THIRD EDITION

Metallic Gasketing Technical Handbook

FLUID SEALING ASSOCIATION FSA

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This technical handbook has been prepared by members of the Fluid Sealing Association to assist designers, engineers and maintenance personnel in the selection of metallic and metallic composite gasketing materials for a wide range of applications, and also to aid in their proper installation and maintenance for efficient service. The information set forth is based upon the experience of the Fluid Sealing Association members that participated in the preparation of the handbook, as well as published literature on metallic gaskets.

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Extensive research and practical experience is required in achieving efficient and dependable seals. Satisfactory performance, however, depends on the selection of the most suitable type of gasket and material for the condition, the optimum gasket thickness, and on the type and condition of flange surfaces as well as proper installation procedures.

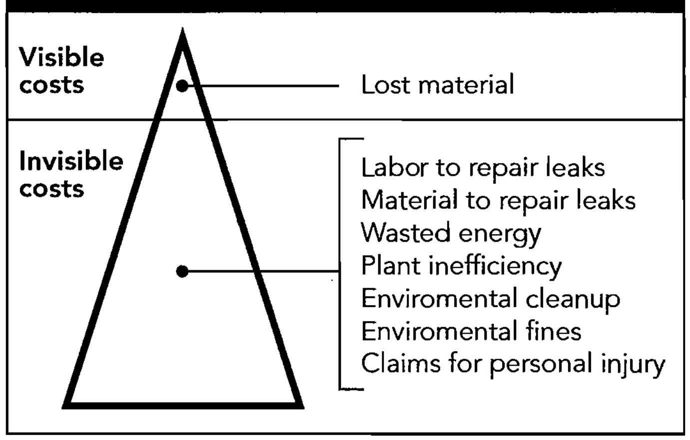
Careful selection of the gasket design and material for a given application, as well as properly engineered installations, are all important factors in determining performance. These factors should be fully evaluated when selecting and applying gasket materials for any application. We hope that the suggestions in this handbook will help users achieve long and trouble-free service for the wide variety of equipment and application for gasketed components.

It is recognized that industry must reduce the impact of fugitive emissions on the environment if we are to continue global development for future generations. A major contributory factor will be through the lowering of fugitive emissions.

A proportion of emissions occurs through unanticipated or spurious leaks in process systems. These equipment leaks are usually referred to as ***"fugitive emissions"***, and in this area the sealing industry is playing a vital role, through the development and application of innovative sealing technology with a low to zero emission goal in mind

To put the scale of the challenge in perspective, fugitive emissions from leaking valves, pumps and flanges in the USA have been estimated to be in excess of 300,000 metric tons per year, accounting for about one third of the total organic emissions from chemical plants. Irrespective of any environmental impact which it may cause, this is a tremendous financial burden on industry because it represents a huge loss of potentially valuable materials, and a cause of plant inefficiency.

FIG. 1



Yet in most instances, the true costs to industry are not appreciated, since many of the costs associated with fugitive emissions are invisible see Fig 1.

The development of legislation to control fugitive emissions has been well reported for both USA[1] and Europe[2]. Inevitably, these limits will tighten, and good gasket performance will play an increasingly important role in ensuring efficient plant operation and emission control.

A word of thanks is due to the many who have contributed in preparing this handbook, including members of the Fluid Sealing Association (FSA), the European Sealing Association (ESA) and users.

DEFINITION AND FUNCTION OF METALLIC GASKETS

A gasket is a deformable material, which when clamped between essentially stationary members, prevents the passage of matter through or across the gasketed joint.

Joint and gasket design must be considered conjunctively. A leak-tight assembly depends upon successful interaction between the surfaces to be sealed, the gasket, the bolting or clamping force, and its environment. The gasket is but one component of the joint system and its selection is based upon matching its characteristics to those of the other components.

The gasket must deform and fill surface irregularities to effect a pressure boundary. It must be capable of maintaining this boundary for the intended life of the joint. A successful gasket selection must consider the following criteria:

SELECTION CRITERIA

TEMPERATURE: Gaskets are affected in two ways by temperature. Gross physical characteristics are determined by temperature, including material state, oxidation point, and resilience. Secondly, mechanical (creep or stress relaxation) and chemical properties are highly temperature dependent. Table 1 on page 5, lists temperature limits of common metallic gasket materials.

PRESSURE: Internal pressure acts in two ways against a gasket. The hydrostatic end force, equal to the pressure multiplied by the area of pressure boundary, tends to separate the flanges. This force must be opposed by the flange clamp force. The difference between the initial flange clamp force and the hydrostatic end force is the residual flange load. The residual load must be positive (see Fig. 2) to prevent joint leakage. The magnitude of the residual flange load required to prevent leakage is dependent upon the style of metal gasket selected and its material of construction. Secondly, the pressure acts to blow-out the gasket across the gasket-flange interface. See Fig. 2.

FLUID COMPATIBILITY: The gasket must be resistant to deterioration from corrosive attack. The severity of attack and resulting corrosion is dependent upon temperature and time. Table 2 or pages 6 and 7 lists the corrosion resistance of several gasket metals.

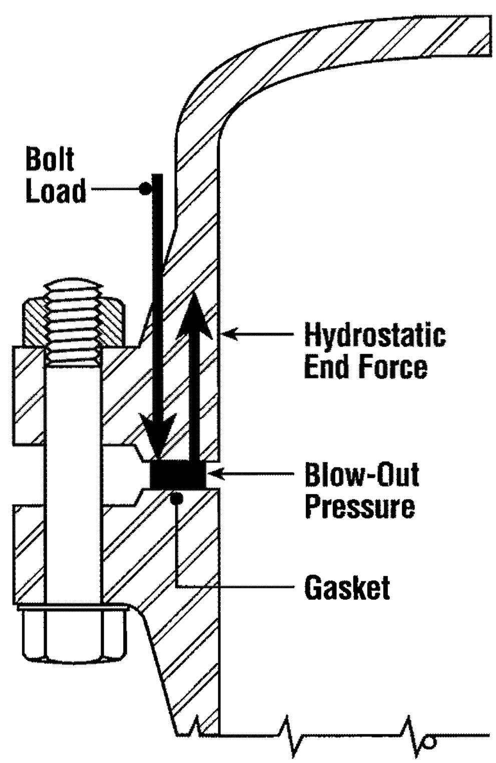
FLANGE COMPATIBILITY: The gasket is intended to be the renewable component in the joint system therefore it should be softer or more deformable than the mating surfaces. It must also be chemically compatible. For metallic gaskets, this means consideration must be given to galvanic corrosion. Galvanic effects can be minimized by selecting metals for gasket and flange which are close together in the galvanic series, or the gasket should be sacrificial (anodic) to prevent damage to the flanges.

JOINT DESIGN: There must be sufficient clamping force to seat the gasket and to prevent flange separation due to confined fluid pressure. The flange must be sufficiently rigid to prevent excessive bending which would cause localized unloading of the gasket. Flanges using full face gaskets must be thick enough to prevent bowing between adjacent bolts. Additional information may be obtained from the ASME Unfired Pressure Vessel Code, Section VIII, Div. I, the Pressure Vessel Research Council (PVRC) and DIN specifications.

SURFACE FINISH: Each gasket type works best when the flange contact faces have a specific surface finish. Surface finish requirements differ with gasket type and must be considered. Consult with the manufacturer for the proper surface finishes.

SEATING STRESS: Gasket sealing is accomplished by the flow of the gasket material into machined surfaces on the flange facings. The amount of force per unit of gasket area required to completely flow the gasket is known as the yield or seating stress. This stress varies with gasket type, material, and flange surface finish.

FIG. 2



Internal pressures are exerted against both the flange and the gasket.

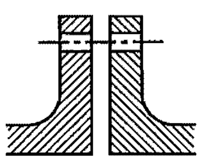
Minimum seating stresses given in Tables 2-5.1 of the ASME Boiler and Pressure Vessel Code are values that have been established empirically and result in satisfactory flange design for pressure vessels. The design calculations ensure that the resulting flange thickness, size and number of bolts will provide a joint of adequate rigidity and clamping force to contain the maximum design operating pressure of the vessel gasket. The design includes a margin of safety of approximately 4:1. It is important to note that these design criteria do not dictate the actual flange bolt loading and resulting gasket seating stress in operating conditions. New gasket constants and design methodology are expected to appear in upcoming editions of the ASME Code. The new constants will be based on testing by the Pressure Vessel Research Council. Effective sealing depends on many inter-related factors: pressure, temperature, type of fluid contained, flange surface finish, flange alignment, gasket type etc. Operating factors such as thermal cycling, vibration and thermal shock must be considered. It is recommended that the operator of the equipment consult with the gasket manufacturer for bolt load recommendations for specific gasket style and operating conditions.

FLANGE FACINGS: There are many types of flange facings in use. See Fig. 3. But, the majority of these fall into one of the following three groups:

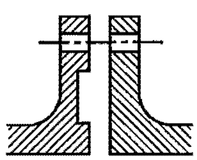
1. Unconfined: Best for all non-circular and large circular shapes.
2. Semi-Confined: For circular shapes and accurate location of gasket.
3. Fully Confined: These flange facings are used for circular shapes, with narrow gaskets at high pressures.

Other special flange facings not covered in Fig. 3 are those which use the Bridgeman closure, the lens ring, and O-ring.

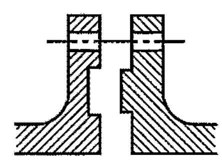
FIG 3. FLANGE FACING TYPES



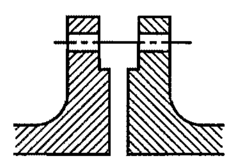
FLAT FACE
Unconfined gasket. Mating faces of both flanges are flat. Gasket may be the ring type, or the full face type, covering essentially the entire face both inside and outside the bolts.



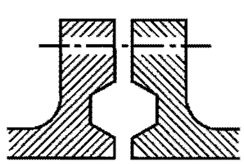
GROOVE-TO-FLAT
Fully confined gasket. One flange face is flat, the other recessed to accept gasket. For applications requiring accurate control of stack height. When flanges are brought together, gasket compression is limited. Only a few metallic gaskets can be used in this type of assembly which assumes maximum gasket resilience. Spiral wound, hollow metal O-ring, pressure-actuated, and metal-mesh filled metal-jacketed gaskets can be used.



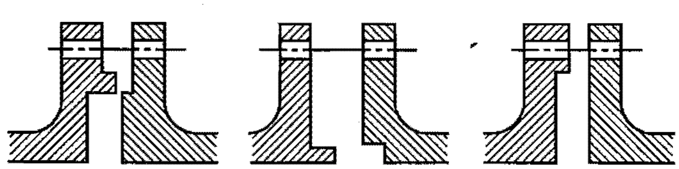
TONGUE-AND-GROOVE
Fully confined gasket. Depth of groove equal to, or less than, height of tongue. Groove normally not over 1/16" wider than tongue. Gaskets for tongue-groove joints are usually dimensioned the same as the tongue. Although this joint must be pried apart for disassembly, tongue-and-groove flanges do produce a high gasket pressure.



RAISED FACE
Unconfined gasket. Mating face is flat but portion inside bolt holes is raised 1/16" or 1/4". Gasket is usually ring type, entirely within bolts. Once assembled, they may be dissasembled easily without stripping the flange. Steel flanges that are to mate with cast iron should have flat faces to prevent breaking the cast iron flange during bolt tightening.



RING GASKET JOINT
This is sometimes referred to as the API joint. Both flange faces have matching flat bottomed grooves with sides tapered from the vertical with angles of 23°. The gasket is machined from solid metal and is either oval or octagonal in cross-section. The octagonal cross-section is preferred.



MALE-FEMALE
Semi-confined gasket. Most frequently used type is shown at left. Depth of recessed face normally equal to, or less than, height of male or raised face to prevent possibility of flanges coming together metal-to-metal when gasket is compressed. Recessed OD normally not more the 1/16" larger than OD of male joint. Joint must be pried apart for disassembly. Shown in center and at right are two other male-female types. In center type, gasket is confined on ID. Type at right is metal-to-metal joint with gasket confined on OD only.

COMMON METALS

Carbon Steel: The most commonly used material for manufacturing double jacketed gaskets. It has poor resistance to corrosion and should not be used in water or diluted acids. The maximum recommended operating temperature is 1,000F (540C)*.

Type 304 Stainless Steel: This material is widely used in the manufacture of industrial gasketing due to its low cost and excellent resistance to corrosion. The maximum recommended operating temperature is 1,400F (760C)*.

Type 316 Stainless Steel: This material offers a higher resistance to corrosion than Type 304 SS. The maximum recommended operating temperature is 1,400F (760C)*.

Type 321 Stainless Steel: This alloy is similar to 304 with titanium added. Its widely used in high temperature corrosive applications. The maximum recommended operating temperature is 1,400F (760C)*.

Type 347 Stainless Steel: This alloy is similar to 304 with columbium and titanium added. It has good performance in high temperature corrosive applications. The maximum recommended operating temperature is 1,600F (870C)*.

Type 410 Stainless Steel: A heat treatable 12% chromium steel which combines good general corrosion resistance with high strength. The maximum recommended operating temperature is 1,200F (650C)*.

Hastelloy "B": A corrosion resistance alloy that resists corrosion of hydrochloric acid under most conditions as well as phosphoric acid, other halogen acids and reducing conditions. The maximum recommended operating temperature is 2,000F (1,090C)*.

Hastelloy "C": Offers exceptional resistance to severe oxidizing conditions encountered with nitric acid, free chlorine and strong aqueous and acid solutions. The maximum recommended operating temperature is 2,000F (1,090C)*.

Inconel: Withstands high temperatures and has excellent resistance to corrosion by halogen gases and compounds. The maximum recommended operating temperature is 2,000F (1,090C)*.

Monel: Excellent resistance to most acid and alkalis except extremely oxidant acids. The maximum recommended operating temperature is 1,500F (820C)*.

Nickel: Excellent resistance to caustic. Has a high degree of corrosion resistance to neutral and distilled water. The maximum recommended operating temperature is 1,400F (760C)*.

Titanium: Has good resistance to wet chlorine and chlorine dioxide. The maximum recommended operating temperature is 2,000F (1,090C)*.

Brass: Copper alloys are generally used with non-oxidizing acids, alkaline and neutral salt solutions. The maximum recommended operating temperature is 500F (260C)*.

Copper: Used successfully in acetic acids, nitrates and many organic chemicals. The maximum recommended operating temperature is 600F (316C)*.

Lead: Good resistance to sulphuric, chromic and phosphoric acids. Is soft and malleable. The maximum recommended operating temperature is 212F (100C)*.

Aluminum: Has excellent corrosion resistance to organic acids except nitric acid. The maximum recommended operating temperature is 800F (472C)*.

FILLER AND FACING MATERIALS

Flexible Graphite: Has excellent chemical resistance. The maximum operating temperature is generally 700°F to 850° F. for facing material, and 950°F in spiral wound gaskets. These limits are dependent on the application and the grade of flexible graphite used.

In some cases, the maximum service temperature may exceed these limits. Avoid use with oxidizing processes. Contact the manufacturer for specific applications.

Mica Graphite: A chlorite, graphite and cellulose based paper with a rubber latex binder, has been used as an asbestos substitute in services up to 450F (232C)*. When subjected to temperatures over this it starts to lose volume which could have an adverse effect on performance.

PTFE, Filled PTFE and Expanded PTFE: These materials are used for high chemical resistance. They have low permeability and are used in vacuum and oxygen services. The temperature limits are cryogenics to 500F (260C)*.

Ceramic: Ceramic materials are used in some corrosive environments. The maximum recommended operating temperature is 2000F (1090C)*.

* Maximum temperature shown does not account for all operating conditions. Please consult metal gasket manufacturers' engineering department.

TABLE 2 – CORROSION RESISTANCE OF GASKET METALS*

	LEAD	COPPER	ALUMINUM	MONEL	NICKEL	IRON AND STEEL	STAINLESS 304	STAINLESS 316	STAINLESS 347
Acetic acid, crude	U	F	F	F	F	U	–	F	–
pure	F	F	S	S	F	U	F	F	–
vapors	U	F	–	F	F	U	–	F	–
150 psi, 400 F	U	F	–	F	F	U	–	F	–
Acetic anhydride	U	U	S	S	–	–	F	F	F
Acetone	S	S	S	S	S	S	S	S	S
Acetylene	S	–	S	S	–	S	S	S	–
Air	S	S	S	S	–	S	S	–	S
Aluminum chloride	U	F	U	S	–	F	U	U	F
Aluminum floride	–	–	U	–	–	–	–	–	–
Aluminum sulphate	S	F	–	F	–	U	F	F	F
Alums	S	F	–	F	–	U	F	F	F
Ammonia gas, cold	S	–	S	S	–	S	S	S	–
Hot	U	U	–	–	–	–	–	–	–
Ammonium choride	S	U	U	F	F	–	F	F	–
Ammonium hydroxide	S	U	F	–	–	S	S	S	S
Ammonium nitrate	U	U	F	–	–	S	S	S	S
Ammonium phosphate,									
monobasic	S	F	U	–	–	U	S	S	–
dibasic	S	F	F	D	–	F	S	S	–
tribasic	S	F	F	S	S	S	S	S	–
Ammonium sulphate	S	F	–	S	–	S	S	S	S
Amyl acetate	–	F	F	S	–	–	S	S	S
Amyl alcohol	–	S	–	S	–	–	–	–	–
Aniline, aniline oil	–	U	U	S	–	S	S	S	S
Aniline dyes	–	–	–	S	–	–	S	–	–
Asphalt	–	S	–	S	–	S	S	–	–
Barium chloride	–	–	U	–	S	–	F	S	–
Barium hydroxide	U	U	U	–	S	–	S	—	–
Barium sulphide	S	U	–	S	–	–	S	S	S
Beer	–	S	S	S	–	S	S	S	–
Beet sugars, liquors	–	S	S	S	–	S	S	S	–
Benzene, benzol	S	S	S	S	–	S	S	S	–
Benzine, petroleum									
ether, naphtha	S	S	S	S	–	S	S	S	–
Black sulphate liquor	–	F	–	S	–	S	S	–	–
Blast furnace gas–	U	U	–	–	–	S	–	–	S
Borax	–	F	F	S	S	S	S	S	S
Boric acid	S	F	S	S	S	U	S	S	S
Bromine	U	U	–	–	–	U	U	U	U
Butane	–	–	S	S	–	S	–	S	–
Butyl acetate	–	S	S	–	–	–	S	S	S
Butyl alcohol, butanol	–	S	–	S	–	S	–	–	–
Calcium bisulphite	S	U	–	U	–	U	–	S	S
Calcium choride	U	S	–	F	–	S	–	–	–
Calcium hydroxide	–	–	–	S	S	S	F	F	–
Calcium hypochlorite	U	–	U	–	–	–	–	–	–
Caliche liquors	–	–	–	S	–	S	S	–	–
Cane sugar liquors	S	S	S	S	–	S	S	S	–
Carbolic acid, phenol	S	U	S	S	–	–	S	S	–
Carbon dioxide, dry	S	S	S	S	–	S	S	S	–
wet	U	F	F	S	–	F	S	S	–
Carbon bisulphide	–	U	S	S	–	S	S	S	–
Carbon monoxide, hot	–	U	–	–	–	S	S	S	S
Carbon tetrachloride	F	–	–	S	–	–	–	–	–
Castor oil	–	–	S	S	–	S	S	–	–
China wood oil, tung oil	–	–	S	S	–	S	S	–	–
Chorine, dry	S	S	S	S	–	S	S	S	–
wet	F	U	U	U	–	U	U	–	–
Chorinated solvents,									
dry	S	S	S	S	–	S	S	–	–
wet	F	U	U	S	–	U	–	–	–

	LEAD	COPPER	ALUMINUM	MONEL	NICKEL	IRON AND STEEL	STAINLESS 304	STAINLESS 316	STAINLESS 347
Chloroacetic acid	U	U	U	–	F	U	U	U	U
Chlorosulphonic acid	F	–	–	F	–	–	F	–	–
Chromic acid	S	U	U	F	–	–	–	S	–
Citric acid	S	S	S	S	–	U	S	S	–
Coke-oven gas	–	S	–	S	–	S	–	S	–
Copper chloride	S	–	U	F	–	F	U	U	–
Copper sulphate	S	–	U	S	–	U	S	S	–
Corn oil	S	–	S	S	–	S	S	S	–
Cotton seed oil	S	–	S	S	–	S	S	S	–
Creosote, coal tar	–	S	S	S	–	S	S	S	–
wood	–	S	S	S	–	S	S	S	–
Cresols, cresylic acid	–	S	S	F	–	F	–	S	–
Dowtherm									
A	–	U	S	–	–	S	–	–	–
E	–	S	U	–	–	S	–	–	–
Ethers	S	S	S	S	–	S	–	–	–
Ethyl acetate	–	S	F	S	–	S	S	S	–
Ethyl cellulose	–	–	–	S	S	–	–	–	–
Ethyl chloride	–	S	–	S	S	S	S	S	–
Ethylene glycol	S	S	S	S	–	S	S	S	S
Ferric chloride	U	U	U	U	U	U	U	U	U
Ferric sulphate	S	U	U	U	U	U	F	S	–
Formaldehyde	U	F	F	S	–	F	S	S	–
Formic acid	U	F	U	–	–	U	F	F	–
Freon	S	S	S	S	–	–	–	–	–
Fuel oil	S	S	–	S	–	S	S	–	–
Fuel oil, acid	S	–	–	S	–	–	–	–	–
Furfural	–	S	S	S	–	S	S	S	–
Gasoline, sour	S	–	–	S	–	–	–	S	–
Refined	S	S	S	S	–	S	S	S	–
Gelatin	–	–	S	S	–	–	S	S	–
Glucose	–	S	S	S	–	S	S	S	–
Glue	–	–	S	S	–	S	S	S	–
Glycerine, glycerol	S	F	S	S	–	S	S	S	–
Green sulphate liquor	–	–	–	S	–	S	–	–	–
Hydrobromic acid	–	–	U	–	–	U	–	–	–
Hydrochloric acid,									
less than 150° F	F	U	U	–	–	U	U	U	–
more than 150° F	U	U	U	–	–	U	U	U	–
Hydrocyanic acid	–	–	–	S	–	–	S	S	–
Hydrofluric acid,									
cold, less than 65%	F	–	U	F	U	U	U	U	U
more than 65%	–	F	U	S	–	F	U	U	U
hot, less than 65%	U	U	U	–	U	U	U	U	U
more than 65%	U	F	U	S	–	–	U	U	U
Hydrofluosilicic acid	S	–	–	–	–	U	U	U	U
Hydrogen gas, cold	S	S	S	S	–	S	S	S	–
hot	U	U	–	S	–	S	S	S	S
Hydrogen peroxide	F	U	S	F	F	U	S	S	–
Hydrogen sulphide,									
dry, cold	–	U	S	S	S	S	S	S	S
dry, hot	–	U	S	U	U	U	–	–	S
wet, cold	–	U	S	S	S	–	S	S	S
wet, hot	–	U	S	U	U	U	–	–	S
Kerosene	S	S	–	S	–	S	S	S	–
Lacquers	–	–	S	S	–	–	S	S	–
Lacquer solvents	–	–	S	S	–	–	S	S	–
Lactic acid, cold	–	–	–	S	S	U	–	F	F
hot	–	–	U	–	–	U	–	–	–
Linseed oil	S	S	S	S	–	S	S	S	–
Lubricating oils,									
sour	S	–	–	S	–	–	–	–	S
refined	S	S	S	S	–	S	S	–	S

* Materials known to be satisfactory have been given an S rating. Those whose resistance is only fair, but not so low as to be dangerous, have been given an F rating. A U denotes that a material is totally unsatisfactory. A dash indicates that the data are not available, or that use of a material is dependent on specific service conditions and should not be selected unless carefully investigated.

TABLE 2 – CORROSION RESISTANCE OF GASKET METALS*

	LEAD	COPPER	ALUMINUM	MONEL	NICKEL	IRON AND STEEL	STAINLESS 304	STAINLESS 316	STAINLESS 347
Magnesium chloride	U	F	U	F	F	F	F	F	–
Magnesium sulphate	–	S	–	S	–	S	S	S	–
Mercuric chloride	–	U	U	U	U	–	U	U	U
Mercury	–	U	U	S	–	S	S	S	–
Methyl alcohol, methanol	S	S	S	S	–	S	S	S	–
Methyl chloride	S	S	–	S	–	S	–	–	–
Milk	–	–	S	S	S	S	–	S	–
Mineral oils	S	S	S	S	–	S	S	S	–
Natural gas	S	–	S	S	–	S	S	S	–
Nickel chloride	–	U	U	–	–	–	F	F	–
Nickel sulphate	–	U	U	–	–	–	S	S	–
Nitric acid, crude	U	U	–	U	U	U	–	–	–
diluted	U	U	S	U	U	U	F	F	–
concentrated	U	U	S	U	U	U	F	F	–
Nitrobezene	–	F	–	–	–	S	–	S	–
Oleic acid	U	U	S	S	S	–	S	S	–
Oleum spirits	–	S	–	S	–	S	–	–	–
Oxalic acid	U	–	S	S	–	–	–	–	–
Oxygen, cold	S	S	S	S	–	S	S	S	–
less than 500° F	U	S	S	S	–	S	S	S	–
500° F to 1000° F	U	U	–	S	–	S	S	S	S
more than 1000° F	U	U	U	U	S	U	U	U	S
Ozone	–	–	–	–	–	–	–	–	–
Palmitic acid	S	S	S	S	–	S	S	S	–
Petroleum oils, crude,									
less than 500° F	–	–	S	–	–	S	S	S	–
more than 500° F	U	U	S	U	U	S	S	S	–
more than 1000° F	U	U	U	U	U	U	–	–	S
Phosphoric acid,									
crude	–	U	U	U	U	–	–	–	–
pure, less than 45%	S	F	–	F	–	U	S	S	–
more than 45%									
cold	S	F	U	F	–	U	S	S	–
hot	U	–	U	–	–	U	U	–	–
Picric acid, molten	U	U	F	U	U	S	S	S	–
water solution	U	U	U	–	U	–	S	S	–
Potassium chloride	S	S	–	S	S	S	S	S	–
Potassium cyanide	U	U	U	S	–	S	S	S	–
Potassium hydroxide	U	U	U	S	S	–	F	F	–
Potassium sulphate	S	S	S	S	S	S	F	F	–
Producer gas	S	–	S	S	–	S	–	–	–
Propane	S	–	–	S	–	S	S	S	–
Sewage	S	–	F	S	–	F	F	F	–
Soap solutions	S	–	–	S	–	S	S	–	–
Soda ash, sodium carbonate	S	–	U	S	–	S	S	S	–
Sodium bicarbonate, baking soda	S	–	U	S	S	–	S	S	–
Sodium bisulphate	S	F	–	S	S	U	–	–	–
Sodium chloride	S	F	U	S	S	S	F	S	–
Sodium cyanide	U	U	U	F	–	S	–	S	–
Sodium hydroxide	F	U	U	S	S	S	F	F	–
Sodium hypochlorite	U	–	U	–	–	U	U	U	–
Sodium metaphosphate	S	–	S	S	S	–	S	–	–
Sodium nitrate	S	F	S	S	S	S	F	S	–
Sodium perborate	–	–	S	S	S	–	S	S	–
Sodium peroxide	–	–	S	S	S	–	S	S	–
Sodium phosphate,									
monobasic	–	–	S	S	S	–	–	S	–
dibasic	–	S	S	S	S	–	–	S	–
tribasic	S	U	U	S	S	S	–	S	–
Sodium silicate	U	–	U	S	S	S	–	S	–

	LEAD	COPPER	ALUMINUM	MONEL	NICKEL	IRON AND STEEL	STAINLESS 304	STAINLESS 316	STAINLESS 347
Sodium sulphate	S	S	–	S	S	S	S	S	S
Sodium sulphide	S	U	U	F	F	S	S	S	S
Sodium thiosulphate, "hypo"	S	U	U	–	–	–	S	S	–
Soybean oil	–	–	–	–	–	–	S	S	–
Stannic chloride	–	U	U	U	U	–	–	–	–
Steam,									
less than 500° F	–	S	S	S	S	S	S	S	S
500° F to 1000° F	U	–	–	–	–	S	S	S	S
more than 1000° F	–	U	U	U	U	U	S	S	S
Stearic acid	S	–	–	S	S	–	S	S	–
Sulphur	–	U	S	U	U	S	F	F	–
Sulphur chloride	S	U	–	–	–	–	–	–	–
Sulphur dioxide, dry	S	S	S	S	S	S	S	S	–
Sulphur trioxide, dry	S	S	S	S	–	S	S	–	–
Sulphuric acid,									
less than 10%									
cold	S	–	–	–	–	U	F	F	–
hot	S	U	–	–	U	U	U	F	–
10% to 75%									
cold	S	U	–	–	–	U	U	F	–
hot	S	U	U	–	U	U	U	U	–
75% TO 95%									
cold	S	U	–	–	–	–	S	S	–
hot	S	U	U	–	U	F	U	U	–
fuming	S	U	–	U	U	–	–	F	–
Sulphurous acid	S	–	–	U	U	S	U	–	–
Tannic acid	U	S	U	S	S	–	F	F	–
Tar	–	–	S	–	–	S	S	–	–
Tartaric acid	S	–	S	–	–	U	–	S	–
Toluene	S	–	S	S	–	S	–	–	–
Trichloroethylene	F	–	–	S	–	–	–	–	–
Turpentine	S	–	S	S	–	–	S	S	–
Vinegar	–	–	–	S	–	–	F	S	–
Water, acid mine,									
with oxidizing slats	–	–	–	U	U	U	S	S	–
no oxidizing salts	–	–	S	S	–	–	–	U	–
Water,									
fresh, tap	S	S	S	S	–	–	S	S	–
distilled, lab grade	U	U	S	–	S	U	S	S	–
return condensate	S	S	S	S	–	S	S	S	–
Water, seawater	S	–	U	S	–	–	F	F	–
Whiskey and wines	–	S	–	S	–	U	F	S	–
Zinc chloride	S	U	U	S	–	–	U	U	–
Zinc sulphate	–	U	–	S	–	–	S	S	–

* Materials known to be satisfactory have been given an S rating. Those whose resistance is only fair, but not so low as to be dangerous, have been given an F rating. A U denotes that a material is totally unsatisfactory. A dash indicates that the data are not available, or that use of a material is dependent on specific service conditions and should not be selected unless carefully investigated.

TYPES OF METALLIC GASKETS

Metallic gaskets can be grouped into two distinct categories; semi-metallic and metallic.

SEMI-METALLIC:

Semi-metallic gaskets are made by combining soft materials as fillers, facings or insertions together with a metallic component. Many synthetic composites and/or mineral based materials are used as well as elastomer compounds. These may be inserted in a specifically designed metallic profile, applied to a metallic face or carrier partially or completely encapsulated by metal. They are categorized as follows:

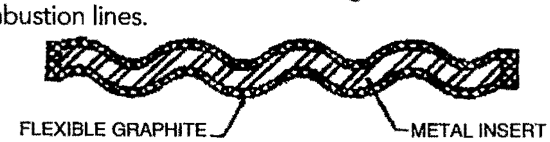
- Corrugated
- Laminated
- Metal Jacketed
- Spiral wound

1. **Corrugated Gaskets:** Consists of thin metal, corrugated or with embossed concentric rings. They are used plain; coated at the time of installation with gasket compound; or with glass fiber, flexible graphite or expanded PTFE cord cemented in the corrugations. See Fig. 4. This type of gasket requires the least costly tooling for non-standard sizes or irregular shapes. They can be used at temperatures within the limits of the materials selected.

   Corrugated gaskets are essentially a line contact seal. Multiple concentric corrugations provide a labyrinth effect, along with mechanical support for the gasket compound or cord inserts if they are used. Corrugations provide some degree of resilience, depending on their pitch and depth, and the type and thickness of metal used.

FIG 4. CORRUGATED GASKETS

Plain metal with corrugations. For low pressure (500 psi) applications such as valve bonnets, gas turbines fuel and combustion lines.

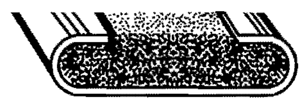


CORRUGATED with facing material on the corrugations. The seal is formed between the peaks of the corrugations and the flange mating surfaces. The metal provides excellent recovery and the peaks reduce the surface area providing for low initial seating stress.

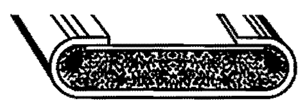
Corrugated metal gasket with glass filler cord cemented in corrugations. Generally best suited for low pressure (600 psi) applications with relatively large, uneven surfaces.

FIG 5. METAL JACKETED, SOFT FILLER GASKETS

One Piece French Type: Used for narrow circular applications requiring positive, unbroken metal gasket face across full width. Requires flange surface finish of 80 rms or better in sizes less than 1/4" wide. Over 1/4" wide requires concentric serrated flange face. Minimum gasket width is gasket thickness x 1.5.

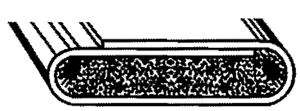


Single Jacket: Used for relatively narrow applications similar to French type but width-diameter limitations do not apply. Generally less costly than French type. Non-circular as well as circular shapes can be furnished. If over 1/4" wide, use double-jacketed type. Requires flange surface finish of 80 rms or better.

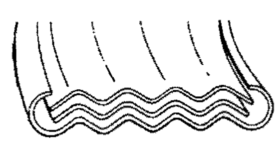


Double Jacket: Used when complete protection of the filler material is required. Also provides additional support of flange at outer edge by addition of lapped over jacket. Available in irregular non-circular shapes. For widths less than 5/32", use French or single jacket types. Requires flange surface finish of 80 rms or better.

Corrugated Jacket: Jacket is corrugated to increase its resilience. Used for circular and moderately non-circular shapes in widths 1/2" and wider. Sealability can be greater improved by use of gasket compound. When corrugated metal filler is used, temperature is limited only by the metal selected.



Modified Double Jacket: Used when completely enclosed gasket is required in widths less than those available in plain double jacket. Also available with filler made from metal wire mesh which imparts more resilience than non-metallic filler.



Corrugated Jacketed Corrugated Metal Filler: Is typically used for high temperature applications. The only limitations are those of the metal kind.

MATERIALS: These gaskets are made of almost all metals in thicknesses from 0.010" to 0.031".

Thicknesses less than 0.010" are likely to rupture when corrugated. Gaskets with a cord insert are normally made from nominal 0.018" to 0.020" thick material.

CORRUGATIONS: Although a minimum of three concentric corrugations is desirable on each gasket face, many applications use only one. For full face gaskets in thin, lightly bolted flanges, one to three corrugations inside of bolt circle and one or more outside of the bolt circle will equalize compressive stresses, and may be helpful in preventing flange distortion.

2. **Metal-Jacketed, Soft Filler Gaskets:** Consists of soft compressible filler partially or wholly encased in a metal jacket. See Fig. 5. These gaskets are more compressible than plain corrugated types without facing material.

   The primary seal against leakage is the inner metal lap, where the density of the gasket is greatest when compressed. This area cold flows, effecting the seal. The entire inner lap must be under compression. The outer lap, if any, provides a secondary seal between flange faces when compressed. Intermediate corrugations may contribute to the labyrinth effect.

   These gaskets are used for non-circular as well as circular applications and for applications at temperatures up to those which limit the filler and metal endurance. These gaskets are normally specified in 3/32" or 1/8" nominal thicknesses. The thickness of jacketed gaskets is not precise due to accumulated tolerances of the metal and filler and the metal springback when it is formed. Because of limited resilience they should not be used in joints requiring close maintenance of the compressed thickness.

MATERIALS: Typical filler materials are Flexible graphite, non-asbestos millboard, PTFE, and in some cases, corrugated metal.

LAP WIDTH: Jacketed gaskets have certain limitations as far as lap width is concerned. The maximum lap width is that which can be drawn and folded over without cracking or wrinkling. This is a function of the metal, its thickness, the gasket thickness, and the diameter. The maximum lap width must be taken into consideration when relatively small diameters or radii are to be formed.

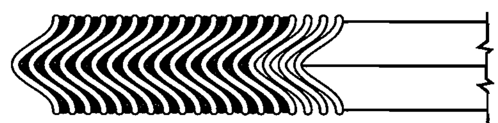
3. **Spiral Wound:** These gaskets are comprised of preformed "V" shaped metal strips alternately wound with a conformable filler material. The metal windings provide strength and resilience, while the non-metallic portion conforms to the irregularities of the flanges aiding in the seal of the joint. These gaskets can be constructed in a variety of densities accommodating available bolting and pressure conditions. Sealing is achieved through a combination of yielding and flowing of the "V" shaped metal and conformable fillers during the compression phase.

   Spiral wound gaskets are suited for assemblies subject to temperature and pressure cycling, joint relaxation, thermal shock and vibration. Due to its inherent resilient characteristics the spiral wound gasket can tolerate effects of minor flange separations.

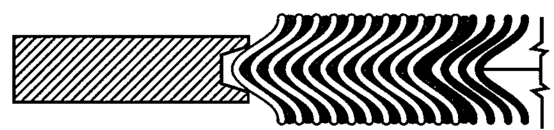
SHAPES: Spiral wound gaskets can be furnished in moderately non-circular shapes depending upon the size, and desired configuration. Consult the manufacturer for non-circular gaskets.

DENSITY: By varying filler thickness and winding tension, spiral wound gaskets with suitable compression characteristics can be designed to meet many various design conditions. A low density gasket would be used on lightly bolted flanges for low pressure service. A high density gasket is used in high pressure service where adequate bolting is available. See Fig 7.

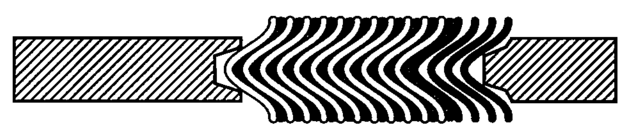
FIG 6. SPIRAL WOUND GASKETS



No centering or compression ring provided. Generally used with tongue and groove, groove to flat and male and female flanges. When used with standard tongue and groove flanges consideration must be made to provide a positive stop to prevent possible overcompression of the gasket.



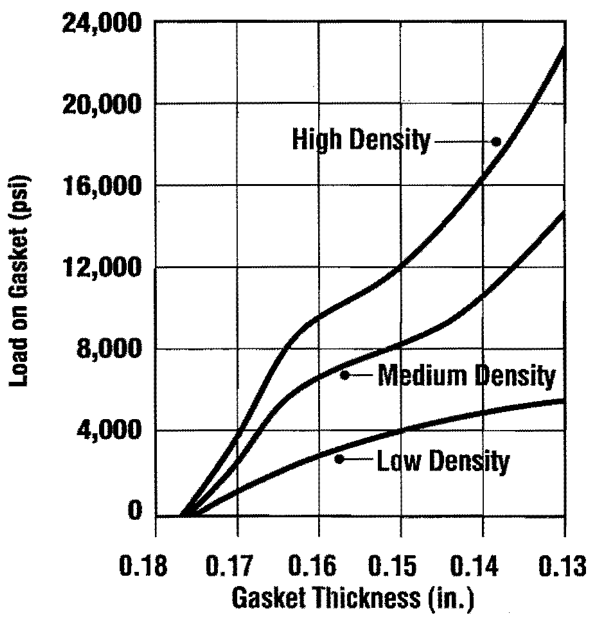
This type is typically used with raised face and flat face flanges. The outer guide ring is dimensioned to center the gasket within the bolts and assures that the sealing portion is within the raised face portion of the flange. The guide ring also serves as a compression stop, preventing overcompression of the gasket.



This gasket is fitted with both an outer and inner ring. Inner rings ensure that the windings are contained between the flange faces and are recommended for the following applications:

- High temperature
- High available bolt loads
- Vacuum service
- When experiencing inward buckling of the windings.
- To fill the space between the bore and the inside diameter of the gasket to minimize the affects of corrosion, erosion, turbulence or material build up.

FIG 7. TYPICAL COMPRESSION CURVES FOR 0.175" THICK SPIRAL WOUND GASKET



Two gasket thicknesses, 0.125-±0.005" and 0.175"± 0.005" are most common and are suitable for most applications. For 0.125" thick gaskets, compression to a thickness of 0.095-±0.005" is recommended. For the 0.175" thick gasket, a compression to 0.130-±0.005" is preferable.

Refer to ASME B16.20 for standard gasket dimensions used on standard pipe flange connections.

MATERIALS: Spiral wound gaskets may be manufactured from a wide range of metals. Metal selection is dependent on compatibility with the process or media to be contained. Operating temperature and the ability to resist corrosion are key factors in the selection process. The standard metal winding is 304 stainless steel. Outer guide rings are carbon steel unless otherwise specified. When inner rings are required the metal selection is typically the same as that of the metal windings. Refer to Tables 1 and 2 for material selection.

Table 3 lists metal winding materials and their recommended maximum temperature as well as the standard color coding for these materials.

FILLER MATERIALS: Spiral wound gaskets are manufactured using a variety of filler materials. Selection of fillers is dependent on chemical and temperature compatibility.

Flexible graphite to date is the most versatile material used. This material provides excellent sealing characteristics, exhibits outstanding thermal stability and resistance to many chemicals.

Polytetrafluoroethylene, PTFE, is known to be impervious to most chemicals.

TABLE 3. TEMPERATURE RANGE AND STANDARD COLOR CODES

METALLIC WINDINGS	MAXIMUM TEMPERATURE	COLOR CODE*
304SS	1400F	YELLOW
316-LSS	1400F	GREEN
347SS	1600F	BLUE
321SS	1400F	TURQUOISE
MONEL	1500F	ORANGE
NICKEL	1400F	RED
TITANIUM	2000F	PURPLE
ALLOY 20	1500F	BLACK
INCONEL	2000F	GOLD
CARBON STEEL	1000F	SILVER
HASTELLOY B	2000F	BROWN
HASTELLOY C276	2000F	BEIGE
INCOLOY	2000F	WHITE
PHOSPHOR BRONZE	500F	COPPER
NON-METALLIC FILLERS	**MAXIMUM TEMPERATURE**	**COLOR CODE***
MICA-GRAPHITE	450F	PINK STRIPE
PTFE	500F	WHITE STRIPE
CERAMIC	2000F	LIGHT GREEN STRIPE
FLEXIBLE GRAPHITE	950°F**	GRAY STRIPE

** for use in spiral wound gaskets
** In some cases, this limit can be exceeded.
Avoid use with oxidizing processes.
Contact manufacturer for specific applications.
* ASME B16.20 standard for metal and filler material as adopted by Metallic Division of Fluid Sealing Association.

Mica-graphite paper filler may be selected for non-critical, general purpose applications.

Ceramic filler is typically selected for applications above the temperature threshold of flexible graphite. Ceramic exhibits some resistance to some oxidizing compounds at elevated temperatures.

WIDTH: The recommended width for spiral wound gaskets is shown in Fig. 8. Gaskets can be fabricated below these recommended widths, and frequently are, for valve bonnet applications. However, this requires careful control of joint tolerances and surface finish. Spiral wound gaskets must not be allowed to protrude into the flange bore or extend beyond a raised face, otherwise mechanical damage will occur to the gasket during compression.

FLANGE SURFACE FINISH: Compliance with B16.5 is preferred for spiral wound gaskets.

4. **Flat Metal Gaskets:** These are defined as gaskets that are relatively thin compared to their width. See Fig. 9. They can be used as cut from sheet metal, or with the surface area reduced by machining to improve sealability.

   Plain metal, washer-shaped gaskets are relatively inexpensive to produce and can perform satisfactorily in a variety of applications over a wide temperature range. The machined types known as profile or serrated gaskets, with reduced surface area, may be the answer to high pressure, high temperature, or highly corrosive applications in flanges where bolting forces are too light for the plain flat type.

   All of these designs seal by flow of the gasket surface from compressive loads. Load must exceed the yield strength of the gasket metal on the gasket contact area. Therefore, surface finish of both flange and gasket is very important.

GASKET FINISHES: Plain metal gaskets are normally furnished as cut from the metal in the "as received" condition. Therefore, the gasket will have the surface finish from mill rolling plus any storage or in-transit damage. Furthermore, depending on the method of cutting, the gasket edges may have burrs or other irregularities which may or may not affect performance. If higher quality levels are required, such as no burrs, scratch-free surface, close decimal tolerance, etc., cost is increased.

FLANGE FINISHES: For best performance, plain flat metal gaskets should be used between flange faces with concentric serrated surfaces. If this is not practical, a very light-cut spiral tool finish of 80 rms may be used.

5. **Round Cross-Section Solid Metal Gaskets:** These gaskets are generally made from round wire of the desired diameter cut to the length of the gasket mean circumference, then formed into a circle and welded. See Fig. 10. They provide positive, gas-tight seals at relatively low flange pressures. Since only line contact occurs, they have high local seating stress at low bolt loads. The contact faces increase in width as the gasket is compressed, effectively flowing into flange faces.

   Round solid gaskets are essentially used on equipment designed specifically for them. Flanges are usually grooved or otherwise faced to accurately locate the gasket during assembly. However, there are some applications in which they are used between flat faces.

FIG 8. RECOMMENDED GASKET WIDTH

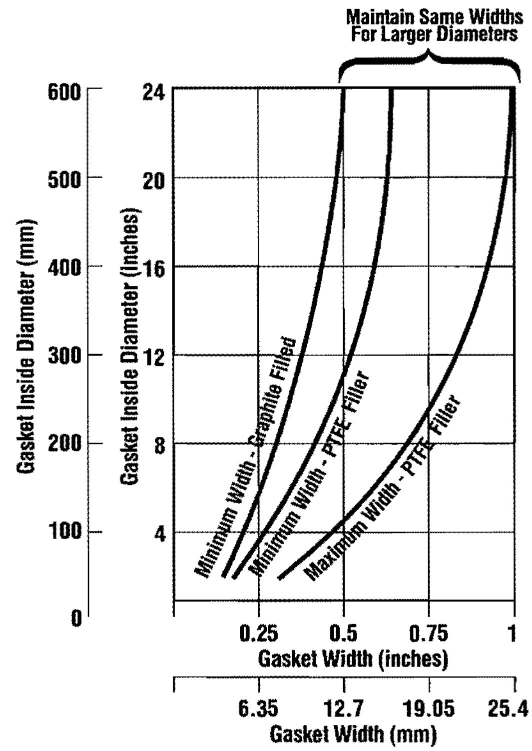
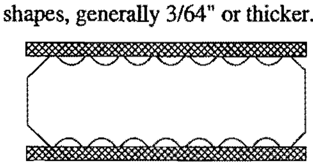


FIG 9. FLAT METAL GASKETS

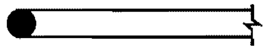
Plain, solid flat gasket. Probably more widely used than any other type where compressibility is not required to compensate for flange surface finish, warpage or misalignment, and sufficient clamping force is available for the metal selected. Can be fabricated in any desired configuration. Unless the gasket is machined, width should be at least metal thickness plus 50%. There are no limitations on flat gasket dimensions. However, width of metal sheet commercially available may limit size and require welding to obtain gaskets beyond certain sizes. The hardness of welded areas frequently can be different than that of the parent material even after annealing and should be specified separately in critical applications.

Serrated or grooved, flat metal gasket. Used when a solid metal gasket is required because of pressure (radial strength), temperature, or highly corrosive attack from the confined fluid and bolting force is not sufficient to seal a flat gasket. Another application is for screwed closures where the relatively small contact area of the thin serration peaks keep friction down to a level low enough to seal the joint. Available in some simple non-circular shapes, generally 3/64" or thicker.



Serrated or grooved gaskets with soft sealing element on both sides. Applications include high temperatures, pressures and fluctuating conditions. Typical sealing layers can be supplied in Flexible Graphite, or Expanded PTFE.

FIG 10. ROUND CROSS-SECTION SOLID METAL GASKETS



Round cross-section wire ring. Used on valve bonnets, air or gas compressors, vacuum pumps, and accessory connections. Flanges are usually grooved to locate gasket during assembly.

Taper-faced flanges are satisfactory as long as the volume of enclosed space is less than the gasket volume. Surface finish should be 150 to 200 rms.

6. **Solid Metal Heavy Cross-Section Gaskets:** These gaskets are machined from solid metal and are designed for high pressure, high temperature service where operating conditions require a special joint design. The most commonly used gaskets for joints of this type are oval, octagonal, RX and BX. These more common rings are covered by API-6A and ASME B16.20 specifications. See Fig. 11.

   Solid metal heavy cross-section gaskets generally seal by initial line contact or wedging action, causing high unit stresses and forcing the metal surface to flow at this line contact. This high unit load line contact provides a high reliability seal, however, the gasket and flange surfaces must be carefully controlled both with regard to surface finish and dimensional accuracy to obtain a seal.

   Table 4 lists the most commonly used metals. It is recommended that the gaskets be softer than the flanges although this may not be possible with certain alloys, i.e., stainless steel alloy flanges heat-treated for optimum corrosion resistance will have the same range of hardness as the ring gasket of the same material annealed to minimum hardness.

OVAL: The oval cross-section is the original ring joint design.

OCTAGONAL: The octagonal cross-section is an evolution of the oval design.

Both oval and octagonal rings can be used with flanges having the standard ring joint flat bottom groove. The former round bottom groove is no longer shown in the flange specifications and can only be used with an oval gasket. Standard sizes of these gaskets are manufactured to ASME B16.20 and API 6A specifications.

FIG 11. TYPES OF SOLID METAL HEAVY CROSS-SECTION GASKETS

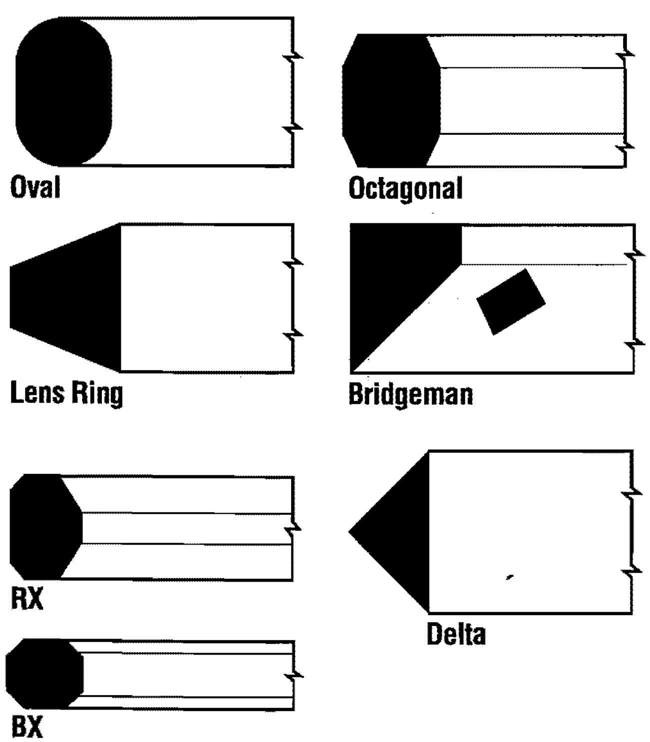


TABLE 4. STANDARD SPECIFICATIONS ①,② FOR SOLID METAL CROSS-SECTION GASKETS

Metal	Brinell Hardness Number[3] (Maximum)	Rockwell "B" Scale[4] (Maximum)	Maximum Service Temperature[5]	Identification
Soft Iron[6]	90	56	1000°F	D
Low Carbon Steel[6]	120	68	1000°F	S
Type 502 Alloy (4% to 6% Chrome, ½% Molybdenum)	130	72	1200°F	F5
Type 410 Alloy (11-13% Chrome)	170	86	1200°F	S410
Type 304 Alloy (18% Chrome, 8% Nickel)	160	83	Depends	S304
Type 316 Alloy (18% Chrome, 12% Nickel)	160	83	upon the	S316
Type 347 Alloy (18% Chrome, 10% Nickel)	160	83	Service	S347
Monel	125	70		M
Nickel	120	68	Conditions	N
Copper	Hardness as agreed upon			CU

1. Standard specification in accordance with ASME B16.20 for oval and octagonal cross-sections.
2. Standard specification in accordance with ASME B16.20 or API 6A for Style BX and Style RX cross-sections.
3. Brinell hardness measured with 3000 kg load, except for soft iron, which is measured with 500 kg load
4. Rockwell "B" measured with 100 kg load and 1/16" diameter ball.
5. Maximum service temperatures shown are in accordance with ANSI B16.20 for oval and octagonal cross-sections only. For Style BX and Style RX cross-sections, maximum working temperature is 255° F.
6. Where coatings and platings are employed. Thickness shall be .0005" maximum.

STYLE RX: The RX style ring joint has a unique self-sealing action. The outside bevels of the ring make the initial contact with the groove as the flanges are brought together with the flange bolting. This provides initial sealing of the joint with the gasket seating against the groove surfaces. During pressurization the gasket loading increases against the groove.

Style RX ring joint gaskets as specified in ASME B16.20 and API 6A are completely interchangeable with the oval and octagonal series of identical reference numbers, and are used in the same flange grooves.

STYLE BX: The BX style ring is designed to specifications shown in ASME B16.20 or API 6A for use with grooved flanges on special applications involving high pressures from 5000 psi to 15,000 psi. The pitch diameter of the ring is slightly larger than the pitch diameter of the groove, thus initial contact is made on the outside of the ring, pre-loading the gasket and creating a pressure-energized seal.

Connections utilizing Style BX have a limited amount of positive interference, ensuring that the gasket will be "coined" in the flange grooves. These gaskets are not recommended for re-use.

Style BX ring joint gaskets can only be used with API BX flanges and are not interchangeable with the Style RX series.

LENS RINGS: These are for high temperature, high pressure applications on pipework, valves and pressure vessels.

Lens rings have two spherical faces and are used between flanges with straight tapered (20°) faces. Providing a line contact seal approximately one-third across the gasket face, the specially designed cross-section effects a pressure-energized seal.

BRIDGEMAN: This pressure-activated design is used for pressure vessel and valve bonnet gaskets at pressures 1500 psi and higher. This design has also been adapted to pipe joints subject to extreme thermal shock conditions.

DELTA: The pressure-activated Delta. The Delta cross-section is essentially a pressure vessel or valve bonnet gasket, useful for pressure ranges of 5000 psi and higher.

GASKET SELECTION PROCEDURE FOR STANDARD FLANGES

The Fluid Sealing Association, in conjunction with API and ASME have devoted a great deal of effort toward developing gasket standards to simplify gasket design and selection. This work has resulted in ASME standard B16.20-1998, titled Metallic Gaskets for Pipe Flanges - Ring Joint, Spiral Wound, and Jacketed. Both API 6A, and ASME B16.20, provide specifications for Ring Joint Gaskets and Ring Joint Flanges.

The above referenced standards provide dimensional specifications for double-jacketed corrugated, spiral wound and ring joint gaskets for use with appropriate ASME B16.5, B16.47 Series A and B16.47 Series B flanges. When these standards are used, the user must first select the gasket corresponding to the flange. Secondly, user must verify that standard materials are suitable for the intended service or specify appropriate alternative materials.

TABLE 5 – METALLIC AND SEMI-METALLIC GASKET RECOMMENDATIONS

Application	Recommended Choices
Autoclave	Delta, Bridgeman, spiral wound, double jacketed, corrugated double jacketed or filler faced corrugated metal.
Heat Exchangers	Spiral wound, double jacketed, corrugated double jacketed or filler faced corrugated metal.
Boiler Openings	Spiral wound, filler faced corrugated metal.
Valve Bonnets	
Screwed, less than 1/4"	French jacket
Screwed, more than 1/4"	Flat metal, serrated
Bolted, round	Spiral wound
Bolted, rectangular	Two piece French jacket

All too often we hear that the gasket leaks. This is not strictly true. It is the joint that leaks and the gasket is one component of several that make up the joint. Unfortunately, the gasket is expected to make up for any and all deficiencies in a joint design, improper installation procedures and to compensate for all flange movement due to thermal changes, pressure changes, vibrations, etc. In many cases, the gasket may be able to compensate for these things, but only when careful attention is given to all the aspect of gasket selection, design and installation.

GASKET INSTALLATION PROCEDURES (AND BOLT TIGHTENING)

1. Inspect the gasket. Make sure the material is as specified and look for any damage or defects.
2. Inspect the gasket seating surfaces. Look for tool marks, cracks, scratches or pitting. Make sure that the gasket seating surface is proper for the type of gasket being used. Radial tool marks on a gasket seating surface are very difficult to seal regardless of the type of gasket being used, therefore, every attempt must be made to eliminate or minimize these.
3. Inspect each fastener, nut and washer for signs of over-stress or corrosion. If any of these items is damaged, replace it. Ensure the contact areas of the fasteners and nuts are clean. The facing on the flanges where the nuts or washers will contact should also be inspected for galling, pitting or corrosion. If apparent damage has occurred, re-machine or replace.
4. Lubricate all thread contact areas and nut facings. Proper cleanliness and lubrication ensures that the applied torque results in corresponding achieved compressive force of the fastener. When flanges are subjected to high temperatures, the use of an anti-seize compound on the bolts should be considered to facilitate subsequent disassembly.
5. With raised face horizontal installation, loosely install the stud bolts on the lower half of the flange. Insert the gasket between the flange facings to allow the bolts to centre the gasket. Install the balance of the studs and nuts finger-tight.
6. Torque bolts in a minimum of four stages, utilizing the following procedures;
   a. Number the bolts so that proper torque sequence requirements can be followed. Torque the bolts up to 30 percent of the final torque value in the recommended sequence pattern (see charts for bolting sequence). With any gasket, it is extremely important to follow a proper tightening sequence. If this sequence is not followed, the flanges can become cocked or rotated. Not only is it impossible to bring the flanges back into parallel with subsequent tightening, but this will also result in non-uniform deformation and irreparable damage to the gasket.
   b. Repeat step a, increasing the torque to approximately 60 percent of the final torque required.
   c. Repeat step b, increasing the torque to the final torque value.
   d. Use a rotational pattern of torque verification on all studs or bolts to the final torque value until no further rotation of the nuts can be achieved. This may require several passes since as one stud is tightened it will relieve the stress on the adjacent studs until such time as equilibrium is achieved.
   e. On high pressure, high temperature applications, it is suggested that the flanges be retightened to the required torque 4 hours after the initial assembly and prior to start-up or re-start to compensate for any relaxation or creep that may have occurred.

The following checklist is provided to assist the user in the investigative process of joint leakage. Due to the numerous variables associated with a bolted assembly the list is not intended to be all inclusive.

FLANGES

Flanges should be inspected for the following:

- Surface condition - Chemical attack and evidence of nicks, dings, pitting, scratches, scores, as well as overall cleanliness.
- Surface flatness - waviness, non-parallelism, distortion, deformation
- Surface finish - Surface finish appropriate for the selected gasket. Machined in accordance with applicable national standards, e.g. ASME B16.5 and MSS-SP44.

FASTENERS

Bolts, studs and nuts should be checked for the following:

Note: For optimum performance of the gasket, new fasteners are recommended.

- Correct size and grade.
- Overall condition of the fasteners, e.g. threads.

GASKET

The used gasket can provide several clues to identify the cause of leakage and should be visually examined for:

- Correct size - check for fit, appropriate clearances.
- Appropriate material
- Damage - dings, scratches, workmanship
- Under, over or uneven compression
- Chemical attack
- Oxidation
- Mechanical damage
- Foreign matter
- Thermal shock, process or environmentally induced.

JOINT ASSEMBLY

The degree of accuracy to achieve the required bolt load is dependent on the selection of tools in the assembly process. For proper evaluation the following should be considered:

- Installation Method - bolt torque sequence, final torque selection and thread lubricant.
- Use of hardened washers.
- Use of datum rods.
- Tools used - Calibrated torque wrenches, bolt tensioners and ultrasonics.

EXTERNAL LOADS

Extraneous loads applied to the joint assembly may cause leakage to occur. Check for the following possible sources:

- Equipment and flanged components, e.g. valves, pumps
- Structure, e.g. lack of piping supports
- Vibration
- Torsion
- Misalignment
- Pipe tension, pipe spacing

TORQUE REQUIRED TO PRODUCE BOLT STRESS

The torque or turning effort required to produce a certain stress in bolting is dependent upon a number of conditions, some of which are:

1. Diameter of bolt.
2. Type and number of threads on bolt.
3. Material of bolt.
4. Condition of nut bearing surfaces.
5. Lubrication of bolt threads and nut bearing surfaces.

The tables below reflect the results of many tests to determine the relation between torque and bolt stress. Values are based on steel bolting well lubricated with a heavy graphite and oil mixture.

It was found that a non-lubricated bolt has an efficiency of about 50 percent of a well lubricated bolt and also that different lubricants produce results varying between the limits of 50 and 100 percent of the tabulated stress figures.

Data for Use with Machine Bolts and Cold Rolled Steel Stud Bolts

Load in pounds on Bolts and Stud Bolts when Torque Loads Are Applied

NOMINAL DIAMETER OF BOLT (Inches)	NUMBER OF THREADS (Per Inch)	DIAMETER AT ROOT OF THREAD (Inches)	AREA AT ROOT OF THREAD (Sq. Inch)	STRESS 7,500 PSI Torque Ft. Lbs.	7,500 PSI Compression, Lbs.	15,000 PSI Torque Ft. Lbs.	15,000 PSI Compression, Lbs.	30,000 PSI Torque Ft. Lbs.	30,000 PSI Compression, Lbs.
1/4	20	.185	.027	1	203	2	405	4	810
5/16	18	.240	.045	2	338	4	675	8	1350
3/8	16	.294	.068	3	510	6	1020	12	2040
7/16	14	.345	.093	5	698	10	1395	20	2790
1/2	13	.400	.126	8	945	15	1890	30	3780
9/16	12	.454	.162	12	1215	23	2430	45	4860
5/8	11	.507	.202	15	1515	30	3030	60	6060
3/4	10	.620	.302	25	2265	50	4530	100	9060
7/8	9	.731	.419	40	3143	80	6285	160	12570
1	8	.838	.551	62	4133	123	8265	245	16530
1 1/8	7	.939	.693	98	5190	195	10380	390	20760
1 1/4	7	1.064	.890	137	6675	273	13350	545	26700
1 3/8	6	1.158	1.054	183	7905	365	15810	730	31620
1 1/2	6	1.283	1.294	219	9705	437	19410	875	38820
1 5/8	5 1/2	1.389	1.515	300	11363	600	22725	1200	45450
1 3/4	5	1.490	1.744	390	13080	775	26160	1550	52320
1 7/8	5	1.615	2.049	525	15368	1050	30735	2100	61470
2	4 1/2	1.711	2.300	563	17250	1125	34500	2250	69000

Data for Use with Alloy Steel Stud Bolts

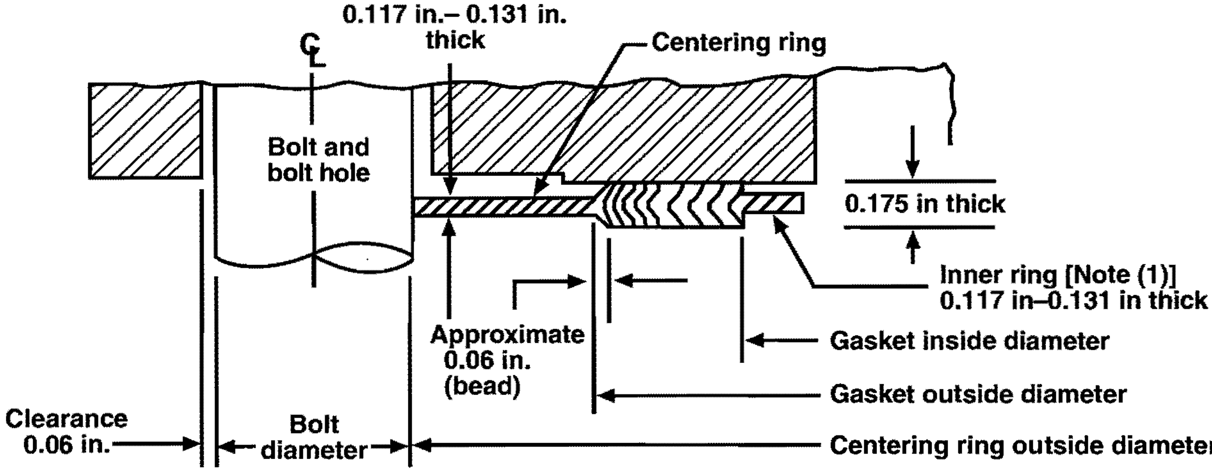
Load in Pounds on Stud Bolts when Torque Loads Are Applied

NOMINAL DIAMETER OF STUD (Inches)	NUMBER OF THREADS (Per Inch)	DIAMETER AT ROOT OF THREAD (Inches)	AREA AT ROOT OF THREAD (Sq. Inch)	STRESS 30,000 PSI Torque Ft. Lbs.	30,000 PSI Compression, Lbs.	45,000 PSI Torque Ft. Lbs.	45,000 PSI Compression, Lbs.	60,000 PSI Torque Ft. Lbs.	60,000 PSI Compression, Lbs.
1/4	20	.185	.027	4	810	6	1215	8	1620
5/16	18	.240	.045	8	1350	12	2025	16	2700
3/8	16	.294	.068	12	2040	18	3060	24	4080
7/16	14	.345	.093	20	2790	30	4185	40	5580
1/2	13	.400	.126	30	3780	45	5670	60	7560
9/16	12	.454	.162	45	4860	68	7290	90	9720
5/8	11	.507	.202	60	6060	90	9090	120	12120
3/4	10	.620	.302	100	9060	150	13590	200	18120
7/8	9	.731	.419	160	12570	240	18855	320	25140
1	8	.838	.551	245	16530	368	24795	490	33060
1 1/8	8	.963	.728	355	21840	533	32760	710	43680
1 1/4	8	1.088	.929	500	27870	750	41805	1000	55740
1 3/8	8	1.213	1.155	680	34650	1020	51975	1360	69300
1 1/2	8	1.338	1.405	800	42150	1200	63225	1600	84300
1 5/8	8	1.463	1.680	1100	50400	1650	75600	2200	100800
1 3/4	8	1.588	1.980	1500	59400	2250	89100	3000	118800
1 7/8	8	1.713	2.304	2000	69120	3000	103680	4000	138240
2	8	1.838	2.652	2200	79560	3300	119340	4400	159120
2 1/4	8	2.088	3.423	3180	102690	4770	154035	6360	205380
2 1/2	8	2.338	4.292	4400	128760	6600	193140	8800	257520
2 3/4	8	2.588	5.259	5920	157770	8880	236655	11840	315540
3	8	2.838	6.324	7720	189720	11580	284580	15440	379440

BOLTING DATA FOR STANDARD FLANGES

NOMINAL PIPE SIZE (Inches)	150 PSI SERIES				300 PSI SERIES				400 PSI SERIES				600 PSI SERIES			
	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)
1/4	3 3/8	4	1/2	2 1/4	3 3/8	4	1/2	2 1/4	3 3/8	4	1/2	2 1/4	3 3/8	4	1/2	2 1/4
1/2	3 1/2	4	1/2	2 3/8	3 3/4	4	1/2	2 5/8	3 3/4	4	1/2	2 5/8	3 3/4	4	1/2	2 5/8
3/4	3 7/8	4	1/2	2 3/4	4 5/8	4	5/8	3 1/4	4 5/8	4	5/8	3 1/4	4 5/8	4	5/8	3 1/4
1	4 1/4	4	1/2	3 1/8	4 7/8	4	5/8	3 1/2	4 7/8	4	5/8	3 1/2	4 7/8	4	5/8	3 1/2
1 1/4	4 5/8	4	1/2	3 1/2	5 1/4	4	5/8	3 7/8	5 1/4	4	5/8	3 7/8	5 1/4	4	5/8	3 7/8
1 1/2	5	4	1/2	3 7/8	6 1/8	4	3/4	4 1/2	6 1/8	4	3/4	4 1/2	6 1/8	4	3/4	4 1/2
2	6	4	5/8	4 3/4	6 1/2	8	5/8	5	6 1/2	8	5/8	5	6 1/2	8	5/8	5
2 1/2	7	4	5/8	5 1/2	7 1/2	8	3/4	5 7/8	7 1/2	8	3/4	5 7/8	7 1/2	8	3/4	5 7/8
3	7 1/2	4	5/8	6	8 1/4	8	3/4	6 5/8	8 1/4	8	3/4	6 5/8	8 1/4	8	3/4	6 5/8
3 1/2	8 1/2	8	5/8	7	9	8	3/4	7 1/4	9	8	7/8	7 1/4	9	8	7/8	7 1/4
4	9	8	5/8	7 1/2	10	8	3/4	7 7/8	10	8	7/8	7 7/8	10 3/4	8	7/8	8 1/2
5	10	8	3/4	8 1/2	11	8	3/4	9 1/4	11	8	7/8	9 1/4	13	8	1	10 1/2
6	11	8	3/4	9 1/2	12 1/2	12	3/4	10 5/8	12 1/2	12	7/8	10 5/8	14	12	1	11 1/2
8	13 1/2	8	3/4	11 3/4	15	12	7/8	13	15	12	1	13	16 1/2	12	1 1/8	13 3/4
10	16	12	7/8	14 1/4	17 1/2	16	1	15 1/4	17 1/2	16	1 1/8	15 1/4	20	16	1 1/4	17
12	19	12	7/8	17	20 1/2	16	1 1/8	17 3/4	20 1/2	16	1 1/4	17 3/4	22	20	1 1/4	19 1/4
14	21	12	1	18 3/4	23	20	1 1/8	20 1/4	23	20	1 1/4	20 1/4	23 3/4	20	1 3/8	20 3/4
16	23 1/2	16	1	21 1/4	25 1/2	20	1 1/4	22 1/2	25 1/2	20	1 3/8	22 1/2	27	20	1 1/2	23 3/4
18	25	16	1 1/8	22 3/4	28	24	1 1/4	24 3/4	28	24	1 3/8	24 3/4	29 1/4	20	1 5/8	25 3/4
20	27 1/2	20	1 1/8	25	30 1/2	24	1 1/4	27	30 1/2	24	1 1/2	27	32	24	1 5/8	28 1/2
24	32	20	1 1/4	29 1/2	36	24	1 1/2	32	36	24	1 3/4	32	37	24	1 7/8	33

NOMINAL PIPE SIZE (Inches)	900 PSI SERIES				1500 PSI SERIES				2500 PSI SERIES			
	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)	Diam. of Flange (Inches)	Number of Bolts	Diam. of Bolts (Inches)	Bolt Circle (Inches)
1/2	4 3/4	4	3/4	3 1/4	4 3/4	4	3/4	3 1/4	5 1/4	4	3/4	3 1/2
3/4	5 1/8	4	3/4	3 1/2	5 1/8	4	3/4	3 1/2	5 1/2	4	3/4	3 3/4
1	5 7/8	4	7/8	4	5 7/8	4	7/8	4	6 1/4	4	7/8	4 1/4
1 1/4	6 1/4	4	7/8	4 3/8	6 1/4	4	7/8	4 3/8	7 1/4	4	1	5 1/8
1 1/2	7	4	1	4 7/8	7	4	1	4 7/8	8	4	1 1/8	5 3/4
2	8 1/2	8	7/8	6 1/2	8 1/2	8	7/8	6 1/2	9 1/4	8	1	6 3/4
2 1/2	9 5/8	8	1	7 1/2	9 5/8	8	1	7 1/2	10 1/2	8	1 1/8	7 3/4
3	9 1/2	8	7/8	7 1/2	10 1/2	8	1 1/8	8	12	8	1 1/4	9
4	11 1/2	8	1 1/8	9 1/4	12 1/4	8	1 1/4	9 1/2	14	8	1 1/2	10 3/4
5	13 3/4	8	1 1/4	11	14 3/4	8	1 1/2	11 1/2	16 1/2	8	1 3/4	12 3/4
6	15	12	1 1/8	12 1/2	15 1/2	12	1 3/8	12 1/2	19	8	2	14 1/2
8	18 1/2	12	1 3/8	15 1/2	19	12	• 1 5/8	15 1/2	21 3/4	12	2	17 1/4
10	21 1/2	16	1 3/8	18 1/2	23	12	1 7/8	19	26 1/2	12	2 1/2	21 1/4
12	24	20	1 3/8	21	26 1/2	16	2	22 1/2	30	12	2 3/4	24 3/8
14	25 1/4	20	1 1/2	22	29 1/2	16	2 1/4	25	....	....	....	....
16	27 3/4	20	1 5/8	24 1/4	32 1/2	16	2 1/2	27 3/4	....	....	....	....
18	31	20	1 7/8	27	36	16	2 3/4	30 1/2	....	....	....	....
20	33 3/4	20	2	29 1/2	38 3/4	16	3	32 3/4	....	....	....	....
24	41	20	2 1/2	35 1/2	46	16	3 1/2	39	....	....	....	....



DIMENSIONS FOR SPIRAL WOUND GASKETS USED WITH ASME B16.5 FLANGES

Flange Size (NPS)	Outside Diameter of Gasket (2): Classes 150, 300, 400, 600	Outside Diameter of Gasket (2): Classes 900, 1500, 2500	Inside Diameter of Gasket by Class (3): 150	300	400	600	900	1500	2500	Outside Diameter of Centering Ring by Class (4): 150	300	400	600	900	1500	2500
1/2	1.25	1.25	0.75	0.75	(5)	0.75	(5)	0.75	0.75	1.88	2.13	(5)	2.13	(5)	2.50	2.75
3/4	1.56	1.56	1.00	1.00	(5)	1.00	(5)	1.00	1.00	2.25	2.63	(5)	2.63	(5)	2.75	3.00
1	1.88	1.88	1.25	1.25	(5)	1.25	(5)	1.25	1.25	2.63	2.88	(5)	2.88	(5)	3.13	3.38
1 1/4	2.38	2.38	1.88	1.88	(5)	1.88	(5)	1.56	1.56	3.00	3.25	(5)	3.25	(5)	3.50	4.13
1 1/2	2.75	2.75	2.13	2.13	(5)	2.13	(5)	1.88	1.88	3.38	3.75	(5)	3.75	(5)	3.88	4.63
2	3.38	3.38	2.76	2.75	(5)	2.75	(5)	2.31	2.31	4.13	4.38	(5)	4.38	(5)	5.63	5.75
2 1/2	3.88	3.88	3.25	3.25	(5)	3.25	(5)	2.75	2.75	4.88	5.13	(5)	5.13	(5)	6.50	6.63
3	4.75	4.75	4.00	4.00	(5)	4.00	3.75	3.63	3.63	5.38	5.88	(5)	5.88	6.63	6.88	7.75
4	5.88	5.88	5.00	5.00	4.75	4.75	4.75	4.63	4.63 (1)	6.88	7.13	7.00	7.63	8.13	8.25	9.25
5	7.00	7.00	6.13	6.13	5.81	5.81	5.81	5.63	5.63 (1)	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	8.25	8.25	7.19	7.19	6.88	6.88	6.88	6.75	6.75 (1)	8.75	9.88	9.75	10.50	11.38	11.13	12.50
8	10.38	10.13	9.19	9.19	8.88	8.88	8.75	8.50	8.50 (1)	11.00	12.13	12.00	12.63	14.13	13.88	15.25
10	12.50	12.25	11.31	11.31	10.81	10.81	10.88	10.50	10.63 (1)	13.38	14.25	14.13	15.75	17.13	17.13	18.75
12	14.75	14.50	13.38	13.38	12.88	12.88	12.75	12.75 (1)	12.50 (1)	16.13	16.63	16.50	18.00	19.63	20.50	21.63
14	16.00	15.75	14.63	14.63	14.25	14.25	14.00	14.25 (1)	(5)	17.75	19.13	19.00	19.38	20.50	22.75	(5)
16	18.25	18.00	16.63	16.63	16.25	16.25	16.25	16.00 (1)	(5)	20.25	21.25	21.13	22.25	22.63	25.25	(5)
18	20.75	20.50	18.69	18.69	18.50	18.50	18.25	18.25 (1)	(5)	21.63	23.50	23.38	24.13	25.13	27.75	(5)
20	22.75	22.50	20.69	20.69	20.50	20.50	20.50	20.25 (1)	(5)	23.88	25.75	25.50	26.88	27.50	29.75	(5)
24	27.00	26.75	24.75	24.75	24.75	24.75	24.75 (1)	24.25 (1)	(5)	28.26	30.50	30.25	31.13	33.00	35.50	(5)

GENERAL NOTES:

(A) The gasket-thickness tolerance is ± 0.005 in. measured across the metallic portion of the gasket not including the filler, which mat protrude slightly beyond the metal.

(B) For limitations on the maximum flange bore for use with these spiral-wound gaskets, see ASME B16.20.

NOTES:

(1) Inner rings are required for all PTFE filled gaskets and for Class 900 gaskets, NPS 24; Class 1500 gaskets, NPS 12 through NPS 24; and Class 2500 gaskets, NPS 4 through NPS 12 (see ASME B16.20).

(2) The gasket outside diameter tolerance for NPS 1/2 through NPS 8 is ± 0.03 in.; for NPS 10 through NPS 24, + 0.06 in., - 0.03 in.

(3) The gasket inside diameter tolerance for NPS 1/2 through NPS 8 is ± 0.016 in.; for NPS 10 through NPS 24, ± 0.03 in.

(4) The centering ring outside diameter tolerance is ± 0.03 in.

(5) There are no Class 400 flanges in NPS 1/2 through NPS 3 (use Class 600, Class 900 flanges in NPS 1/2 through NPS 2 1/2 (use Class 1500), or Class 2500 flanges NPS 14 and larger.

INNER RING INSIDE DIAMETERS FOR SPIRAL WOUND GASKETS PER ASME B16.20 1998

Flange Size (NPS)	Pressure Class 150	300	400 (1)	600	900 (2,3)	1500 (2,3)	2500 (1-3)
1/2	0.56	0.56	-	0.56	-	0.56	0.56
3/4	0.81	0.81	-	0.81	-	0.81	0.81
1	1.06	1.06	-	1.06	-	1.06	1.06
1 1/4	1.50	1.50	-	1.50	-	1.31	1.31
1 1/2	1.75	1.75	-	1.75	-	1.63	1.63
2	2.19	2.19	-	2.19	-	2.06	2.06
2 1/2	2.62	2.62	-	2.62	-	2.50	2.50
3	3.19	3.19	-	3.10	3.10	3.10	3.10
4	4.19	4.19	4.04	4.04	4.04	3.85	3.85
5	5.19	5.19	5.05	5.05	5.05	4.90	4.90
6	6.19	6.19	6.10	6.10	6.10	5.80	5.80
8	8.50	8.50	8.10	8.10	7.75	7.75	7.75
10	10.56	10.56	10.05	10.05	9.69	9.69	9.69
12	12.50	12.50	12.10	12.10	11.50	11.50	11.50
14	13.75	13.75	13.50	13.50	12.63	12.63	-
16	15.75	15.75	15.35	15.35	14.75	14.50	-
18	17.69	17.69	17.25	17.25	16.75	16.75	-
20	19.69	19.69	19.25	19.25	19.00	18.75	-
24	23.75	23.75	23.25	23.25	23.25	22.75	-

GENERAL NOTES:

(A) The inner ring thickness shall be 0.117–0.131 in.

(B) For sizes NPS 1 1/4 through NPS 3, the inside diameter tolerance is ± 0.03 in.; for larger sizes the inside diameter tolerance is ± 0.06 in. See ASME B16.20 for minimum pipe wall thicknesses that are suitable for use with standard inner rings.

NOTES:

(1) There are no Class 400 flanges NPS 1/2 through NPS 3 (use Class 600), Class 900 flanges NPS 1/2 (use Class 1500), or Class 2500 flanges NPS 14 and larger.

(2) The inner ring inside diameters shown for NPS 1 1/4 through NPS 2 1/2 in Class 1500 and 2500 will produce inner ring widths of 0.12 in., a practical minimum for production purposes.

(3) Inner rings are required for Class 900, NPS 24 gaskets; Class 1500, NPS 12 through NPS 24 gaskets; and Class 2500, NPS 4 through NPS 12 gaskets.

References

① *USA Regulations on Fugitive Emissions*
(ESA Report N° 003/94), published by the European Sealing Association, June 1994.

② *European Emission Legislation*
(ESA Report N° 004/95), published by the European Sealing Association, April 1995.

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