and full face plate flanges (commonly called API flanges, such as used on atmospheric storage tanks), should use full faced sheet gaskets.

4.4.2 For a non-metallic or brittle metal flat faced flange that mates to a raised face lined or metallic flange, a filler ring should be provided from the outside diameter of the raised face to the outside diameter of the flange to convert the raised face to a “flat face”. This permits full contact with the sheet gasket as shown in Figure 5. The surface of the filler ring should be flush with and in the same plane as the raised face. The surface of the filler ring and the raised face surface should be machined to the required (probably rougher) finish for the
selected gasket. The filler ring material normally should match the flange material.

![FILLER PLATE](figure.png)

**Figure 5 – Filler Plate for Flat Faced Flanges**

5. **Standard Flange Gaskets**

5.1 **Double Jacketed Gaskets**

5.1.1 DJGs may be used with all raised face flanges in the following flange classes:

- a. *ASME B16.5* Class 150 and greater
- b. *ASME B16.47* Class 150 and greater

5.1.2 DJGs should be the corrugated type.

5.2 **Spiral Wound Gaskets**

5.2.1 SWGs may be used with all raised face flanges in the following flange classes:

- a. *ASME B16.5* Class 150 and greater
- b. *ASME B16.47* Class 150 and greater

5.2.2 SWGs should have outer and inner rings.

5.2.3 Outer ring should extend to the inside edge of the bolt holes.

5.2.4 Inner ring should extend to the inside diameter of the flange. Standard inner ring dimensions are based upon the use of Schedule 40 pipe; therefore, thinner pipe may require additional considerations regarding the inner ring to prevent it from projecting into the flowing area of the pipe. For flanges 4 NPS or less the inner ring is extremely narrow.

5.2.5 Thicker wall pipe (i.e., greater than Schedule 40) may require a SWG with a wider inner ring to extend to the bore.

5.2.6 The inner ring should not project beyond the diameter of the flange bore.

5.2.7 Inner and outer ring thickness should permit full gasket compression without flange contact. The rings also act as over-compression stops.
5.3 Grooved Metal Gaskets with Covering Layer

5.3.1 GMCLs may be specified for use with all raised face flanges in the following flange classes:

a. *ASME B16.5* Class 150 and greater
b. *ASME B16.47* Class 150 and greater

5.3.2 GMCLs should have outer rings that extend to the inside edge of the bolt holes.

5.3.3 For use with *ASME B16.5* flanges, the outer ring may be integral (one piece, not welded) with the metallic core or separate, loose fit, unless the gasket is subject to thermal or pressure cycling. For thermal or pressure cycling services, use of a separate, loose fit, outer centering ring should be used. See Figure 6.

![Integral Ring](integral-ring.png) ![Loose Ring](loose-ring.png)

**Figure 6 – GMCL Outer Ring for ASME B16.5 Flanges**

5.3.4 For all gaskets for *ASME B16.47* flanges, a loose fit outer centering ring, should be used. See Figure 7.

![Loose Ring](loose-ring.png)

**Figure 7 – GMCL Outer Ring for ASME B16.47 Flanges**

5.4 Corrugated Metal Gaskets

CMGs may be used with all raised face flanges in the following flange classes:

a. *ASME B16.5* Class 150 and 300
b. *ASME B16.47* Class 150 and 300

5.5 Sheet Gaskets

Sheet gaskets may be used with raised face and flat face flanges as follows:

a. *ASME B16.1* Class 125 and 250
b. *ASME B16.5* Class 150 and 300
c. *ASME B16.42* Class 150 and 300
d. *ASME B 16.47* Class 150 and 300
5.6 Multi-piece Gaskets

5.6.1 Very large diameter metallic cored gaskets (e.g., CMG and GMCL) may require that the metallic parts be fabricated in two or more sections because a single piece may be too large to be cut in one section from one piece of plate.

5.6.2 If multi-piece metallic parts are required, the following fabrication recommendations should be applied:

a. All of the pieces used for an individual gasket should be cut from one plate. This minimizes the possibility of hardness or thickness differences between pieces, and ensures that the pieces are of the same metallurgy.

b. Sections should be aligned at the joint to avoid the presence of a thickness “step”.

c. Assembled gasket should be in a single plane.

d. Welds between sections should be configured as follows:

   (1) Full penetration
   (2) Ground flush on the top and bottom after welding. All portions of each gasket surface (top and bottom) should be in the same plane
   (3) Dye penetrant examined from both sides. Additionally, radiographic examination may be required for critical services.
   (4) Weld metal hardness approximately the same as the parent metal
   (5) Grooves or corrugations should be machined or formed after all welding and surface operations are complete. Grooves or corrugations should align across the welds.

6. Custom Designed Gaskets

6.1 Custom design is necessary if the flange design conditions (i.e., temperature and/or pressure), size (i.e., NPS) or other dimensions, or the material are outside of the scope of the flange standards referenced by the applicable design code for the equipment or piping. Flanges conforming to a standard not referenced by the applicable design code should be reviewed as custom designed flanges. These flanges may require specially designed gaskets to accommodate the flange dimensions, bolting, sealing surface shape, and design conditions.

6.2 Except as specified in this Practice, dimensions and other requirements of custom designed gaskets should be in accordance with the requirements specified for standard flange gaskets.

6.3 DJGs or GMCLs are a suitable custom designed gasket choice for applications requiring a gasket seating width of less than ½ inch (13 mm). GMCLs require a minimum width of 3/8 inch (10 mm).

6.4 SWGs or CMGs are a suitable custom designed gasket choice for seating widths greater than ½ inch (13 mm). CMGs are a suitable custom designed gasket choice for design conditions that permit use of Class 150 or 300 standard flanges.
7. Gasket Materials

7.1 Metallic Components

7.1.1 The jacket material for DJGs should be compatible with the process. Type 304 stainless steel should be the minimum alloy.

7.1.2 For SWGs the following materials should be used:
   a. The winding and inner ring material should be compatible with the process. Type 304 stainless steel should be the minimum alloy. The inner ring material should match the winding material.
   b. The outer ring should typically be carbon steel with a coating to protect against corrosion. The protective coating should be compatible with all of the component metallurgies of the flange and the equipment or piping that could be exposed both as the coating is installed and if the coating is vaporized. Type 304 stainless steel outer rings should be used with high alloy (i.e., stainless steel or higher alloy) flanges or in high temperature service, (i.e., design temperature greater than 850 °F (455 °C)).

7.1.3 The metal core material for GMCLs should be compatible with the process. Type 304 stainless steel should be the minimum alloy. Loose outer or centering ring material should be Type 304 stainless steel as the minimum alloy.

7.1.4 The metal core material of CMGs should be compatible with the process. Type 304 stainless steel should be the minimum alloy.

7.2 Facing/Filler Material

7.2.1 General

7.2.1.1 Asbestos or asbestos containing filler/facing materials should not be used.

7.2.1.2 Typically, common filler materials are non-compressible and may impose stresses (including radial stresses) throughout SWG and DJG assemblies upon seating.

7.2.2 Flexible Graphite

7.2.2.1 Inhibited flexible graphite is the most common filler/facing material used in gaskets. This material should be used unless it is not compatible with the process.

7.2.2.2 Inhibited flexible graphite should contain a minimum of 98% graphite, oxidation/corrosion inhibitors, and less than 50 ppm leachable chlorides.

7.2.2.3 In reducing environments, inhibited flexible graphite functions well under a wide variety of atmospheres and temperatures.

7.2.2.4 In oxidizing environments, inhibited flexible graphite functions well in a variety of environments up to a design temperature of 850 °F (455 °C). At higher temperatures the material may degrade. The binder material may degrade at even lower temperature than the graphite. The gasket manufacturer’s recommendation (e.g., temperature limitation) should be followed.
7.2.3 **ePTFE**

7.2.3.1 ePTFE should be used if product purity is a concern or if flexible graphite is not compatible with the process but ePTFE is compatible (e.g., HF acid and sulfuric acid).

7.2.3.2 ePTFE sheet gaskets are typically used for the following applications:
   a. Glass-lined flanges
   b. Non-metallic full face flanges
   c. Cast iron or ductile iron full-face flanges
   d. Full face storage tank manways
   e. Services with pressures less than 15 psig (0.1 MPa)
   f. Applications where seating forces and induced bending moments (e.g., as present with raised face flanges) may damage the flange, facing, piping, etc.

7.2.3.3 ePTFE sheet gaskets should not be used for temperatures greater than 450 °F (230 °C).

7.2.4 **Proprietary Materials**

7.2.4.1 Proprietary materials should be used only if standard materials (e.g., graphite, ePTFE) are not acceptable.

7.2.4.2 Proprietary materials are developed for specific services and can only be used in the services and conditions (e.g., atmosphere, temperature, cyclic conditions, etc) for which they are specifically developed and marketed.

7.2.4.3 Before using a proprietary material, its performance in the proposed service should be verified through independent sources.

7.3 **Gasket Adhesives**

7.3.1 Adhesives should not be used for gasket installation.

7.3.2 An adhesive may be used between gasket layers if a part of the normal gasket manufacturing process. When possible, a mechanical bond between layers (e.g., tanged CMGs) is recommended.

7.3.3 Hydrocarbon based adhesives should not be used in the manufacture of gaskets.

7.4 **Positive Material Identification (PMI)**

7.4.1 The gasket manufacturer should perform 100 percent PMI on the gasket core, jacket, winding (for SWGs), and ring (if separate from other components) metals before assembly or encapsulation. Each part of multi-piece gaskets should be examined.

7.4.2 Immediately before gasket installation the following should be performed:
   a. Except as provided in Section 7.4.2.d, PMI standard gaskets on the ring, core, and jacket for a minimum of 10 percent of each lot of gaskets. Sampled gaskets should be selected at random.
   b. PMI of all metal parts for standard gaskets should be in accordance with *PIP VESPMI01*. 
c. Typically the rim metal of a standard gasket is exposed for PMI. If necessary, the coating outside of the seating contact area should be removed to expose the metal for PMI. If direct access (i.e., without removing coating) is available or coating from a non-sealing area can be removed, 10 percent of cores should be examined.

d. If direct access is not available and coating from a non-sealing area of a standard gasket cannot be removed 1 percent, with a minimum of 2 gaskets of each lot of the gaskets, should be examined by removing the coating to test the core. The sampled gaskets should not be used.

e. Custom gasket examination requirements should be developed and applied by the purchaser. Examination of each gasket is recommended.

8. Gasket Dimensions

8.1 DJGs
The dimensions of DJGs for standard flanges should be in accordance with ASME B16.20.

8.2 Custom DJGs
The minimum width for custom DJGs should be 1/2 inch (13mm) and the minimum thickness should be 1/8 inch (3mm).

8.3 SWGs
The dimensions of SWGs for standard flanges should be in accordance with ASME B16.20.

8.4 Custom SWGs
8.4.1 The minimum width for custom SWGs should be 1/2 inch (13mm) and the minimum thickness should be 1/8 inch (3mm).

8.4.2 Inside and outside radius of the windings should be determined by the custom SWG designer.

8.4.3 The windings should be fully seated against the sealing surface (i.e. should not extend radially past the sealing surface).

8.5 GMCLs
The dimensions of GMCLs for standard flanges should be in accordance with ASME B16.20.

8.6 Custom GMCLs
8.6.1 Except for custom GMCLs used for pass partitions (e.g., heat exchangers), the minimum gasket width should be 3/8 inch (10 mm).

8.6.2 Custom GMCLs used for pass partitions (e.g., heat exchangers) may be 1/4 inch (6 mm) wide or greater.

8.6.3 A 1/8 inch (3 mm) minimum core thickness with 0.020 inch (0.5 mm) minimum covering layer on each side should be used. Thicker cores and covering layers may be used if required for the application.
8.6.4 Custom GMCLs should have an outer centering ring. Unless the gasket is subject to thermal or pressure cycling, or is used on a flange that is larger than NPS24, the ring should be integral with the core.

8.6.5 For custom GMCLs used in thermal or pressure cycling services, consider using a separate, loose fit, outer centering ring for NPS 24 and smaller flanges.

8.6.6 Custom GMCLs for flanges larger than 24 inch should have a separate, loose fit outer centering ring.

8.7 CMGs

8.7.1 The inside diameter of a CMG should match the flange bore and the outside diameter should extend to the inside edge of the bolt hole.

8.7.2 CMG dimensions should conform to the manufacturer’s standard. Typical dimensions are shown in Figure 8 (below). The peak to peak should be minimized, but should not be less than 1/8 inch (3 mm).

8.8 Custom CMGs

8.8.1 The inside diameter of a custom CMG should match the flange bore and the outside diameter should extend to the inside edge of the bolt holes.

8.8.2 Except for custom CMGs used for pass partitions (e.g., heat exchangers), the minimum gasket width should be 1/2 inch (13 mm).

8.8.3 Custom CMGs used for pass partitions (e.g., heat exchangers) can be supplied in widths of 3/8 inch (10 mm) and greater in corrugated form.

8.8.4 Typical dimensions are shown in Figure 8. The peak to peak dimension should be minimized, but should not be less than 1/8 inch (3mm).

8.9 Sheet Gaskets

8.9.1 Flat faced flanges should use full face sheet gaskets.

8.9.2 The gaskets for standard flanges should be in accordance with ASME B16.21.

8.9.3 If bolt load is limited, an engineer experienced with gasket and flange joint design, evaluation, and behavior should be consulted to evaluate a reduced area gasket design.
8.10 **Custom Sheet Gaskets**

8.10.1 The inside diameter of custom sheet gaskets should match the flange bore and the outside diameter should match the outer diameter of the flange.

8.10.2 The minimum gasket thickness should be 1/16 inch (1.5 mm).

8.11 **Gasket Records**

8.11.1 Records of custom gasket dimensions and other requirements necessary to replace a custom gasket with an identical gasket should be recorded on the equipment drawings and/or other location. The gasket records should be retained for reference as long as the subject flanged joint is, or could be, in service.

8.11.2 Records of proprietary materials and the process conditions in which they are used in any gasket should be recorded on the equipment drawings and/or other location. The gasket records should be retained for reference as long as the subject flanged joint and the gasket is, or could be, in service.

9. **Gasket Marking**

9.1 The location and content of markings and color coding of DJGs and SWGs should be in accordance with *ASME B16.20*. Markings should be in a conspicuous location. Color coding should be visible in the assembled flanged joint.

9.2 GMCLs should be marked in accordance with *ASME B16.20*. Loose centering ring material should be identified separately from the core identification. Color coding should be visible in the assembled flanged joint.

9.3 CMGs should be marked with the manufacturer’s name or trademark, style or model, flange size, flange Class (for standard flanges), core material designation, and sealing layer material designation. Color coding should be visible in the assembled flanged joint.

9.4 Sheet gaskets should be marked in accordance with *ASME B16.21*. Markings should be on the surface. Color coding should be visible in the assembled flanged joint.

9.5 Color coding provides a visual means of confirming the gasket materials.

9.6 Gaskets for *ASME B16.47* flanges should be marked “B16.47A” or “B16.47B” to indicate their use with either Series A or Series B flanges, as applicable.

9.7 Except for flange class and applicable gasket standard, which do not apply, custom gaskets should also be marked in accordance with the recommendations provided in this Section.

9.8 Markings should include an identification of multi-piece gaskets.

9.9 Paint (including its vaporized form if the paint could be vaporized) used for marking should be compatible with the gasket, flange and equipment materials, internals, the process, external environment and contents (e.g., catalyst).

10. **Gasket Purchase, Packaging, Shipping, and Handling**

10.1 Gasket purchasing, packaging, shipping, and handling should be in accordance with *PIP PNSM0105*.

10.2 Gaskets should be protected from damage (e.g., scrapes, tears, cuts, distortion, compression, etc.), contamination (e.g., moisture, dirt, chemicals), and corrosion at all times before installation.
10.3 Gaskets should be stored flat in a cool, dry, shaded location.

10.4 Gaskets should not be removed from their shipping protection or brought to the installation site until they are to be installed.

10.5 Care should be taken when handling gaskets to prevent damage or contamination of the gasket or the flange sealing surface. SWGs are prone to “unraveling” and the sealing material of GMCLs and CMG’s is exposed and therefore susceptible to damage.

11. Gasket Factors for Custom Flange Design

11.1 Typically, the “m” factors and “y” values are recommended by the gasket manufacturer. If these values are not available, the values in the Code Division 1, Appendix 2 or Code Division 2, paragraph 4.16 should be used as applicable.

11.2 Flange design may require use of the full gasket width, rather than an effective width, to ensure gasket seating. The Code provides guidance on the appropriate gasket width for design. The manufacturer should also be consulted.

12. Nubbins

12.1 Nubbins should not be permitted for new flanges.

12.2 Removal of nubbins from existing flanges is recommended.

12.3 Removal of nubbins should be evaluated by an engineer experienced with bolt, gasket and flange joint design, evaluation and behavior to ensure the flange and bolts are adequate for gasket seating and operation after the nubbin has been removed. The engineer should also be capable of evaluating the metallurgical and mechanical effects of the removal process and the necessary nondestructive examination.

12.4 If existing nubbins are not removed, non-corrugated DJGs should be used. DJGs should be installed with the smooth side (i.e., the side opposite the overlap of the metallic jacket components) against the nubbin.

13. Flange Surface Finishes

13.1 Unless a differing value is required by the gasket manufacturer, flange surface finish should be 125 to 250 μ-inch Ra (3.2 – 6.3 μ-meter). However, some exceptions are as follows:

a. DJGs typically require a finish of 63-125 μ-inch (1.6 – 3.2 μ-meter)

b. Sheet gaskets typically require a finish of 250-500 μ-inch (6.3 – 12.6 μ-meter)

13.2 Finishes should be evaluated by visual comparison with surface finish roughness standards that are in accordance with ASME B46.1.

13.3 Finishes should be formed by spiral or concentric grooves in accordance with the governing flange standard (e.g., ASME B16.5 and B16.47).

13.4 Flanges with gasket seating area damage or flatness that are outside the acceptance criteria of ASME PCC-1, Appendix D, should be repaired or replaced.
14. **Bolted Joint Assembly**

14.1 The goal of the assembly method is to provide a uniform gasket stress sufficient to seat the gasket and maintain a seal during operation. A uniform stress requires the same force/stress in each bolt.

14.2 Before assembly, the flanges should meet the alignment criteria of *ASME PCC-1*, Appendix E.

14.3 Bolted joint assembly procedures should ensure that the flanges remain parallel throughout assembly and that the gasket is uniformly compressed over the entire sealing surface.

14.4 Bolted joint assembly should be performed in accordance with *ASME PCC-1*; the legacy method is recommended. The target bolt stress (or torque) should be in accordance with the gasket manufacturer’s requirements to ensure the correct stress is applied to the gasket.

14.5 Direct bolt tensioners should be used to apply tension to bolts greater than 1 ½ inch (32mm) diameter or for bolting used with flanges greater than 36 inches (900mm) diameter. Direct bolt tensioning is recommended for bolting all flanges whenever practical. The bolt elongation method described in *ASME PCC-1* is an acceptable alternative to direct tensioning.

14.6 In some cases (e.g., hot services, large diameter flanges, or some combinations of materials), retightening of the bolts after reaching service conditions may be a consideration.

14.7 If ePTFE facing or filler material is used in the gasket, bolts should be retightened before placing them into service and a minimum of 6 hours after completion of the initial tightening. This recommendation addresses cold flow of the ePTFE under load that may cause a reduction of the initial gasket load.

14.8 All safety issues related to bolted joint assemblies should be properly addressed, and a detailed, approved, procedure should be developed and followed. All assembly should be performed under the guidance of an engineer experienced with bolt, gasket and flange joint design, evaluation, and behavior.

14.9 Flange joint assemblers should be trained and experienced in the assembly of joints in accordance with *ASME PCC-1* or another accepted, recognized standard.

15. **Gasket Reuse and Replacement**

15.1 Non-metallic and semi-metallic gaskets should not be reused after their initial seating. Gaskets should be replaced with identical new, unused, gaskets each time the flange is opened or the bolts loosened, relaxing the gasket stress.

15.2 The metallic core of GMCLs may be reused if the compressible layer is removed from each side without damaging the grooves and new sheets of compressible material are used.

15.3 A replacement gasket should be intended for use with the flange Class used in the joint.

15.4 A replacement gasket should be the same type as the original gasket.
15.5 In some cases replacement with a different style of gasket (e.g., GMCL for SWG) may be a possibility. In these cases, the following should be considered:

a. The new gasket should be compatible with the dimensions of the flange sealing surface, bolt circle, and bore.

b. Installation should not require excessive flange separation (e.g., GMCLs may be thicker than SWGs)

c. The bolting and flange stress capacity should be adequate for the alternative gasket under all conditions (e.g., seating and operation).

d. Flange refinishing may be necessary for other than SWG’s and GMCL’s.

e. The design should be reviewed by an engineer experienced with gasket and flanged joint design, evaluation, and behavior. For example, the flange system should be reviewed to ensure that it is adequate for the gasket seating (i.e., “y” value) and seal maintenance (i.e., “m” factor) requirements of the new gasket.

16. Refinishing of Flanges

16.1 Refinishing of flange surfaces restores the original or provides a newly required surface finish (i.e., roughness or smoothness) necessary for seating of gaskets. Refinishing may be considered for correcting leakage problems or flange sealing surface defects.

16.2 Refinishing is performed by machining the entire flange sealing surface to remove groves, scratches, raised spots, or other defects. Low or severely damaged areas may be filled with weld deposit before machining.

16.3 The refinished surface should be perpendicular to the axis of the flange and should be planar (i.e., not concave or convex).

16.4 Refinishing should be provided by concentric or spiral grooves in accordance with ASME B16.5 or ASME B16.47. Lapping or any method producing grooves with any radial component or any other non-uniform finish should not be used.

16.5 The refinished surface should comply with all of the provisions of all applicable standards (e.g., ASME B16.5, B16.20, etc.)

16.6 After refinishing, sufficient thickness, raised face height, etc., should remain to permit the flange to perform as originally designed/intended.

16.7 See ASME PCC-2, Article 3.5, for flange repair criteria.

17. Gaskets Between Flanges of Dissimilar Materials

17.1 Joining flanges of dissimilar material should be avoided, especially at high temperatures where differing coefficients of thermal expansion subject the gasket to radial shear. Frequent thermal cycling increases the severity of the problem.

17.2 Subject to review by an engineer experienced in gasket and flanged joint design, analysis, and behavior, SWGs may be able to absorb limited non-cyclic differential radial growth.

17.3 If joining flanges with dissimilar materials is proposed, the risk of galvanic corrosion should be evaluated. Preventive measures may include an insulated gasket and other isolation methods.
Appendix A

Common Leakage Causes and Corrective Methods

A-1. Leakage Causes

A-1.1 No seal is perfect; some amount of leakage is inevitable. Leakage depends upon the contained fluid (e.g., molecule size, viscosity), driving force (e.g., pressure differential), and the pressure drop necessary to flow along the leak path (e.g., between the gasket and the flange surface). The tighter the gasket fits against and follows the flange surface profile, and the longer and more convoluted the profile, the higher the necessary pressure drop and the better the seal.

A-1.2 Leaks usually develop because of a reduction of the pressure drop necessary for flow along the leak path (e.g., a decrease in the gasket stress which slightly increases the flowpath size or damage to or distortion of the flange surface). Causes of leakage may be complex and are best determined by an engineer experienced in the design, evaluation, behavior, and performance of gaskets and flanged joints. Among the causes of leakage are the following:

a. Incorrect flange surface finish for the selected gasket
b. Damage to the sealing surface including radial scratches, corrosion (rust), dirt and low spots
c. Damage to the gasket; creasing or folding of the gasket as installed
d. Use of the wrong gasket (e.g., a Class 150 gasket in a Class 600 flange)
e. Reuse of a previously used gasket
f. Imposed loads from piping movement, flange misalignment at assembly, eccentric loads, etc.
g. Flange distortion removing or redistributing gasket loads. Flange to flange contact is especially undesirable because it quickly reduces gasket stress because the contact point is much stiffer than the gasket.
h. Improper bolt tightening methods resulting in non-uniform bolt loads and gasket stress
i. Bolts spaced too far apart or too flexible of a flange, permitting flange distortion between the bolts or other bending of the flange. This is addressed by the Rigidity Index (J) in the Code, (e.g., Section VIII, Appendix 2).
j. Insulation of flanges designed for uninsulated conditions (i.e., the lower temperature of an uninsulated flanged joint was considered in the original joint design)
k. Differential thermal expansion between the flange and bolts, including temporary differences because of differing rates of heating or cooling (e.g., heat transfer rate, thermal mass, etc.). This may result in bolt overstress; possibly resulting in inelastic deformation of the bolt. As the bolt later heats and thermally expands it may loosen. Creep deformation in high temperature service also leads to inelastic deformation. Leakage may occur immediately, a few days after joint assembly, after a period of successful operation, or at shutdown.
1. Rain or operational characteristics that result in a non-uniform temperature around the circumference of the flange; especially a large diameter flange. An example is the body flange on a horizontal Steam Generator. The flange can be cool on the bottom (the portion containing water) and hotter on the top (the portion containing steam).

A-2. Leakage Correction

Many methods of leakage correct are possible and available. They range from small, simple, adjustments, to major redesigns. Among the leakage correction methods are the following:

a. Flange refinishing, cleaning and/or rust removal
b. Gasket replacement
c. Bolt replacement; possibly with a different alloy to better match the flange’s thermal growth through the thickness or to reduce bolt deformation, yield or creep
d. Piping system design modification to reduce or remove imposed loads
e. Addition of weather shielding or in some cases insulation to even the flange temperature around the circumference by protecting against local atmospheric effects (e.g., rain and wind). Shielding also counters the effect of shading (e.g., the underside of horizontal piping is warmer than the top side during rain exposure).
f. Use of spring washers to maintain bolt load under small amounts of differential flange and bolt thermal growth. See Figure A1.

![Figure A1 – Flange Assembly with Conical Spring Washers](image)

g. Use of bolt extenders to reduce the amount of strain resulting from a given differential thermal growth between the flange thickness and the bolt. See Figure A2.
h. Application of slow heat up and cool down to minimize the differential temperature between the bolt and flange thickness. Because of the heat transfer characteristics, the bolt will heat and cool more slowly than the flange.

i. Tightening the bolts in strict accordance with recognized methods (e.g., ASME PCC-1). Using direct bolt tensioners or load indicating bolts/washers to provide a more uniform bolt stress.

j. ASME PCC-1, Appendix P, provides additional guidance on troubleshooting flanged joint leakage. Included are signs (symptoms), possible causes and suggested solutions.

k. In extreme cases a lip seal (e.g., seal welding the flange) may be necessary. The weld is inside the bolt circle and is for sealing only, not strength. The bolts continue to carry the loads. The weld can be cut off and the flange opened. The weld can be replaced when the joint is reassembled. Figure A3 is an example of one type of lip seal.
Appendix B
Commentary

The purpose of this Commentary is to provide background and basis behind the provisions of this Practice as well as additional comments related to those provisions. This information is presented for the user’s information only. The contents are not to be considered guidelines or otherwise a part of the body of this Practice. The Section identification is the Section of the text to which the comment applies.

Section 1.1 This Practice contains general guidelines, not requirements, regarding gasket characteristics and use. It does not provide recommendations for specific services or situations. Determination of the gasket style and characteristics for specific applications and gasket selection for the application are the responsibility of the designer. This work should be performed by an engineer experienced with gasket and flange joint design, evaluation and behavior and familiar with the specific application conditions and related concerns. Additional information on gasket considerations/recommendations for specific services, i.e., gasket style, filler materials, etc. may be considered for inclusion in future revisions of this Practice.

Section 1.2 Confined gaskets include those for ring joint, male-female, and tongue and groove flanges as well as a variety of special styles. Although the types of gaskets included in this Practice are the types most commonly used in process plants, confined gaskets are still preferred by some users for severe services. Among those services are high pressure (i.e., flange Classes 900 and higher), high temperature (i.e., over 1000 °F (540 °C)), hydrogen service, and toxic or lethal services. Confined gaskets may be considered to provide very reliable resistance to blowout (i.e., radial failure due to internal pressure) and very reliable gasket sealing because of a more difficult leakage path. However, confining the gasket requires grooves in one or both mating flanges, which requires thicker flanges and incurs machining costs. If only one flange is machined, the flanges are not identical; if both are machined the grooves must align. Also, corners of the grooves may lead to flange cracking unless machined to a generous radius. Confined gaskets are not able to accommodate much differential flange movement (e.g., mating flanges of different metallurgies and coefficients of thermal expansion). Also, use of confined gaskets requires that the flanges be spread farther apart to insert or remove the gasket, and the gasket may need to be thicker to allow for the depth of the groove. Users have found that the gasket styles covered by this Practice work as well as confined gaskets in all services, the flanges are less costly and less susceptible to cracking and assembly is easier and less subject to error or problems.

Section 1.2 Custom designed gaskets for temperatures or pressures beyond those in the standard (e.g., ASME 16.5) ratings are not covered. Gaskets for flange sizes and materials not included in the flange standards are covered.

Section 2 Until 2013, serrated metal gaskets with covering layers were specified in accordance with Fluid Sealing Association (FSA) Standards FSA-MG-502-05 - Serrated Metal Gaskets with Covering Layers (SMCL) Standard for Raised Face and Flat Faced Flanges in accordance with ASME B16.5 and FSA-MG-503-06 - Serrated Metal Gaskets with Covering Layers (SMCL) Standard for Raised Face and Flat Faced Flanges in accordance with ASME B16.47. In 2013 ASME B16.20, Metallic Gaskets for Pipe Flanges, Ring-Joint, Spiral-Wound and Jacketed, added grooved metal gaskets with covering layers. ASME B16.20 does not mention the FSA Standards, but nearly all of the requirements of the FSA Standards are included. For example, all of the dimensions are identical excepting a few differences up to 0.2mm due to round off. A few other differences are
addressed in the text of this Practice. For example, FSA-MG-503-06 requires the centering ring to be separate from the core for large diameter gaskets but B16.20 does not. One other change was modification of the gasket name from serrated metal gaskets to grooved metal gaskets.

Section 3 Custom Designed Flanges – ASME 16.5 flanges are limited to NPS 24, NPS 12 for Class 2500. ASME B16.47 covers larger sizes of Class 150 through Class 900 flanges, but does not contain nearly as many materials as ASME B16.5. Depending upon the flange Class and Series (i.e., A or B), ASME B16.47 covers flanges to a maximum size of NPS 36 to NPS 60.

Section 3 Grooved Metal Gaskets with Covering Layer – Seating presses the compressible material into the grooves in the metal, creating a mechanical anchorage for the sealing material. In the radial direction a series of high stress sealing points are created at the peaks between the grooves, enhancing the seal.

Section 4.1 The fluids (liquid or vapor) may be toxic, flammable, high pressure, high temperature, corrosive, polluting, etc. Leaking can also result in economic loss.

Section 4.2.1 The jacket on DJGs protects and contains the compressible material and restricts its ability to deform or flatten. This allows large compressive stresses to develop quickly when the gasket is compressed between two flanges, allowing creation of large seating stress and a seal. The outer jacket also protects the compressible material from mechanical damage.

Section 4.2.2.1d. The chevrons seen in the metallic windings allow the windings to be compressible. They can also act a little like springs, imparting a small ability to rebound if the gasket compression is reduced. This is not considered in design but may aid in maintaining a seal under variable conditions, such as caused by weather, which can affect temperatures around the flange circumference. The chevrons also allow accommodation of very small amounts of differential radial expansion (e.g., a gasket between flanges of materials with different coefficients of thermal expansion) by flexing of the chevrons in the radial direction. That is generally better than accommodating the differential radial expansion by sliding (shear) across the gasket surface.

Section 4.2.2.3 Low stress SWGs are used if the flange may not be able to accommodate the seating stress required for normal SWGs. They may have a reduced sealing ability as compared with standard gaskets. The gasket manufacturer should be consulted to confirm a low stress gasket is appropriate for the planned service.

Section 4.2.3 GMCLs are normally more expensive (i.e., capital cost) than SWGs. However, they may be cost competitive if life cycle cost is considered because of the ability to reuse the metallic portions of the gasket rather than replace the entire gasket. This is especially true for large diameters and other custom gaskets.

GMCLs may produce an even better seal than SWGs because all of the load is focused at the peaks of the corrugations; the core of the gasket does not compress. This also may allow a little more tolerance for surface imperfections because an imperfection between gasket peaks has less of an effect.

Section 4.2.3f. Representative “y” and “m” values for GMCLs are “y” of 2500 to 5000 psi and “m” of 2 – 3.

Section 4.2.4 CMGs are often less expensive than other types of gaskets. They are not suitable for high pressure services (typically defined as requiring a flange class greater than Class 300) because the seating stress tends to flatten the gasket, turning it into the equivalent of a
sheet gasket. The forces are then spread over a much larger area; therefore, the stress is much lower and the potential for leakage increases. CMGs are not typically suitable for difficult to seal fluids (e.g., hydrogen) or high temperature service. High temperature is defined by the manufacturer, typically as greater than 850 °F (455 °C). The lower seating stress required by CMGs may be preferred with Class 150 flanges, where the seating stress required for a spiral wound gasket may exceed the flange’s calculated capacity. CMGs may not be available in large sizes. Some users have been concerned that the bond between the core and the coating could shear, increasing the potential for blow out in high pressure services.

Section 4.2.5 The centroid, therefore the resultant force location, of a full face gasket is much nearer to the bolts than it is with other, narrow, gaskets that are placed near the flange bore and/or seated and sealed only in a limited area such as a raised face. Additionally, although the gasket surface area is large, the required seating stress is low possibly resulting in a lower seating force than required by other gasket styles. The overall result is a much lower bending moment and, therefore, stress in the flange material. This reduces the possibility of fracture of a brittle material (e.g., cast iron) or excessive flange distortion that may damage a lining (e.g., glass) or decrease the ability to seal because of distortion of a weak (e.g., plate) flange.

Although it is possible to install a sheet gasket in a joint using raised face flanges, only a portion of the gasket is then available to provide the seal. Caution is necessary to ensure that the small sealing area of the gasket is not overstressed, even crushed; a reduced bolt load is necessary. Obtaining a good seal is difficult. Sheet gaskets should only be considered for use with raised face flanges as a temporary measure in very easily sealed, non-toxic, non-flammable services and with ductile flange materials. The lower moment arm advantage over SWGs is lost, though the force is less since the gasket cannot withstand a large applied stress.

Section 4.3.1 Several special conditions may also apply including the following:

a. Fire safety (i.e., the ability to maintain a seal if exposed to a fire). This is measured by the ability to pass an *API 6FB* test.

b. Electrical insulating ability. This may be necessary to prevent formation of a galvanic cell between flange materials separated on the galvanic scale or ladder. Typically an aqueous environment is also necessary. Creation of a cell can result in material loss (i.e., corrosion) at the anode. An insulated gasket alone is not sufficient. Insulating washers at the bolting nuts, sleeves around the bolts, and perhaps other measures are also necessary.

c. Cyclic service performance. Frequency and range of cyclic loading and movement are key. Experience is the best guide. Test data from the gasket manufacturer or performance data in a similar cyclic situation may be adequate.

Section 4.3.4 One method to specify gaskets and other requirements for equipment joints that do not connect to piping and therefore are not covered by the pipe class of attached piping is to specify a “Miscellaneous Pipe Class” for the equipment. This Pipe Class applies to joints where there is no attached piping (e.g., manways and direct connected equipment such as a stab-in reboiler into a fractionation column). Other defined methods may be effective, too.

Section 4.4.1 Flat faced flanges may also use narrow gaskets located near the bore (e.g., gaskets normally used with raised face flanges such as SWGs and GMCLs). This increases the bending stress in the flange, which should be avoided if brittle or low strength flange
materials are used. Also, the flanges may rotate or deflect, resulting in uneven gasket loading. Lower stress on some parts reduces their ability to seal and increased stress on other parts may over compress, even crush, the gasket. The result is an increased potential for leakage. If the flanges come into contact at their outer diameter, additional bolt forces can be transmitted through the flange contact points rather than via increased gasket stress. This is one of the reasons for the use of raised face flanges; the flange separation is greater at the outer diameter, greatly reducing the potential for flange contact.

Section 4.4.2 The filler ring is not welded to the flange because welding could warp the filler plate, creating a high spot on the sealing surface, and welding may damage the raised face surface. A weld would also need to be ground flush with the raised face, without damaging the surface finish.

Section 5.1 The outer diameter of standard DJGs extends to the bolt circle and can be used to center the gasket.

Sections 5.1-5.4 DJGs, SWGs, GMCLs and CMGs are not used with iron flanges because the gasket reaction is near the bore, relatively far from the bolts, resulting in a large moment imposed within the flange. The high stresses are a concern with brittle materials (e.g., iron).

Section 5.2.2 Outer and inner rings maintain gasket integrity with the currently used pliable but incompressible filler materials (e.g., graphite and ePTFE), unlike asbestos, which was fibrous and compressible. As the gasket compresses during seating, it “squeezes” out radially, retaining nearly the same volume. Inner and outer rings control this distortion, preventing gasket damage, such as separation of the windings, which could affect the ability of the gasket to seal. The rings also act as compression stops and serve to stabilize the gasket during handling. The outer ring provides additional blowout resistance and is dimensioned to fit just inside of the flange bolts. The windings also provide blowout resistance because they are placed into tension by the internal pressure (like a mini pressure vessel) and are not radially continuous, therefore a crack cannot propagate radially. The outer ring utilizes the flange bolts to properly center the gasket on the sealing surface. Inner rings provide resistance to inward distortion/buckling as the gasket is compressed. The outer ring has the same effect for outward distortion. Distortion can affect the sealing ability and in a more extreme case the windings could “spring” or unravel. Inner rings provide some protection to the inner sealing surface of the flange (e.g., by preventing collection of stagnant, corrosive fluids) and may also (slightly) reduce process fluid turbulence at the flanged joint. They are very narrow and prone to distortion and damage due to their low radial strength. Damage to inner rings cannot be seen in the assembled joint. Damage to outer rings (i.e., buckling) is revealed by observing wavy rings in the installed position.

ASME B16.20 requires inner rings for all gaskets with ePTFE filler material, all gaskets with graphite filler unless otherwise specified by the purchaser, and for other gaskets based upon size and flange Class (see ASME B16.20, paragraph 3.2.5). Many users require inner rings for SWGs; other users require inner rings for any gasket for Class 300 and greater flanges.

Section 5.3.2 A loose outer ring permits differential thermal movement between the core and the outer ring. The outer ring is more exposed to the cooling external atmosphere and is a smaller thermal mass; therefore it will be cooler than the core. Thermal cycling can cause a greater temperature difference and radial expansion. The amount of the radial expansion
difference will be greater for larger diameter flanges for any temperature condition; therefore loose fit rings should be specified for ASME B16.47 flanges.

Section 5.3.3 Welding the centering ring to the core may warp the ring. The weld must be full penetration, adds cost and, for some materials, may require PWHT. Therefore a one piece ring and core is called for. The recommended centering ring details (including the recommendation of Section 5.3.4) are based upon FSA-MG-502-05 and FSA-MG-503-06 (see commentary for Section 2), which preceded inclusion of GMCLs in ASME B16.20.

Section 5.4 CMGs have become common for exchanger channels and tubesheets (used in place of DJGs) and perhaps in small diameter Class 150 and 300 flanges where the bolting may not be adequate to seat spiral wound gaskets.

Section 5.5 Limitation to Classes 150 and 300 is an industry norm because of concerns with gasket blowout.

Section 5.6.2.a Even slight differences in gasket thickness or hardness can create different degrees of gasket compression and sealing around the gasket circumference, increasing the difficulty of achieving a seal. In most cases when a multi-piece gasket is used, achieving a seal is already difficult because of the large diameter of the gasket.

Section 5.6.2.c Use of low heat welding processes (e.g., TIG) intended for welding thin materials may reduce distortions caused by welding. Metallic portions of gaskets are very unlikely to be subjected to PWHT because they are thin and typically austenitic stainless steel. However, if PWHT is performed, the gaskets should be planar after completion of PWHT.

Section 5.6.2.d(2) Welding distortions and assembly inaccuracies can result in a change of plane at the joint. If the gasket is not in a single plane an uneven seal can develop when the gasket is installed. This may result in difficulty seating and sealing the gasket. The reference to a “single plane” in the text refers to the surfaces of the welded plate prior to machining the grooves or forming the corrugations.

Section 5.6.2.d(3) Volumetric nondestructive examination is difficult to perform and is not often effective on very thin welds. Ultrasonic examination should not be considered.

Section 5.6.2.d(5) Grooves and corrugations are typically, and preferably, cut or formed after completion of fabrication of the metallic portions of the gasket. Therefore alignment of the grooves or corrugations at the weld between sections is not a problem.

Section 7.1.2.b The coating on carbon steel is intended to protect the steel from corrosion (e.g., rust) before placing the gasket into service or at low operating temperatures {less than 300 – 400 °F (150 – 200 °C)}. At these low temperatures the steel can be exposed to aqueous water. At high operating temperatures aqueous water cannot be present; therefore most corrosion mechanisms are not active. Various coatings may be used; Titanium oxide is commonly baked onto the ring. The coating vaporizes at a temperature greater than 300 – 500 °F (150 – 260 °C). The coating must be compatible with all of the gasket and base metal materials when intact and when vaporized (e.g., do not use galvanizing in the presence of austenitic stainless steel, e.g., gasket windings, because of the presence of zinc in the coating). If high temperature corrosion resistance is required, a coating suitable for the temperature or another ring material should be used.

Various temperatures up to 1000 °F (540 °C) are used as the break between carbon and stainless steel outer rings. 850 °F (455 °C) is selected because of rapid loss of strength and possible concerns with graphitization of the carbon steel at higher temperatures. Graphitization can occur at 800 °F (425 °C). The temperature limit is the design
temperature and includes a margin, typically 50 °F (28 °C), above the normal operating
temperature. In addition, the outer ring is typically a little cooler than the process.

Section 7.1.3 The loose outer ring is always a material that thermally expands more than the core to
avoid over stressing either the core or ring; therefore Type 304 stainless steel is the
minimum alloy for the ring.

Section 7.2.1.1 The use of asbestos is prohibited by nearly all owner-operators and by national
environmental and safety organizations such as the Environmental Protection Agency
(EPA) and Occupational Health and Safety Administration (OSHA) due to safety
concerns such as aspiration of the fibers.

Section 7.2.1.2 The filler materials are non-compressible, meaning their volume does not change
significantly when compressed. They are deformable, thus can become thinner when
compressed if they expand in the perpendicular direction to retain their volume. Fibrous
materials, such as asbestos, may be compressible due to the contained void volume,
which can allow a thickness decrease without a significant perpendicular dimension
increase. If other dimensions do not attempt to increase they will not impose stresses,
e.g., radial stresses, if the dimension change is restricted.

Section 7.2.2.2 PIP PNSM0105 requires 95% pure graphite with a density of 1120kg/m$^3$ (70 lb/ft$^3$) ±5%.
More stringent requirements are specified in this Practice because they are consistent
with the graphite used by the gasket manufacturers. It is denser; around 80 lb/ft$^3$ (1300
kg/m$^3$). There is an even purer form of graphite, nuclear grade, that is 99+% graphite.
The grade of graphite and the level of impurities, can affect the gasket performance.

Section 7.2.2.4 Manufacturers have developed proprietary materials, some of which have very complex
formulations, or specific designs, such as SWGs that utilize mica, or another filler
material that does not oxidize at high temperature, between the outer windings. This
protects the inner graphite windings, which provide the process seal, from high
temperature oxidation. Most proprietary materials are targeted at specific situations; use
in a different situation may be worse than using a standard material, even if the standard
material is not adequate either.

Section 7.3.1 Adhesives tend to “glue” the flanges together, making disassembly difficult. The gasket
may shred and stick to the flange. Removal of the gasket remnants may damage the
flange sealing surface and require refinishing. Adhesives do not improve the seal and
may even interfere with the ability of the gasket to seal by slightly flowing over the
flange surface.

There may be a few unique situations where a very light application of a gasket adhesive
would help. This must be done with full recognition of the potential future problems as
outlined above. An example might be placing a DJG between the tubesheet and shell of a
heat exchanger. The gasket is installed vertically and there may not be a centering ring
allowing centering against the bolts. Therefore, ensuring a proper gasket location can be
difficult. There also may be personnel safety issues (e.g., pinch points) as the system is
assembled.

Section 7.3.2 If used in a hydrocarbon process, a hydrocarbon based gasket adhesive can dissolve.

Section 7.3.3 FSA-MG-503-05 and FSA-MG-503-06 (see commentary for Section 2) required an
adhesive between the core and the covering layers. ASME B16.20, which has replaced the
FSA standards, does not mention an adhesive, nor do manufacturer catalogs. However, an
adhesive is typically used.
Section 7.4.2.a The material heats used for gasket metallic parts, including windings, are not tracked, therefore the mix of heats is not traceable. A practical approach is to randomly sample 10 percent of the gaskets, the same approach used for PMI of bolts. Portable PMI analyzers normally have a 3/8 inch (9 mm) head {though it can be as small as 1/8 inch (3 mm)}, therefore requiring access to a base metal area greater than 3/8 inch (9 mm) diameter. As an alternative to removing coating from 1 percent of the gaskets, the purchaser may witness the manufacture of the gaskets. Acceptance of the manufacturer’s material certificates without confirmation may be considered from known manufacturers with whom the purchaser has experience and can trust.

Section 7.4.2.b Thus far it is not possible to PMI the winding material of an assembled SWG. Techniques are being developed and software written to allow this PMI in the (possibly near) future. Until then, winding material is confirmed at manufacture and thereafter reliance is placed upon the gasket documentation.

Section 10.5 SWGs are held together like a coiled (e.g., watch) spring, pressing against the outer ring. They are not welded. Deformation perpendicular to the gasket plane can cause the windings to spring out and unwind over a considerable area. Larger gaskets are more susceptible to unwinding. Large SWGs are often taped to cardboard or other material to aid in maintaining integrity during handling. The cardboard should not be removed until the last possible moment. After removal of the cardboard the SWG should be handled only in a vertical orientation. If a non-vertical orientation becomes necessary, a backing material (e.g., cardboard) should be used. Large diameter gaskets should be handled by a minimum of two people to minimize possible distortion.

Section 11.1 The “m” factors and “y” values are used in the flange design method described in Code, Division 1, Appendix 2, and Code, Division 2, paragraph 4.16. Values from the manufacturer are based on testing and are more up-to-date, than those in the Code, which have not changed in many years. The Code uses a stress based design method, an indirect method of addressing leakage that is known to be inaccurate but conservative in most cases. If designing a joint with pass or partition sealing (e.g., a multi-pass exchanger) where there are no bolts directly compressing the gasket, the gasket sealing force (“y” value) and the need to prevent leakage across the pass or partition (“m” factor) should be considered.

A more direct, leak based, method has been developed by the Pressure Vessel Research Council but has not yet been accepted by and incorporated into design codes, not even as a Code Case. Leak based methods account for the fluid being sealed and can consider the total leakage potential, accounting for the flange size and the number of flanges, when determining the acceptable leak rate from a given flanged joint.

The rating tables in flange Standards (e.g., ASME B16.5) are based upon performance, not calculation in accordance with Code, Division 1, Appendix 2 or Code, Division 2 paragraph 4.16. It is possible that a standard flange will not “check out” for operation or, more likely, for gasket seating (e.g., small and moderate diameter SWGs for Class 150 or 300, for sizes just less than the point where the number of bolts increases), however they are known to work and are accepted for use.

Section 11.2 The flange may rotate and load only a portion of the gasket width in the sealing zone. Also, if GMCLs are slightly crowned, the entire gasket width is not loaded. The flange may also deform by “rolling” over the crown of the GMCL, imposing extra strain and stresses into the flange.
Section 12.3  After removal of a nubbin the flange surface may require repair and refinishing to create an adequate sealing surface. Dye penetrant examination or magnetic particle examination, if applicable, should be performed where the nubbin was removed. The flange bolts and the flange itself need to be reviewed to ensure they are capable of handling the force necessary to seat the gasket, which now has a greater contact area and therefore a greater required seating force than when a nubbin was present.

Section 12.4  As shown in Figure B1, a nubbin concentrates the seating force onto a small area of the gasket, creating a high sealing stress. The opposite side of the gasket is pressed against the flange, with the points of the jacket overlap creating two points of high seating stress. These points become two radial seals. The construction of DJGs allows this concentration of force. SWGs or sheet gaskets would be crushed at the high stress points; CMGs would flatten and lose their ability to form multiple seals. GMCLs would also be overloaded at the nubbin point.

![Figure B1 – DJG Used with Nubbin](image)

Section 13.1  Flange finishes outside of the range recommended for the gasket, either too rough or too smooth, may not seat or seal and are much more likely to leak. If the finish is too rough, the gasket cannot deform to conform to the flange surface. If the finish is too smooth the roughness of the gasket cannot deform and “bite” against the flange surface. Often, a slightly too smooth surface is a worse problem than one that is slightly too rough. Rougher finishes also create a longer leak path with more direction changes which, directionally, can improve the seal. Gaskets are designed to function over a defined range of flange surface finishes and thus are not optimally designed (e.g., gasket thickness, roughness and compressibility) over most of the range.

Section 13.2  Flange standards (e.g., *ASME B16.5*) define the means of making and measuring the surface finish. Spiral or concentric grooves are typical because they form a series of ridges across the radial leak path. Typically, 45 – 55 grooves per radial inch is specified by the applicable flange Standard. The finish is judged by visual comparison, and feel, using a comparator which has a number of defined finishes (see figure B2). Mechanical means are not accepted by industry standards (e.g., *ASME B16.5*, paragraph 6.4.5). One reason is that they may not differentiate well between a uniform roughness and a very smooth surface with a very rough area. Both may have the same average roughness but gasket sealing potential can be greatly different. The difference is easily detected by sight or feel.
Section 13.4 For flatness tolerance, *ASME PCC-1*, Appendix D includes references *PIP VESV1002*, *Code* Division 2 paragraph 4.4.3.13 and *API 660*, Table 3. Flanged joint alignment is also a factor. *ASME PCC-1*, Appendix E provides guidance on acceptable limits. These limits are more specific than the criteria noted in other documents (e.g., *ASME B16.5*, paragraph 6.4.6 and *ASME B16.47*, paragraph 6.1.5).

Section 14.5 Bolt elongation measurements may provide even more consistent bolt loads. *ASME PCC-1* provides some guidance on this method. Bolt tension may vary more than 20 percent if torque wrenches are used, but less than 10 percent if direct tensioning devices are properly used. Direct tensioning or bolt elongation methods are more expensive and difficult to do than torquing.

Direct tensioning methods normally require slightly longer bolts to allow the tensioning system to grip the bolt above the nut. Consult with the flange assembly contractor to determine the required length. Frequently, additional length equal to the thickness of the nut is adequate.

Section 14.6 In hot services, thermal expansion of the flange thickness and the bolts may differ. If the bolts expand slightly more, a leak is possible, especially with a hard to seal internal fluid
such as hydrogen. Retightening the bolts while hot may help reduce the potential for leakage. Such retightening is called “Hot Torquing” or “Start-up Torquing”, which is retightening after the joint components have heated and reached an equilibrium temperature but before process fluids have been introduced. If process fluids are present it’s called “Live Tightening”, and is a less desirable, more dangerous, operation. It may be a consideration to stop a leak.

There is little industry guidance on the performance of these operations; procedures and precautions are often developed by the users. Torque methods are generally not considered to be accurate methods of tightening after more than a few days at temperature; direct tensioning or turn-of-the-nut methods are commonly used. Turn-of-the-nut consists of bringing the nuts to a sung tight condition (generally the full effort of an Iron Worker or a few impacts with an impact wrench) then turning the nut 1/3 to 2/3 additional turn, depending upon the bolt length. Common guidelines are $L \leq 4D$, 1/3 turn; $4D < L < 8D$, ½ turn; $8D \leq L$, 2/3 turn. $D$ is the bolt diameter, $L$ is the bolt length.

ASME PCC-1, paragraph 10.4 provides some basic guidelines and considerations and Appendix B contains applicable definitions. A future revision of ASME PCC-2 may contain further information. In all cases a detailed hazard analysis should be performed and all necessary safety and emergency response measures should be in place.

Section 14.7 Retightening after a minimum of six hours accommodates cold flow of the ePTFE under load. Cold flow is continuing compressive deformation of the gasket under the initial load (like a shock absorber). As the gasket deforms, and the bolt does not, the bolt force, therefore the gasket stress, is reduced, increasing the potential for leakage. Follow-up bolt tightening restores the bolt force and gasket stress. Waiting a minimum of six hours for the gasket cold flow to stabilize is industry common practice. Some users have had success with a shorter wait period.

Section 14.9 Currently there is no formal, recognized, certification program for bolted joint assemblers. Such a program may be developed (e.g., by ASME) in the future. ASME PCC-1, Appendix A, describes the basics of a certification program.

Section 15.1 Non-metallic and semi-metallic gaskets do not behave elastically and do not follow the initial stress-strain curve, or any other well defined curve, upon unloading and reloading. Performance of a gasket after seating and subsequent unloading (opening of the flange) is unpredictable and inability to seat the gasket, and leakage, is likely.

Section 15.5a. SWGs and GMCLs often (but not always) have compatible dimensions and require the same surface finish. They can frequently be interchanged. CMGs and DJGs may require different flange dimensions and finish. Additional review is recommended before exchange with each other or with other gasket styles.

Section 16.2 Local refinishing has been attempted, without success. The locally refinished area is lower than the surrounded untouched portion of the sealing surface, creating a possibly worse leak than was originally present.

Section 16.6 Removal of material may result in slightly greater separation of the mating surfaces and increased flange loads as the flanges are pulled together and bolted to create the seal. In some cases this may be a significant concern.

Section 17.2 This is based upon spiral wound gasket experience in high pressure (>1000 psig (70 kg/cm²g)), hydrogen services operating at about 850 °F (455 °C) which have absorbed radial differential movement between low chrome and austenitic stainless steel flanges up to at least NPS18 without leakage. The construction of SWGs (e.g., thin
metallic windings) allows for radial deflection, thus absorption of shearing radial deformations such as caused by differential radial flange expansions, while maintaining a seal. Many other gasket styles cannot radially deform, and therefore the flange faces slide over the sealing surface if the radial movements of the flanges differ (e.g., because of different rates of thermal expansion). This imposes shear forces onto the gasket that can damage the gasket sealing surface. Experimentation by a gasket manufacturer has shown SWGs may have an ability to successfully absorb radial differential movement of at least 0.02 inches (0.5 mm). Testing was halted at this point without the occurrence of leakage. The gaskets may be able to absorb more differential radial movement, but there is little experience and no experimentation. Performance of other gasket styles (e.g., GMCL, CMG) is unknown but may not be as good because they are not as radially flexible.

Appendix A Paragraph A-1.1 Low gasket sealing (compressive) stress, whether it is local or general, leads to leaks because the gasket is not pressed tight against the flange surface profile. Gasket flow characteristics and compressibility, flange surface finish and damage, process conditions (e.g., pressure), and differential thermal expansion between the bolts and flanges are among the factors that can affect the sealing stress present at any place and time. A scrape on the flange surface or a locally low area may result in a lower gasket stress and compression at that point. The pressure drop along the leak path is reduced and a leak can result. Thermal expansion differences between the flange and bolts can reduce the bolt load and therefore the gasket stress. This can occur because of differing coefficients of thermal expansion and/or heating or cooling at startup or shutdown, even if the steady state condition is acceptable. If the bolts heat more slowly, the expanding flange can yield the bolt during startup. Even if a seal is maintained as the bolts heat and catch up, at shutdown leaks can occur because the permanent deformation of the bolt is not recovered, creating an effectively longer bolt and reduction in the gasket stress as the flange thickness contracts more than the bolt length.

Appendix A Paragraph A-1.2.d Use of the wrong gasket can result in gasket crimping (if it’s too large) or projection into the flowing stream (if it’s too small). If the gasket is for a lower flange Class, it may be inadequate for the imposed pressure and leak or even fail (i.e., blowout). Leakage through the gasket (i.e., permeability) may be a possibility in high pressure services. This is much less of a concern with the current impervious filler materials (e.g., graphite, ePTFE) than with fibrous materials. Compression of the gasket increases the gasket density, reducing permeability and the potential for leakage. Metallic windings (e.g., SWGs) or jackets (e.g., DJGs) also resist through gasket leakage.

Appendix A Paragraph A-2.b For a given gasket style, especially sheet gaskets, thin gaskets may perform better than thick gaskets. Thick gaskets are more compressible, subject to more relaxation, more permeable, possibly less resistant to blowout and more difficult to compress evenly.

Appendix A Paragraph A-2.f Small differential movement between the bolt length and the total thickness of the flanges normally results in a large change in the bolt force and therefore the gasket stress. The washers act like springs, limiting the change in bolt force and therefore gasket stress to the effect of the washer spring constant. Washers may be nested to increase the spring constant. They may also be reversed (i.e., one with the open end down, the other with the open end up) to increase the movement for a given force. These orientations can be combined with washers both reversed and nested to combine both effects.

Appendix A Paragraph A-2.g Bolt extenders reduce the strain change, and therefore the stress change, caused by a given amount of differential movement between the bolt and the thickness of
the flanges through which the bolt passes. The basic principle is as follows: Consider a bolt tightened in a flanged joint; the bolt length between the nuts and the thickness of the flanges are both L. First, consider that the bolt length changes by ΔL (e.g., due to thermal expansion of the flange thicknesses). The strain change is ΔL / L and is directly proportional to the change in bolt stress. Now, consider a system using a bolt extender where the total bolt length has been doubled. Considering the same ΔL as above occurs but this time the bolt length is twice as long. Therefore the strain change is ΔL / 2L or half of the first situation; therefore the stress change is also half. The change in stress on the gasket is also half as much and the potential for leakage is reduced.

General: In vacuum service, consider using solid core gaskets (e.g., GMCLs or CMGs) because of their greater stiffness and resistance to buckling in compression. Other gasket styles (e.g., SWGs) have an excellent performance history, too.

General: To reduce inventory requirements and the risk of error (i.e., installing the wrong gasket style or metallurgy at a given location), gasket styles and metallurgies should be minimized. Some differences are necessary because of special circumstances (e.g., to contain specific fluids) and for cost control (i.e., the highest metallurgy should not be used everywhere even though it can work).

General: Thin gaskets seat more easily form a more effective, resilient, seal than thick gaskets, primarily because of a thicker gasket’s greater gasket stress relaxation with time. Thicker gaskets may be necessary to account for alignment and flatness tolerances and flange out-of-levelness, especially on large diameter flanges. Gaskets are currently manufactured to work over a large range of finishes (e.g., 125 – 250 microinch Ra) to accommodate easy production of the finish on the flange surface. This results in a gasket thickness to seal against the roughest finish; if the actual finish is near the smooth end of the range the ability to seal can be affected. Gaskets made for a small range of finishes can be slightly more effective.