

JOSÉ CARLOS VEIGA

INDUSTRIAL GASKETS

5th Edition

Rio de Janeiro, Brazil

Teadit

2021

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With love for Benjamin and Marina.

Preface

The idea for this book arose by chance. At the end of a technical discussion we were having with a client, one of the participants asked why we couldn't organize all the information and examples that we had just presented into a complete book. He had never seen such book in the market and knew it would be beneficial to him and his co-workers.

Based on this simple request and our acknowledgement that the industry was void of this type of tool, we then decided to create a book that could be used within all aspects of industry. We would compile and organize all the knowledge that our technical team possessed along with the information garnered from product application experiences that our partner/clients had. This application information was critical in establishing a precise correlation between theory and practice.

The guiding influence in our business philosophy is the "Market Driven" Research and Development. Active participation in product applications along with the continuous search for technical and scientific innovations puts us in an outstanding position as it relates to the knowledge of "Best Practices" and the development of the new, innovative solutions. We are always striving for product life cycle improvement and recognize that the constant search for excellence is never ending. The search for excellence is evident in our Developmental Engineering, our Application Engineering and in our industry experts' constant work in the field. Our knowledge and commitment shows through our ability to interact with our clients Production and Engineering departments and our close monitoring of product field performance. The goal is not just to satisfy our clients but also to educate. We hold ourselves to standards set by the leading edge technology, which is evident in our product and service offering.

We are fortunate to have developed an advantageous position as a Premier Global Manufacturer for more than 60 years. This experience, along with being a guiding member of the global standards setting and monitoring organizations for industry, has given us the ability to amalgamate the past experience with the present data and future prospective.

Our purpose with this book is to create a directory of information that would be useful to the experts working in this field who are handling the vast majority of the daily issues present in the industry.

Thanks to the outpouring of support and recognition we have received for this work. Though it encompasses a bit more than the original intent, it is our knowledge and our contribution to a better understanding of the use of gaskets for industrial sealing. This is a book of practical and easy reference.

TEADIT Group

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INTRODUCTION

This book was written with the purpose of providing better design and application of Industrial Gaskets. It has been very successful in several countries and has become a reference for gasket applications. This Fifth English Language Edition, revised and expanded, incorporates the latest advances in gasket technology since the last printing.

On analyzing certain leaks - which at first glance seemed to be caused by gasket deficiencies – we verified, after a more careful observation, that little attention had been paid to details such as:

- Flange and Gasket design.
- Correct choice of gasket materials.
- Installation procedures.

The great problems confronted by industries such as explosions, fires and environmental pollution caused by leaks, can be avoided with the correct gasket design and installation.

The objective of this book is to help prevent accidents by promulgating a wider understanding of industrial gaskets, specialty compressed fiber and spiral wound gaskets; undoubtedly the types most widely used in industrial applications.

Existing North America market conditions were carefully taken into consideration. Materials and gasket styles, which are not commercially available or difficult to find, were omitted; emphasis being given to the most accessible and widely used products and materials.

This book is divided into chapters that cover the following:

- Design, the New Gasket Constants and Fugitive Emissions
- Non-Metallic Gasket Materials.
- Compressed Fiber Sheet Gaskets.
- PTFE Gaskets.

- Metallic Gasket Materials.
- Spiral Wound Gaskets.
- Jacketed and Heat Exchanger Gaskets.
- Solid Metal Gaskets.
- Camprofile Gaskets.
- Electron® Electrical Insulation Gaskets.
- Installation Procedures and Troubleshooting.
- Conversion Factor and References.

The most important changes to this Fifth English Edition are:

- Chapter 4: new Compressed Fiber products
- Chapter 5: new patented Origin technology of PTFE Spiral Wound Gaskets and new Expanded PTFE products
- Chapter 6: ASME B16.20 Spiral Wound Gaskets performance tests
- Chapter 11: rewrite with the introduction of the patented technology Electron® Electrical Insulation Gaskets
- Chapter 12: more troubleshooting examples

The author would welcome commentaries and suggestions. Please send to engineering@teadit.com.

Properties and application parameters shown throughout this book are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications are subject to change without notice; this edition cancels all previous issues.

1. LEAKS

It is a fact that a “zero leakage” condition is non-existent in the industrial gasket environment. A report on a particular gasket leak must include information regarding the method of measurement and other pertinent criteria. For example, in certain applications, the maximum leak index can be only one drop of water per second. In other applications, it can be the absence of soap bubbles when the equipment or piping is under pressure. More rigorous conditions can even require tests with mass spectrometers.

In order to establish the criteria for measuring the maximum admissible leakage, the following should be considered:

- Characteristics of the fluid to be sealed.
- Impact on the immediate environment if the fluid leaks.
- Danger of fire or explosion.
- Emission regulations.
- Other relevant factors for each particular situation.

For industrial applications, it is common to define, as “zero leakage” the value that is lower than a limit set according to the above considerations. The following examples show some of these criteria.

The Jet Propulsion Laboratory of the California Institute of Technology, part of the National Aeronautics and Space Administration (NASA)[1], defines as zero leakage for gases a value lower than $1\text{cm}^3/\text{year}$ when the pressure differential is one atmosphere. For reference, we can establish that a drop of liquid has an average volume of 0.05cm^3 . Thus 20 drops will be necessary to exceed 1cm^3 .

With the need to control fugitive emissions the Environmental Protection Agency (EPA) [2] has initially set the limit of 500 parts per million (ppm) as maximum leak for flanges. However, this value has been considered too high and there already exist requirements for the maximum of 100 ppm [3].

In Germany, the standard VDI 2440 [4] establishes maximum emission values for oil refineries. For gaskets, the value is $10^{-4}\text{ mbar} \cdot \text{sec}$ at room temperature set for specific test with Helium.

The leakage rate is a relative concept, and in critical situations, must be judiciously established.

2. SEALING

If it were technically and economically feasible to manufacture perfectly smooth and polished flanges, and if we could maintain these surfaces in permanent contact, there would be no need for gaskets. This technical and economic impossibility results from:

- Size of the vessel and/or the flanges.
- Difficulty in maintaining these surfaces perfectly smooth and the flange faces perfectly parallel to each other during the handling and/or assembling of the vessel or piping.
- Corrosion or erosion of the sealing surface.

To overcome these difficulties, gaskets are used as a sealing element. When a gasket is seated against flange surfaces, it flows, filling the imperfections between them and providing the necessary sealing. Therefore, in order to obtain adequate sealing, we must consider four factors:

- **Gasket seating stress:** we must provide an adequate way of seating the gasket; so it will be able to flow and fill the flange imperfections. The minimum gasket seating stress detail will be shown later in this chapter. This seating stress must be limited in order to prevent the crushing of the gasket by an excess of compression.
- **Sealing force:** there must be a residual pressure on the gasket in order to keep it in contact with the flange surfaces, thus avoiding leakage.
- **Material selection:** The gasket material must resist the pressure as well as the fluid to which it is subjected. The correct selection of materials will be covered in several chapters of this book.
- **Surface finish:** There is a recommended flange surface finish for each style of gasket. The use of surface finish not compatible with the gasket is one of the primary causes of leakage.

3. FORCES IN A FLANGED JOINT

The Figure 2.1 shows the major forces in a flanged joint.

- **Blow-out Force:** originated by the internal pressure; it tends to blow out the gasket.
- **Separation Force:** also originated by internal pressure; it tends to separate the flanges. It is also known as the hydrostatic force.
- **Bolt (studs) Force:** it is the total load exercised by the bolts or studs.
- **Sealing Force:** it is the force, which compresses the flanges against the gasket.

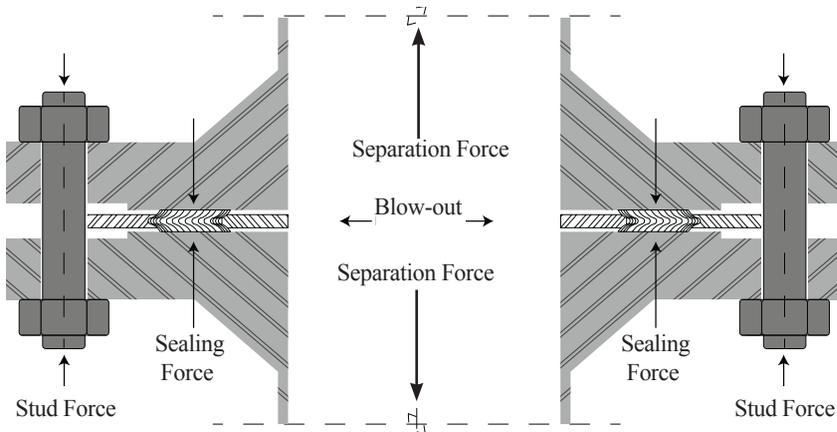


Figure 2.1

Initially, the Sealing Force is equal to the Stud Force. After pressuring the system, it is equal to the Stud Force minus the Separation Force.

The Stud Force initially applied to the gasket, besides causing flow of the gasket material, must:

- Compensate for the separation force caused by internal pressure.
- Be sufficient to maintain a residual stress on the gasket, avoiding fluid leakage.
- Compensate for the relaxation of the flanged joint that will occur during service life.

From a practical point of view, in order to maintain the sealing, the residual stress must be “x” times the fluid pressure. The minimum value of this force can be calculated by various methods.

In North America, the most widely used design procedure for the calculation is the “Appendix 2 – Rules for Bolted Flange Connection with Ring Type Joints” of the ASME Boiler and Pressure Vessel Code Section VIII [5]. However, this procedure does not take under consideration several variables such as the not so precise knowledge of the force application, relaxation of the gasket and effect caused by temperature variations. In parallel with this calculation, it is recommended that the designer checks the integrity of the flanged joint through the methodology established in the Appendix O of ASME (American Society of Mechanical Engineers) PCC-1[6] Guidelines for Pressure Boundary Bolted Flange Assembly.

Studies show that the higher the tightening of the gasket, the better the sealability. Thus, it is recommended that the Seating Stress be as high as possible.

European calculation procedures [50, 51] are different from ASME and will not be shown in this book, which is dedicated to the North American market.

4. ASME PROCEDURE

Appendix 2 sets out the criteria for the design of gaskets and flanges. The design of flanges is not in the scope of this book. To design the gasket, the procedure is described as follows, and should not be applied for the calculation of standard flanges. In this case,

specific tables should be used to take into account other factors, as it will be shown throughout this book.

The procedure recommends typical values for the characteristics of the gasket “m” and “y”. These values are not mandatory. The designer has the freedom to use different values as long as the available data justifies the need for doing so.

At the time of this book editing, the values suggested in Appendix 2 had not been updated after the ban of asbestos in most industrialized countries. For this reason, it is recommended that the designer consults with the manufacturer of the gasket to get its characteristics.

In 2015 a procedure to determine “m” and “y” has been issued by ASTM [67] however, the method has not gained widespread use because it considers an allowable leak rate which is not part of the ASME Section VIII - Boiler and Pressure Vessel Code, Appendix 2 calculations. For this reason, Teadit employs its own procedure [7]. The values of “m” and “y” informed in this book are based on laboratory tests following this procedure and validated in successful actual service applications.

Appendix 2 requires that a calculation of a bolted flanged joint would be made for two independent conditions: operating pressure and minimum seating stress.

4.1. OPERATIONAL CONDITIONS

This condition establishes a minimum seating as per the equation:

$$W_{m1} = (\pi G^2 P / 4) + (2 b \pi G m P)$$

This equation establishes that the minimum bolt load necessary to fulfill the operational conditions is equal to the sum of the pressure force plus a residual load over the gasket which is equal to “m” times the media pressure. Or, interpreting it in a different way, this equation establishes that the minimal bolt load must be such that there always will be a residual stress applied on the gasket greater than the internal pressure of the media. The gasket manufacturer establishes the “m” factor. In the absence of information from the gasket manufacturer the ASME Code suggests minimum values of factor “m” for several gasket styles. In each specific chapter throughout this book, there are the values of “m” for the gaskets manufactured by Teadit.

4.2. GASKET SEATING STRESS

This condition determines a minimum seating gasket stress without taking into consideration the media pressure. This force is calculated by the formula:

$$W_{m2} = \pi b G y$$

where “b” is defined as the effective gasket width and “y” is the value of the minimum gasket seating stress, determined by the manufacturer of the gasket. When there is no defined seating stress, the ASME code suggests generic values of “y”. In each specific chapter throughout this book, the “y” values are given. The value of G is the effective diameter of the gasket and is used to calculate the joint reaction forces.

The “b” value is calculated by:

$$b = b_0 \text{ when } b_0 \text{ is equal to or less than } 1/4''$$

or

$$b = 0.5 (b_0)^{0.5} \text{ when } b_0 \text{ is greater than } 1/4''$$

The ASME Code also explains how to calculate G and b_0 according to the face of the flange, as it is shown in Table 2.1 and Figure 2.2.

4.3. STUD AREA

The minimum stud area to meet the operating conditions and stress on the gasket, A_m must be greater than A_{m1} and A_{m2} , calculated as follows:

$$A_{m1} = W_{m1} / S_b$$

$$A_{m2} = W_{m2} / S_a$$

Where S_b is the allowable stud stress at the service temperature and S_a is the allowable stud stress at room temperature. The values of the allowable stress can be found in the tables of ASME Boiler and Pressure Vessel Code Section II Part D [8].

$$A_m \geq A_{m1}$$

$$\text{if } A_{m2} > A_{m1} \text{ then } A_m = A_{m2}$$

4.4. MINIMUM DESIGN FORCE

The minimum design force (W) is the values obtained in 4.1 and 4.2.

For operating conditions:

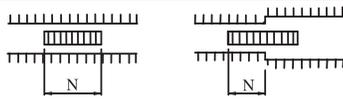
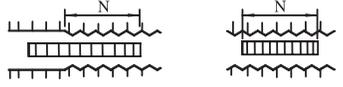
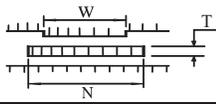
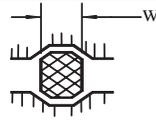
$$W = W_{m1}$$

For seating the gasket:

$$W = (A_m + A_b) S_a / 2$$

The design of the flanges is not included in the scope of this book. According with Appendix 2, the calculations shown above determine the forces needed to design the flange, however, to ensure the seal over the expected lifetime for the equipment or piping, other considerations are necessary, like the joint creep relaxation and temperature effects. They will be shown in this book.

Table 2.1

Flange Facing Sketch	Effective Gasket Width b_0
	$N / 2$
	$N / 2$
	$w \leq N$ $(w + T) / 2$ $(w + N) / 4$ máx
	$w / 8$

Location of Gasket Load Reaction (H_G)

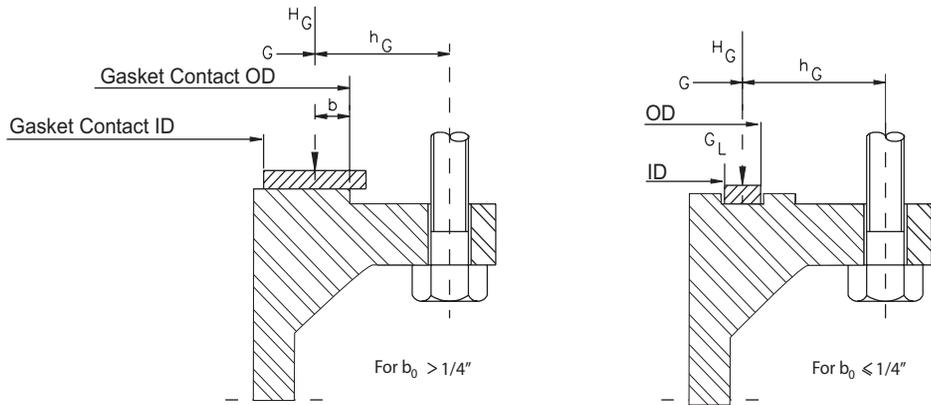


Figure 2.2

4.5. STUD DIMENSIONING

Studs should be selected so that the sum of their areas A_b is equal to or greater than A_m :

$$A_b \geq A_m$$

Where

$$A_b = (\text{number of studs}) \times (\text{minimum stress stud area, sqin})$$

$$A_{m1} = W_{m1} / S_b$$

$$A_{m2} = W_{m2} / S_a$$

$$A_b = A_{m1}$$

If $A_{m2} > A_{m1}$ then $A_b = A_{m2}$

The areas for imperial and metric studs are in Tables 12.1 and 12.2 of Chapter 12.

5. MAXIMUM GASKET SEATING FORCE

Each gasket has a crush limit beyond which there is an excessive deformation; consequently, the gasket loses its sealability characteristics. The maximum gasket seating force $W_{g_{max}}$ is calculated by the formula:

$$W_{g_{max}} = S_{g_{max}} A_g$$

Where

$S_{g_{max}}$ = maximum gasket stress at room temperature

A_g = seating area of the gasket or the gasket contact area with the flange. It is calculated by the formula:

$$A_g = (\pi/4) (OD^2 - ID^2)$$

Where

OD = outside diameter of contact of the gasket with the sealing surface of the flange.

ID = inside diameter of contact of the gasket with the sealing surface of the flange.

The maximum gasket seating stress at room temperature, $S_{g_{max}}$ is obtained experimentally and it varies with material, dimensions, and shape of the gasket. The values $S_{g_{max}}$ for Tedit gaskets styles are shown in each specific chapter throughout this book.

6. RELAXATION

Immediately after installing and tightening up the studs, the relaxation begins [9]. It is a gradual loss of the stud load applied when installing the gasket. This characteristic of the flanged union must be considered to ensure their performance throughout the service life of the equipment or piping. The relaxation can be divided into two phases: the initial phase, which occurs immediately after the installation, and then throughout the service of the gasket. The initial relaxation is caused mainly by the flow of the gasket when filling in the irregularities between the flanges. On a smaller scale the threads of the studs and nuts also suffer a small relaxation. For this reason, for certain critical applications it is recommended that a re-tightening is performed as the system is started-up. The ASME PCC-1 recommends a specific procedure for start-up retorquing.

Recent studies show that in many critical applications, tightening at room temperature may not be sufficient to ensure sealability of the system. For these situations, start-up retightening procedures are performed, as the system is started-up [10, 11]. The chart of Figure 2.3 shows the relaxation of metallic gaskets in laboratory tests. It can be observed that there is a loss of up to 25% of the initial installation stress. The chart also indicates the results of stress loss with hot and cold retightening, making it possible to identify that the results with hot retightening are more efficient than the other two.

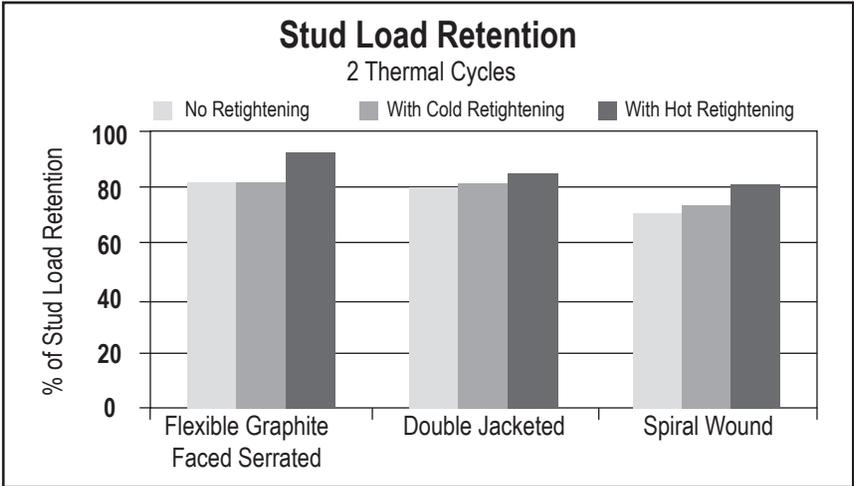


Figure 2.3

The relaxation during the time of service of the gasket occurs primarily in systems operating at elevated temperatures or with thermal cycles. Depending on the type of gasket, the operating temperature, and the frequency of the thermal cycles, the effects can take months or even years before there is leakage of the flanged joint. An example of this relaxation is caused by the oxidation of flexible graphite at elevated temperatures.

The chart of Figure 2.4 shows the relaxation of a Double Jacketed gasket over a period of 17 months. This study was conducted by Mr. David Reeves, Chevron Corp. refinery in El Segundo, California, USA, who kindly authorized its publication in this book. In the initial part of the chart, we can observe the initial relaxation and the hot tightening right after the system start-up. The continued loss of stud load can be observed until the disassembly of the gasket, when the studs had only 45% of the initial tightening stress.

In systems subject to this type of relaxation, it is suggested the application of the highest possible initial stud load, as shown in the figure, to avoid a possible leak during the service life planned for the equipment. Other alternatives such as “live loading” or longer studs can be employed as shown in Chapter 12 of this book.

The fraction of relaxation, ϕ_g , obtained experimentally, indicates the amount of stress retained in the gasket after the relaxation. For each type of gasket and gasket material there is a value for this characteristic, which may vary from 0.90 to 0.50. A typical average value of 0.70 can be considered when there is no specific value determined.

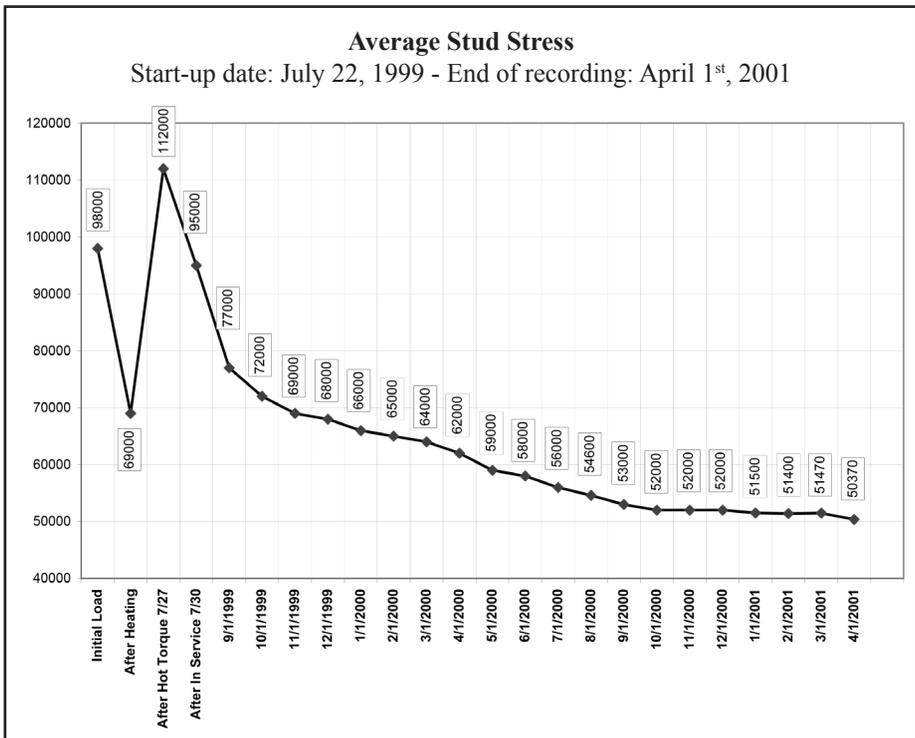


Figure 2.4

7. MINIMUM GASKET OPERATING STRESS

As already shown, the stud load initially applied to the joint is reduced by the relaxation. A further reduction occurs when there is pressurization of the equipment or of the piping; it is caused from the pressure force of the media, which tends to separate the flanges. The minimum gasket operating stress $Sg_{\min-0}$ is determined experimentally. It is the minimum value of the gasket stress, which should be maintained during the operation to assure sealability.

8. DETERMINATION OF THE INSTALLATION FORCE

The gasket installation force (Fig.2.5) shall be established taking into account the gasket, flange and bolts as shown in the following procedure, which follows the methodology introduced in Appendix O of ASME

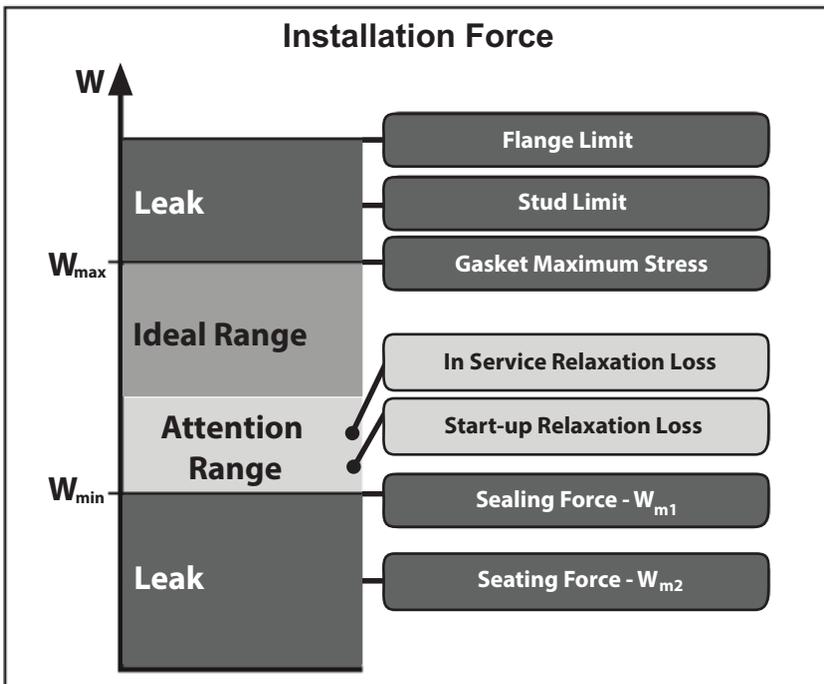


Figure 2.5

PCC-1. As recommended in ASME - PCC-1, the following checks are performed to ensure proper seal over the expected service life of the equipment or piping:

Sufficient gasket stress to assure sealability: the stud tightening should be sufficient to properly seat the gasket, compensate relaxation and the pressure force maintaining the seal.

Gasket Limit: during the installation, tightening should be less than the gasket maximum seating stress Sg_{\max} to avoid damaging the gasket.

Stud Limit: the stress applied should be less than its yield strength to avoid stud failure.

Flange Limit: tightening applied should not cause excessive rotation or perma-

ment deformation to the flange.

To perform the tightening calculation considering the recommendations of ASME - PCC-1 it is necessary to have knowledge of the following properties of the flanges, gasket, and studs:

Maximum permissible flange rotation ($\theta_{g_{max}}$): during installation the rotation of the flange should be less than the maximum permissible value for the gasket that is being installed. The value of the maximum flange rotation for the gasket being installed is obtained experimentally. At the time of the publication of this book, there was no approved procedure to determine this property. In the absence of a specific value the generic value of 1.0 degree is frequently used.

Maximum permissible stud stress (Sb_{max}): the value of maximum stress in the studs should be determined so that there is not damage to the gasket, the flange or the stud. This value should take into account the method that will be used to apply the tension as shown in Chapter 12 of this book. It is recommended that this value to be between 40% and 75% of the room temperature yield stress of the stud.

Minimum permissible stud stress (Sb_{min}): the value of minimum stud stress is determined so that there is not loss of sealability. This value must also take into account the method that will be used to apply the tension as shown in Chapter 12 of this book. It is recommended that this value to be between 20% and 40% of the room temperature yield stress of the stud.

Maximum permissible stud stress to the flange (Sf_{max}): the value of the maximum stud stress that can be applied without damage to the flange. This value is calculated using the equations of ASME Boiler Code Section VIII Appendix 2 or through elastic-plastic finite element analysis evaluation. During this calculation the flange rotation ($\theta_{f_{max}}$) can be obtained for the maximum stud stress.

Target Assembly Stress (Sg_r): the value of installation gasket stress should be as high as possible to ensure that relaxation does not compromise the sealability over the lifetime of the equipment. It should be determined by the end-user with the gasket manufacturer.

Maximum Assembly Gasket Stress (Sg_{max}): is the maximum value of the gasket stress at room temperature that does not damage it during installation. This value is determined experimentally.

Minimum Gasket Seating Stress (Sg_{min-s}): this value is experimentally obtained based on the sealing area of the gasket. It is the minimum stress that the gasket should be installed to ensure an initial seal between the gasket and flanges.

Minimum Gasket Operating Stress (Sg_{min-o}): is the minimum stress value on the gasket to ensure sealability during the operation. This value is determined experimentally.

Gasket Relaxation Fraction (ϕg): is the fraction of gasket stress remaining after

relaxation. This value is determined experimentally.

Once these limits are determined, we can calculate the installation stress of the studs (Sb_{sel}) and check the installation according to the following methodology:

1. Calculation of the installation stress of the studs - Sb_{sel} :

$$Sb_{sel} = Sg_T (A_g / n_b A_b)$$

where n_b is the number of flange studs and A_b is the resistive area of each stud. A_g is the area of the gasket in contact with the sealing surface of the flange.

2. Check the stud upper limit:

$$\text{If } Sb_{sel} \text{ is greater than } Sb_{max} \text{ then } Sb_{sel} = Sb_{max}$$

3. Check the stud lower limit:

$$\text{If } Sb_{sel} \text{ is less than } Sb_{min} \text{ then } Sb_{sel} = Sb_{min}$$

4. Check the flange limit:

$$\text{If } Sb_{sel} \text{ is greater than } Sf_{max} \text{ then } Sb_{sel} = Sf_{max}$$

5. Check the gasket assembly stress:

$$Sb_{sel} \geq (Sg_{min-s} A_g / (A_b n_b))$$

6. Check the gasket minimum operating stress:

$$Sb_{sel} \geq ((Sg_{min-o} A_g) + (\pi / (4P ID^2))) / (\phi g A_b n_b)$$

7. Check the gasket maximum operating stress:

$$Sb_{sel} \leq Sg_{max} (A_g / (A_b n_b))$$

8. Check the flange rotation limit:

$$Sb_{sel} \leq Sf_{max} (\theta g_{max} / \theta f_{max})$$

If any of the 5 to 8 verifications, stated above, are not satisfactory, it is necessary to perform an analysis of the integrity to determine where the limitation is and what is the possible solution for the application that is being analyzed.

The experimental research ASME PVP2014 – Determination of ASME PCC-1 Appendix-O Gasket Parameters [49] proposes a method for determining the gaskets properties for PCC-1 Appendix-O installation force checks. The experimental values obtained in this study are used throughout this book.

9. EXAMPLE CALCULATION AND INSTALLATION ACCORDING TO THE ASME AND PCC-1 PROCEDURES

The following is an example of tightening calculation following the recommendations of Appendix-O of PCC-1 for gaskets as shown in Figure 2.6.

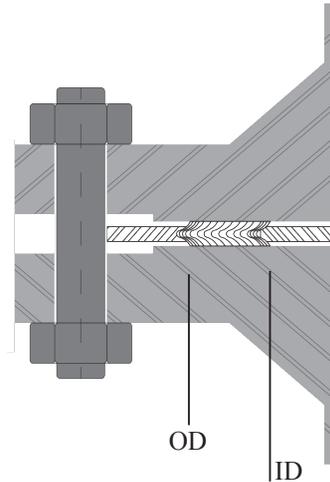


Figure 2.6

Design pressure: 800 psi (55 bar)

Design temperature: 750 F (400 C)

Characteristics of the flange and the studs:

Flange type: RF

Flange sealing surface roughness: 3.2 μm (125 μin)

Flange material: ASTM A105 (forged carbon steel)

Flange limit ($S_{f_{\max}}$): 84,000 psi

Flange rotation limit ($\theta_{f_{\max}}$): 0.39°

Number of the studs (n_b): 12

Diameter of the studs (D_b): 1 1/8 inches

Stud resistive area (A_b): 0.7276 sqin

Stud material: ASTM A 193 B7

Stud yield stress at room temperature (S_y): 105,000 psi

Stud maximum installation stress ($S_{b_{\max}}$) 70% of the yield stress: 73,500 psi

Stud minimum installation stress ($S_{b_{\min}}$) 20% of the yield stress: 21,000 psi

Stud allowable stress at room temperature (S_a): 25,000 psi

Stud allowable stress at operating temperature (S_b): 23,600 psi

Gasket characteristics:

Type: spiral wound gasket, stainless steel winding and flexible graphite filler

Gasket contact outside diameter (OD) = 8.19 in.

Gasket contact inside diameter (ID) = 6.85 in.

$m = 3$

$y = 10\,000$ psi

Minimum Gasket Seating Stress ($S_{g_{min-s}}$): 10,000 psi

Minimum Gasket Operating Stress ($S_{g_{min-o}}$): 3,900 psi

Maximum Assembly Gasket Stress ($S_{g_{max}}$): 43,000 psi

Target Assembly Stress (S_{g_T}): 35,000 psi

Gasket relaxation fraction (ϕ_g): 0.80

Maximum permissible flange rotation ($\theta_{g_{max}}$): 1°

Minimum stud force calculation according to ASME VIII Division 1 Appendix 2:

Flange gasket contact width:

$$N = (OD - ID) / 2 = (8.19 - 6.85) / 2 = 0.67 \text{ inches}$$

Gasket seating width:

$$b_0 = N / 2 = 0.545 / 2 = 0.335 \text{ in}$$

Effective gasket width:

$$b = 0.5 (b_0)^{0.5} = 0.5 (0.2725)^{0.5} = 0.2894 \text{ inch}$$

Effective gasket diameter:

$$G = (OD - 2b) = (8.19 - 2 \times 0.2894) = 7.6112 \text{ in}$$

Minimum design force at the operating pressure and temperature:

$$W_{m1} = (\pi G^2 P / 4) + (2b \pi G m P)$$

$$W_{m1} = (\pi \times 7.6112^2 \times 800 / 4) + (2 \times 0.2894 \times \pi \times 7.6112 \times 3 \times 800) = 69,614 \text{ lbf}$$

Gasket minimum seating force:

$$W_{m2} = \pi b G y$$

$$W_{m2} = \pi \times 0.2894 \times 7.6112 \times 10,000 = 69,199 \text{ lbf}$$

Minimum tightening force:

$$W_m = \text{greater value between } W_{m1} \text{ and } W_{m2}$$

$$W_m = 69,614 \text{ lbf}$$

Minimum stud area:

Minimum stud area at operating temperature:

$$A_{m1} = W_{m1} / S_b$$

$$A_{m1} = 69,614 / 23,600 = 2.9497 \text{ sqin}$$

Minimum stud area at installation (room) temperature:

$$A_{m2} = W_{m2} / S_a$$

$$A_{m2} = 62,875 / 25,000 = 2.7680 \text{ sqin}$$

Minimum stud area:

$$A_m = \text{greater value of } A_{m1} \text{ e } A_{m2}$$

$$A_m = 2.9497 \text{ in}^2$$

Verification of minimum area of studs:

$$A_b \geq A_m$$

where

$$A_b = (\text{number of studs}) \times (\text{resistive area of the studs}) = n_b \times A_b$$

$$A_b = 12 \times 0.7276 = 8.7312$$

therefore, the condition $A_b \geq A_m$ is satisfied

Verifications according with the PCC-1 - Appendix O:

Calculation of Sb_{sel} :

$$Sb_{sel} = Sg_T A_g / (n_b A_b)$$

$$Sb_{sel} = 35,000 \times 15.8286 / (12 \times 0.7276) = 63,450 \text{ psi}$$

Check the stud upper limit:

$$Sb_{sel} = \text{lower value between } Sb_{sel} (63,450) \text{ and } Sb_{max} (73,500)$$

$$Sb_{sel} = 63,450 \text{ psi}$$

Check the stud lower limit:

$$Sb_{sel} = \text{greater value between } Sb_{sel} (63,450) \text{ and } Sb_{min} (21,000)$$

$$Sb_{sel} = 63,450 \text{ psi}$$

Check the flange the limit:

$$Sb_{sel} = \text{lower value between } Sb_{sel} (64,450) \text{ and } Sf_{max} (84,000)$$

$$Sb_{sel} = 63,450 \text{ psi}$$

Check the gasket assembly stress:

$$Sb_{sel} \geq Sg_{min-s} A_g / (A_b n_b)$$

$$Sb_{sel} = 63,450 \text{ psi}$$

$$Sg_{min-s} A_g / (A_b n_b) = 10,000 \times 15.8286 / (12 \times 0.7276) = 18,128 \text{ psi}$$

therefore, the condition $Sb_{sel} \geq Sg_{min-s} A_g / (A_b n_b)$ is satisfied

Check the gasket minimum operating stress:

$$Sb_{sel} \geq ((Sg_{min-o} A_g) + ((\pi / 4) P ID^2)) / (\phi_g A_b n_b)$$

$$Sb_{sel} = 63,450 \text{ psi}$$

$$((Sg_{min-o} A_g) + ((\pi / 4) P ID^2)) / (\phi_g A_b n_b) =$$

$$= ((3,900 \times 15.8286) + ((\pi / 4) \times 800 \times 6.85^2)) / (0.80 \times 0.7276 \times 12) = 13,059 \text{ psi}$$

therefore, the condition $Sb_{sel} \geq ((Sg_{min-o} A_g) + ((\pi / 4) P ID^2)) / (\phi_g A_b n_b)$ is satisfied

Check the gasket maximum operating stress:

$$Sb_{sel} \leq Sg_{max} (A_g / (A_b n_b))$$

$$Sb_{sel} = 63,450 \text{ psi}$$

$$Sg_{max} A_g / (A_b n_b) = 43,000 \times 15.8286 / (0.7276 \times 12) = 77,953 \text{ psi}$$

therefore, the condition has been met

Verification of the rotation limit of the flange:

$$Sb_{sel} \leq Sf_{max} (\theta g_{max} / \theta f_{max})$$

$$Sb_{sel} = 63,450 \text{ psi}$$

$$Sf_{max} (\theta g_{max} / \theta f_{max}) = 84,000 (1 / 0.39) = 215,384 \text{ psi}$$

therefore, this condition $Sb_{sel} \leq Sf_{max} (\theta g_{max} / \theta f_{max})$ is satisfied

The value Sb_{sel} , 63,450 psi in this example, is used to calculate the torque or the force of the hydraulic tensioner for the gasket installation as detailed in Chapter 12 of this book.

10. FLANGE SEALING SURFACE FINISH

For each style of gasket there is a recommended finish for the flange sealing surface. ASME PCC-1 recommends surface finish for different styles of gaskets. As a general rule, it is necessary that the surface be grooved for non-metallic gaskets.

Metallic gaskets require a smoother finish. The reason for this difference is that non-metallic gaskets must be “bitten” by the sealing surface, therefore avoiding an excessive extrusion or blowout of the gasket.

Solid metallic gaskets require a very high force “to flow” the material into the flange surface. Consequently, the smoother the surface the lesser will be the possibility of leakage.

Spiral wound gaskets require some degree of superficial roughness in order to avoid “sliding” under stress.

The style of the gasket, therefore, shall determine the finish of the sealing surface, and there is no “optimum finish” to fit the diverse styles of gaskets. The gasket material should always be softer than the flange, to avoid damaging the flange surface finish.

10.1. RECOMMENDED FINISH FOR FLANGE SEALING SURFACES

The flange surfaces can vary from a rough casting finish to polished. However, the most common commercially available surface finish for steel flanges is concentric or

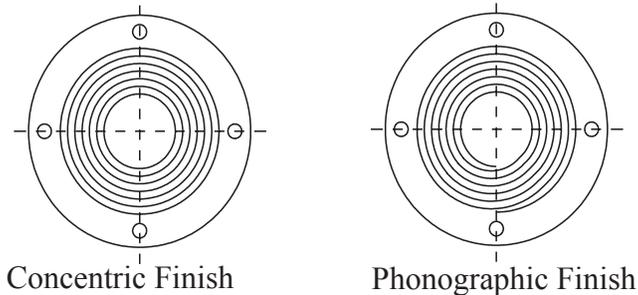


Figure 2.7

phonographic spiral grooves, as shown in Figure 2.7. Both are machined with a tool with a tip radius of $1/16''$ (1.6 mm) and 45 to 55 grooves per inch. This is known as a $125 \mu\text{in } R_a$ ($3.2 \mu\text{m } R_a$) to $250 \mu\text{in } R_a$ ($6.3 \mu\text{m } R_a$) finish.

10.2. RECOMMENDED FINISHING

Table 2.2 shows the Teadit recommended finishing for its most frequently used industrial gasket styles. According to the MSS SP-6 Standards Finishes for Contact of Pipe Flanges and Connecting-End Flanges of Valves and Fittings [53], the value R_a (roughness average), is expressed in micro-meter (μm) or micro-inches (μin). It should be evaluated by visual comparison with the R_a standards of ASME B46.1 [44] and not by instruments with stylus and electronic amplification.

Recommended Flange Sealing Surface Finishes

Table 2.2

GASKET DESCRIPTION		Flat Non-Metallic		Faced Corrugated Metal	Spiral Wound	Metal Jacketed	Faced Grooved Metal	Ring-Joint
		1/16"	>1/16"					
TEADIT STYLE		810 / 820		905	911 / 913 / 913M / 914	923 / 926 / 927	942	950 / 951 RX / BX
GASKET CROSS SECTION						923 926 927		950 951 RX BX
SURFACE FINISH R_A	μm	3.2 to 6.4	3.2 to 13	3.2 to 6.4	2.0 to 6.4	2.5 maximum	3.2 to 6.4	1.6
	μin	125 to 250	125 to 500	125 to 250	80 to 250	100 maximum	125 to 250	63

10.3. SURFACE FINISH AND SEALABILITY

Following are recommendations to harmonize the flange surface finish with the gasket style:

- The surface finish has a great influence on the sealability.
- A minimum seating stress must be obtained in order to seat the gasket against the flange imperfections. A soft gasket (like rubber) requires a seating stress lower than a denser gasket (like compressed fiber sheets).
 - The gasket seating force is proportional to the flange contact area. Reducing the width of the gasket or its contact area with the flange, the seating force can be reduced.
 - Regardless of the style of gasket or finish used, it is important that there are no scratches or radial tool marks on the sealing surface of the flanges. These radial marks are very difficult to seal, and with a metal gasket, it becomes almost impossible.
 - The phonographic grooves are more difficult to seal than the concentric ones. The gasket, when seated, must flow up to the bottom of the grooves to prevent any leak path to be formed from one end of the spiral to the other.
 - Since the materials have different hardness and flow characteristics, the choice of a type of flange surface finish is going to depend basically on the gasket material.

11. STYLES OF FLANGES

Even though flange design is beyond the scope of this book, in the following figures we show the most common combinations of flange faces.

11.1. FLAT FACE

Non-confined gasket (Figure 2.8). The contact surfaces of both flanges are flat. The gasket can be style RF, which goes up to the studs, or FF, covering the entire contact surface. Flat faces are normally used in flanges made out of fragile materials; for this reason it is not recommended to use a RF gasket style (on the right of Figure 2.8) to avoid flange rotation. This flange configuration allows the assembly and removal of the gasket without having to separate the flanges, facilitating maintenance work.

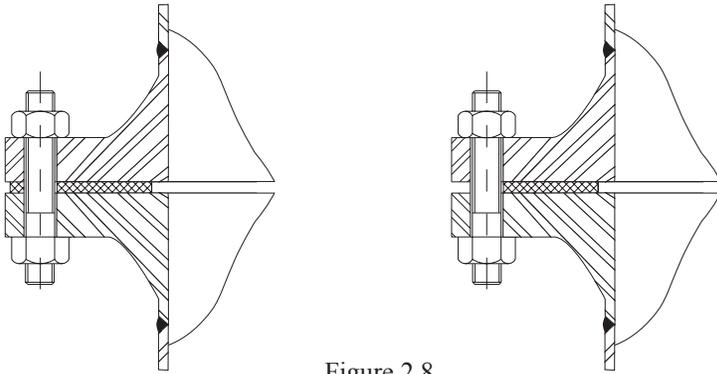


Figure 2.8

11.2. RAISED FACE

Non-confined gasket (Figure 2.9). Contact surfaces are raised about 1/16 in (1.6 mm) or 1/4 in (6.4 mm). Normally the gasket outside diameter is up to the studs. This flange configuration allows the assembly and removal of the gasket without having to separate the flanges, facilitating maintenance work. RF flanges are used more often in piping.

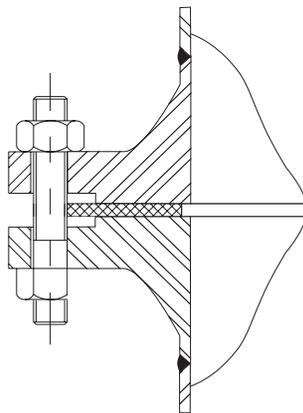


Figure 2.9

11.3. TONGUE AND GROOVE FACE

Totally confined gasket (Figure 2.10). The groove depth is equal or greater than the tongue height. The gasket has, usually, the same width as the tongue. It is necessary to separate the flanges in order to change the gasket. Since this style of flange exerts high seating stress on the gasket, it is not recommended for non-metallic gaskets.

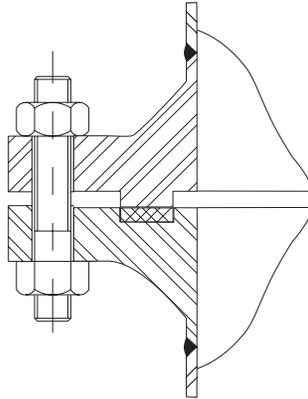


Figure 2.10

11.4. MALE AND FEMALE FACE

Semi-confined gasket (Figure 2.11). The most common style is the one on the left. The depth of the female is equal or less than the height of the male in order to avoid the possibility of direct contact of the flanges when the gasket is compressed. The female external diameter is up to 1/16 in (1.6 mm) larger than the male. The flanges must be separated to change the gasket. In the figures at the right and left, the gaskets are confined by the external diameter. In the center figure it is confined by the internal diameter.

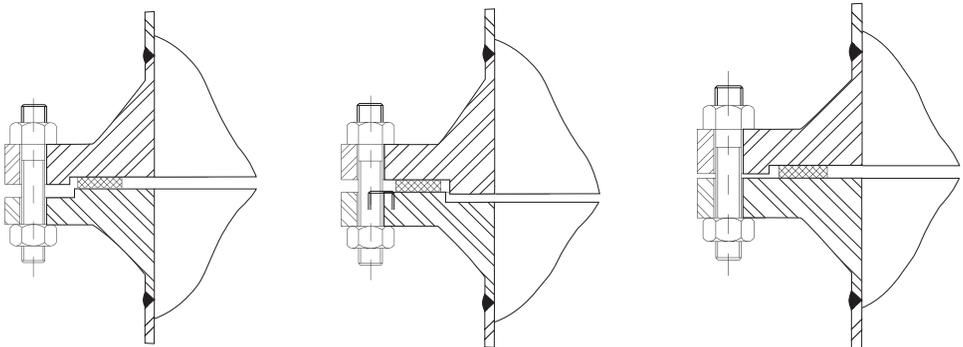


Figure 2.11

11.5. FLAT FACE AND GROOVE

Totally confined gasket (Figure 2.12). The external face of one of the flanges is plain and the other has a groove where the gasket is assembled. They are used in applications where the distance between flanges must be precise. When the gasket is seated the flanges touch each other. Only very resilient gaskets can be used in these types of flanges. Spiral-wound, O-Rings, non-solid metallic, pressure activated, and jacketed with metallic fillers are recommended.

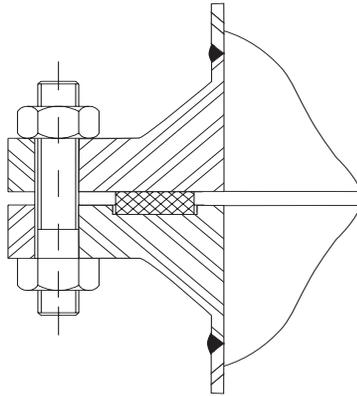


Figure 2.12

11.6. RING-JOINT FACE

Also called API Ring (Figure 2.13). Both flanges have channels with walls in a 23° angle. The gasket is made out of solid metal with an oval or octagonal profile. The octagonal profile is more efficient.

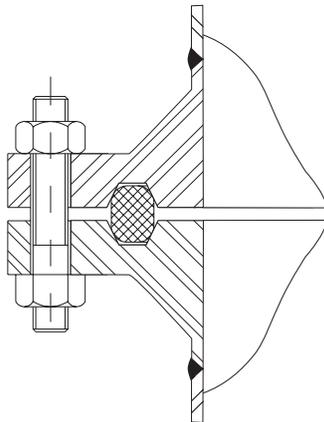


Figure 2.13

12. THE NEW GASKET CONSTANTS

Traditionally calculations for piping flanges and gaskets use values and formulas recommended by the American Society of Mechanical Engineers (ASME) Section VIII of Boiler and Pressure Vessel Code [5].

The ASME Code recommends values for minimum seating stress “y” and the maintenance factor “m” for various styles of gaskets. These values were determined from experimental work in 1943.

With the development of materials like Flexible Graphite, PTFE and the replacement of asbestos-based gaskets for other materials, it became necessary to determine the values of “m” and “y” for those new materials. In 1974, the Pressure Vessel Research Committee (PVRC) initiated an experimental program to better understand the behavior of a gasket in a flanged joint since there was no analytical theory that allowed determination of this behavior. This research was sponsored by thirty institutions, among them ASME, American Petroleum Institute (API), Fluid Sealing Association (FSA), and American Society for Testing Materials (ASTM) and others. The University of Montreal, Canada, was contracted to conduct the tests, and present their results and suggestions.

In the course of the research the impossibility of determining the values of “m” and “y” for the new materials was verified and it was also ascertained that the values for the traditional materials were not consistent with the experimentally obtained results.

The researchers then opted to develop, starting from an experimental basis, a methodology for gasket calculation that was coherent with the practical results. In this section this new form of calculation is demonstrated.

In 2018 ASTM has issued a procedure to determine the gasket constants [67]. However, at the time of editing, this new procedure has not being incorporated in the ASME Section VIII – Boiler and Pressure Vessel Code Appendix 2 calculations.

The gaskets chosen for testing were the most prevalent in industry.

- Metallic gaskets flat and corrugated in low carbon steel, soft copper and stainless steel.
- Metal o-rings.
- Compressed Fiber: NBR and SBR binders with different fibers.
- Flexible Graphite and PTFE sheets.
- Spiral Wound gaskets.
- Double Jacketed carbon and stainless steel with asbestos and non-asbestos fillers.

The gaskets were tested in the device shown in Figure 2.14.

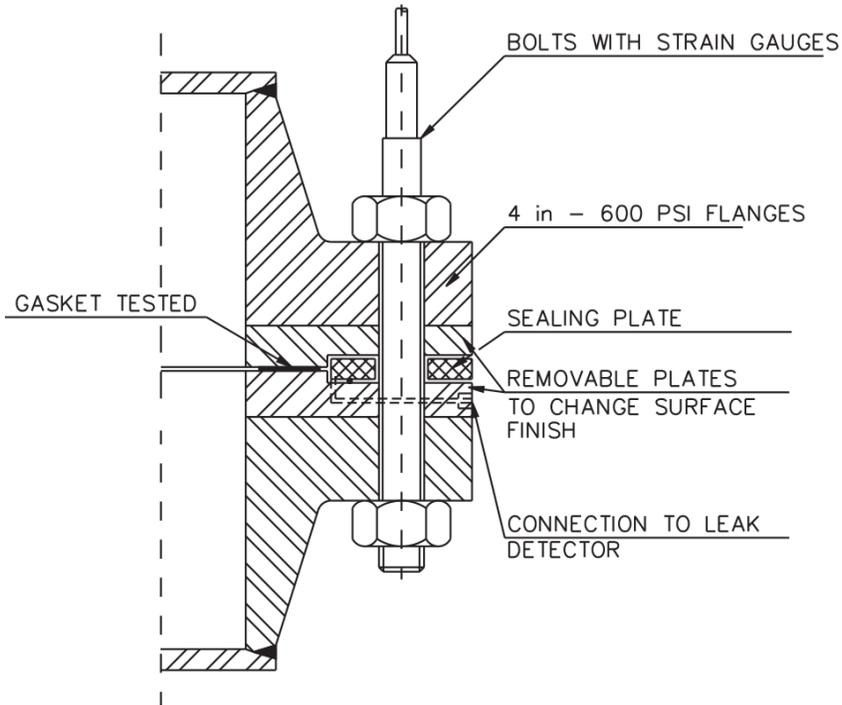


Figure 2.14

The tests were conducted with three pressures: 100, 200, and 400 psi with nitrogen, helium, kerosene and water. Sequence of steps followed during the test:

- The initial stress - part A of the chart Figure 2.15 -the gasket is tightened until deflection D_g keeping S_g constant, pressure is increased to 100 psi and the leak rate L_r is measured.
- The same procedure is repeated for 200 and 400 psi.
- The operating stress - part B of the Figure 2.15 - with pressure constant (100, 200 and 400 psi) S_g is decreased at regular intervals, deflection, D_g , and leak rate, L_r , are measured.
- This procedure is repeated until L_r exceeds the leak detector measuring capacity.
- Keeping the pressure constant, S_g is increased measuring D_g and L_r at regular intervals.

The Figure 2.16 shows an example of the fluid pressure as a function of mass leak rate for each value of gasket stress.

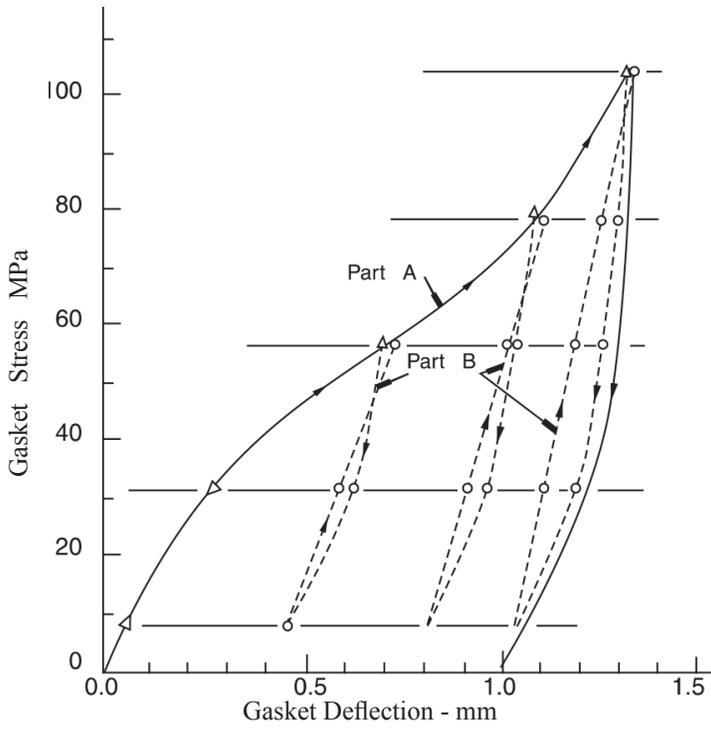


Figure 2.15

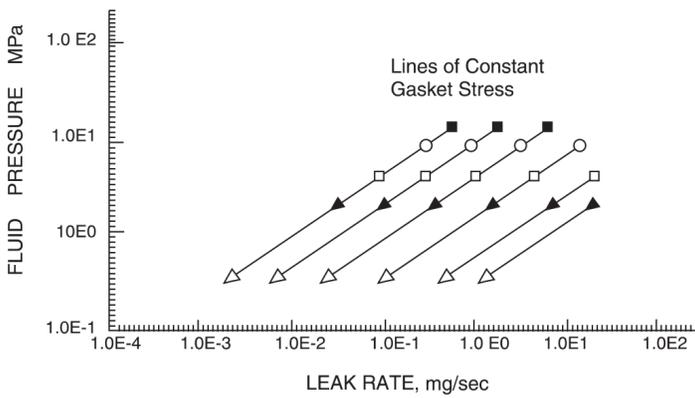


Figure 2.16

From experiments conducted at the University of Montreal various conclusions were reached:

- The gaskets demonstrate similar behavior no matter what style, or material they are made of.
- The tightness of a gasket is a direct function of the seating stress.
- The non-dimensional Tightness Parameter, T_p , was suggested as the best way to represent the behavior of the diverse styles of gaskets and materials.

$$T_p = (P/P^*) \times (L_{mm}^*/(L_{mm} \times D_t))^a$$

where:

$0.5 < a < 1.2$ being 0.5 for gases and 1.2 for liquids

P = Fluid Pressure (MPa)

P^* = Atmospheric Pressure (0.1013 MPa)

L_{mm} = mass leak rate per unit of diameter (mg/sec-mm)

L_{mm}^* = mass leak rate with 1 mg/sec-mm reference. Normally taken for a reference gasket with a 150mm outside diameter.

D_t = gasket outside diameter (mm)

The Tightness Parameter can be defined as the pressure necessary to create a certain level of leakage. For example a T_p equal to 100 signifies that a pressure of 100 atmospheres (1470 psi or 10.1 MPa) is necessary to create a leak of 1mg/sec in a gasket with an external diameter of 150 mm (6 in).

By plotting on a scale log-log the experimental values of the Tightness Parameter in function of the Gasket Stress we have the chart in Figure 2.17.

From the chart we can establish the Gasket Constants, obtained experimentally, that determine the gasket behavior. The constants are:

- G_b = intersection point of the seating stress line (part A of the test)
- a = inclination of the seating stress line
- G_s = focal point of the gasket stress relief lines (part B of the test)

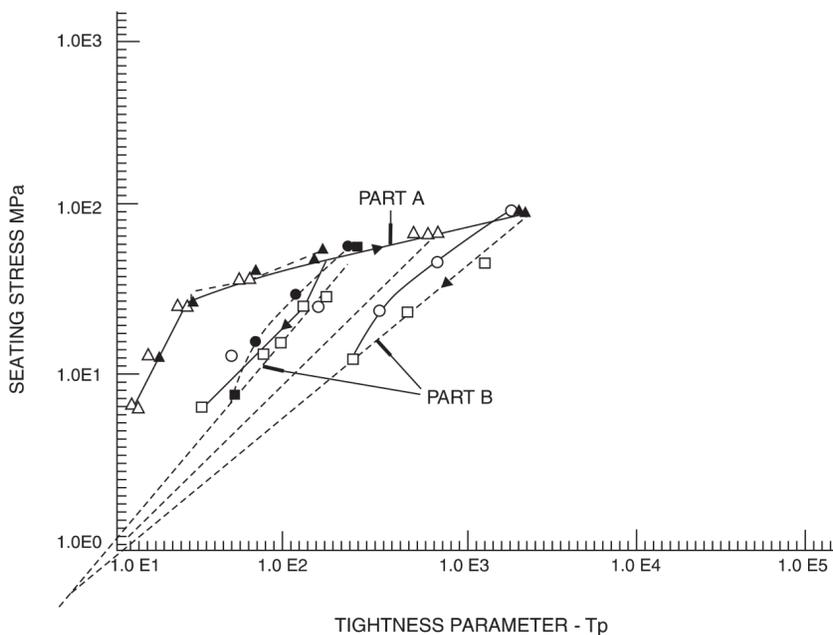


Figure 2.17

13. FUGITIVE EMISSIONS

To assure the life of future generations it has become necessary to reduce the pollutants released into the environment. Additionally the loss of products into the environment is a cost to the industry.

The great majority of pollutants like the Oxides of Carbon, Nitrogen and Sulfur are the result of burning of fossil fuels or the evaporation of Hydrocarbons. Their emissions are part of the industrial process and are subject to specific controls.

However, there are undesirable losses in pump shafts, valve stems and flanges, which in normal condition should not happen. These losses are known as Fugitive Emissions. It has been estimated that in the USA, the Fugitive Emissions are in the order of 300,000 tons per year. Most of the time it is necessary to have special equipment to detect them.

The control of the Fugitive Emissions is also a benefit to the plant safety and overall cost. Non-detected leaks are a major cause of fire and explosions in plants and oil refineries.

The USA was one of the first countries to control Fugitive Emissions with the 1990 Clean Air Act (CAA), which was cooperation between the industry and the Environmental Protection Agency (EPA). The CAA defined the list of Volatile Hazardous Air Pollutants (VHAP). If any product has more than 5% of a VHAP in its composition it has to be controlled.

To monitor the Fugitive Emissions the EPA has published the Reference Method 21, [54] which uses an Organic Vapor Analyzer (OVA). This equipment, calibrated for Methane, measures the concentration in parts per million (ppm) of the product. The OVA,

pumps the gas through a sensor to determine its concentration.

Flanges, valve stems, pump and agitator shafts and any other equipment that can cause a leak are subject to monitoring. For flanges, the maximum concentration, measured according to the EPA Method 21 is 500 ppm. There has been a trend towards reducing this value to 100 ppm [3].

For flanges, a first measurement must be done at about 1 meter (1 yard) from the source, in a direction against the prevailing wind, then at about 1 centimeter (1/2 in) around it. The value to be taken is the difference between the initial value and the highest value closer to the flange. If the difference is higher than 500 ppm the flange is considered as leaking and must be repaired.

The EPA Method 21 is a “go / no-go” kind of measurement, it determines if the flange is leaking or not. However, it does not give a quantitative value of the leaking. To obtain a quantitative value the equipment must be encapsulated, which is costly and not always possible.

The EPA has developed several studies to correlate the value in ppm and the flow per unit of time. The Chemical Manufactures Association (CMA) and the Society of Tribologists and Lubrication Engineers have also done studies and arrived at similar results. The leakage in grams per hour can be established as:

$$\text{Leakage} = 0.02784 (SV^{0.733}) \text{ g / hour}$$

Where SV is the value measured in parts per million.

The value obtained by this equation gives an approximate quantity of the product being released to the environment. For example if there is a leakage of 5000 ppm we have:

$$\text{Leakage} = 0.02784 (SV^{0.733}) = 0.02784 (5000^{0.733}) = 14.322 \text{ g / hour.}$$

To meet the hydrocarbon emissions requirements ASME has issued in 2017 a revision of the B16.20 - Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound and Jacketed [31] introducing a leakage performance test for Spiral Wound gaskets as shown in Chapter 7 of this book.

The German Standard VDI 2440 Emission Control Mineral Oil Refineries establishes two levels of emissions for flanges according to the type of gasket used. For gaskets previously tested and approved the value per flange is 0.001 milligram / (sec m) and 0.01 milligram / (sec m) for the other gaskets.

To be approved by the VDI 2440 the gasket shall have a maximum leakage 10^{-4} mbar.liter / (sec m) in a test with Helium at 1 bar differential pressure and gasket seating stress of 30 MPa. The design of flanged joints follows the standard VDI 2200.

If the fluid to be sealed is subject to fugitive emissions control it is recommended the type and gasket material be selected to meet the specific requirements of equipment.

MATERIALS FOR NON-METALLIC GASKETS

1. MATERIAL SELECTION

There are many non-metallic materials to choose from, depending on the operating conditions. Materials with similar performance and price are offered by manufacturers, which are continuously developing new products or changes to existing ones.

It is not practical to list and have the characteristics of all materials. For this book the most commonly used materials were listed with their properties. If a deeper knowledge is required it is recommended to consult with the manufacturer.

The four basic conditions, which must be observed on selecting a gasket material, are:

- Operating pressure.
- Bolt load.
- Resistance to chemical attack.
- Operating temperature.

Operating pressure and bolt load were analyzed in the Chapter 2 of this book.

The resistance to chemical attack can be influenced by several factors, mainly:

- Concentration of the chemical agent: a greater concentration does not necessarily make the agent more aggressive.
- Temperature of the corrosive agent: usually higher temperatures accelerate the chemical attack.
- Dew point: the fluid excursion through the dew point, in the presence of sulfur and water frequently found in gases resulting from combustion, can lead to extremely aggressive condensates.

In critical applications, laboratory tests are necessary in order to determine the compatibility of the gasket material with the media to be sealed at the operational conditions.

To design a gasket, an evaluation must be done, starting by the type of flange, bolt load, seating stress, etc. The definition of the style and material of the gasket must follow all steps. Usually gasket selection can be simplified by using the Pressure x Temperature Factor, as shown in this Chapter.

2. SERVICE PRESSURE AND TEMPERATURE

A good starting point in the selection of a gasket material is the service pressure and temperature. It is recommended to compare the application values with the data supplied by the gasket manufacturer, taking into account the continuous and peak values. After this comparison it is possible to select a material compatible with the application.

3. COMPRESSED FIBER SHEET

Since its introduction in the market, compressed fiber sheet has been the most used material in flange sealing since it has a wide spectrum of operating conditions. Due to its importance in the field of industrial sealing, Chapter 4 of this book is entirely dedicated to compressed fiber sheets.

4. POLYTETRAFLUORETYLENE - PTFE

PTFE, because of its exceptional chemical resistance, is the most used plastic for industrial sealing. Chapter 5 of this book is entirely dedicated to PTFE gaskets.

5. FLEXIBLE GRAPHITE

Flexible Graphite produced from natural graphite has Carbon content between 90% to 99.9%.

Graphite flakes are treated with acid, neutralized and dried. The flakes are then subjected to high temperature, and the water, after vaporizing, “blow-out” the flakes, which increase 200 times or more than its original volume. Those expanded flakes are calendered without any additive or binder, producing sheets of flexible material.

Flexible Graphite shows low creep defined as a continuous plastic deformation in a material subject to pressure. Therefore, there is a small loss of bolt load, which reduces the need for retightening of bolts.

Due to its characteristics, Flexible Graphite is one of the most reliable sealing materials. It offers excellent resistance to acids, alkaline solutions and organic composites. However it is not recommended for use in oxidant service in temperatures above 840 F (450 C), the heated Carbon reacts with the Oxygen forming Carbon Dioxide (CO₂). The result of such a reaction is the reduction of the gasket mass and, consequently of bolt load. The mass loss rate is related to the Flexible Graphite quality and use of oxidation

inhibitors. The Fluid Sealing Association (FSA) has developed the FSA-G-604-07 Oxidation Test for Flexible Graphite Materials [12] to evaluate the oxidation rate. Good quality Flexible Graphite without oxidation inhibitors submitted to the FSA test show a maximum of 20% oxidation rate with typical values 10% to 15%. With oxidation inhibitors the maximum is 10% and the typical value is 3%.

The chemical compatibility and temperature limits for several chemical and organic compounds are shown on Annex 3.1 at the end of this Chapter.

5.1. FLEXIBLE GRAPHITE SHEETS

Flexible Graphite sheets are supplied homogeneous or reinforced with AISI 316 Stainless Steel or Mylar insert. Sheet dimensions are 39.4" x 39.4" (1000 mm x 1000 mm) and the standard thickness are 1/64" (0.4mm), 1/32" (0.8 mm), 1/16 (1.6 mm), and 1/8" (3.2mm) 3.2 mm. The different styles are shown on Table 3.1. It is necessary to verify the chemical and temperature compatibility of the insert when designing gaskets with Flexible Graphite sheets.

The values for "m" and "y" and the maximum seating stress are shown in Table 3.3.

Table 3.1
Styles of Flexible Graphite sheets

Style	NA 2660	NA 2661	NA 2663	NA 2664
Insert	Homogeneous Sheet	Bonded AISI 316 stainless steel foil	Reinforced with AISI 316 stainless steel tanged core	Mylar film
Use for	General service, fragile flanges	General service, steam, hydrocarbon service	General service, steam, hydrocarbon service, heat transfer fluids	General service, fragile flanges

Table 3.2
Service Temperature

Service	Temperature F (C)				
	Minimum	Maximum			
		NA 2660	NA 2661	NA 2663	NA 2664
Oxidant	-328 (-200)	840 (450)	840 (450)	840 (450)	840 (450)
Steam	-328 (-200)	1200 (650)	1200 (650)	1200 (650)	1200 (650)
Neutral / reducing	-	5400 (3000)	5400 (3000)	5400 (3000)	5400 (3000)

Table 3.3
Flexible Graphite ASME Gasket Properties

Property	NA2660	NA2661	NA2663	NA2664
m	1.5	2	2	2
y (psi)	900	1000	2800	900
S_{g_{max}} - Maximum Seating Stress - MPa (psi)	140 (20000)	165 (24000)	165 (24000)	140 (20000)
S_{g_{min-s}} - Minimum Assembly Stress - MPa (psi)	30 (4350)	30 (4350)	30 (4350)	30 (4350)
S_{g_{min-o}} - Minimum Operating Stress - MPa (psi)	5 (725)	5 (725)	5 (725)	5 (725)
Relaxation fraction at 80 MPa/100°C ϕ_g	0.97	0.97	0.97	0.97
Maximum rotation $\phi_{g_{max}}$	0.7	0.7	0.7	0.7

The values for calculations according to ASME-PCC-1 have not been determined at the editing time of this book.

5.2. TEADIT GR 1700 APX2 – HOCHDRUCK - GRAPHITE SHEET WITH MULTIPLE FOIL INSERTS

Teadit GR 1700 APX2 Hochdruck is a multilayer, high strength gasket sealing sheet designed for high temperature applications . The sheet is comprised of 0.020” thick layers of highly oxidation resistant SIGRAFLEX APX2 flexible graphite and 0.002” thick layers of 316L stainless steel foil, manufactured with Hochdruck technology. Teadit GR 1700 was created for end users in the process industry to cover a broad range of demanding gasket requirements with a reliable and safe product. It is specifically designed for high temperature flat gasket applications.

5.2.1. TEADIT GR 1700 PROPERTIES

Temperature range: from -418F (-250C) to approx. 1200F (650C). Life time might be limited by the joint design, actual equipment temperatures and operating conditions. For applications above 1020F (550C) please consult Teadit Engineering for advice.

- Pressure range: from vacuum up to 3600 psi.
- Increased gasket life and improved operational safety due to very high temperature resistance
- Reliable product characteristics for high operational reliability
- Outstanding maximum permissible gasket pressure
- High blow-out resistance and mechanical strength
- Very adaptable sealing material during gasket assembly
- Excellent chemical resistance
- Long-term stability of assembly load and gasket stress
- No measurable cold or warm flow characteristics up to the maximum permissible gasket stress
- No aging or embrittlement (no adhesives or binders)
- Very easy to cut into required sealing shapes, even with conventional cutting equipment/tools

5.3. CRINKLED FLEXIBLE GRAPHITE TAPE

Flexible Graphite can also be used in tapes with or without adhesive backing, flat or corrugated, 0.4 mm (1/64") thick. Table 3.4 shows the styles and recommendations

Table 3.4
Flexible Graphite Crinkled Tape

Style	NA 2550	NA 2551
Description	Flat tape no adhesive backing	Corrugated tape with adhesive backing
Service	Valve stem packing molded in place rings	Form-in-place gasket, thread sealant, or for facing jacketed and other difficult-to-seal gaskets
Packaging	12.7 x 8 000 or 25.4 x 15 000 mm	6.4 or 12.7 x 8 000 and 19.1 or 25.4 x 15 000 mm

5.4. BRAIDED TAPE 3110-I

Teadit Style 3110-I is a braided Flexible Graphite tube reinforced with fine metal wires, folded flat to form a tape. It is a very versatile gasket material for static applications. It has excellent temperature resistance and can be used with a wide variety of media. It comes in the cross section of 15x 4 mm, with adhesive backing. Static seal for metallic and non-metallic flanges, lids, covers, hatches, reactors, autoclaves, heaters, etc.

6. ELASTOMERS

Rubber is very often used in gasket manufacturing due to its sealability characteristics. In the market place there are several types of polymers and formulations, which allow a great variety of choices.

6.1. PROPERTIES

The principal properties that make rubber a good material for gaskets are:

- Resilience: rubber is a material with high resilience. Being extremely elastic, it fills out the flange imperfections even when little seating stress is used.
- Polymers: there are various polymers with different physical and chemical characteristics.
- Combination of Polymers: the combination of various polymers in a formulation allows one to obtain different physical and chemical characteristics such as strength, resistance to chemical attack, hardness, etc.
- Variety: sheets or rolls with different thickness, colors, width, length and surface finishes can be manufactured to fulfill the needs of each application.

6.2. SELECTION PROCESS

Elastomeric gaskets are usually used at low pressure and temperature applications. In order to improve the mechanical resistance, reinforcement with one or two layers of cotton lining may be used. Normal hardness for industrial applications is 55 to 80 Shore A and thickness is 0.8 mm (1/32”) to 6.4 mm (1/4”). Following there is a list of elastomers used frequently in industrial gaskets. The ASTM designation is shown in parentheses. Annex 3.2 shows the chemical guidelines for elastomer selection.

6.3. NATURAL RUBBER (NR)

NR rubber offers good resistance to inorganic acids, ammonia, weak acids and alkali; low resistance to oil, solvents and chemical compounds. It ages due to ozone attack losing its strength and characteristics; not recommended for use in applications exposed to the sun and oxygen. It has good mechanical and friction resistance but very limited temperature range: from -60 F (-50 C) to 195 F (90 C).

6.4. STYRENE-BUTADIENE (SBR)

SBR rubber commonly called “synthetic rubber” was developed as an alternative to natural rubber. Recommended for service in cold and hot water, air, steam and some weak acids. It should not be used with strong acids, oils, grease and chlorates. It offers little resistance to ozone and to the majority of hydrocarbons. Temperature limits: -60 F (-50 C) to 250 F (120 C).

6.5. CHLOROPRENE (CR)

CR rubber is also known by its commercial name Neoprene (trademark of Du Pont). It has excellent resistance to oils, ozone, sunlight and aging. Low permeability to gases. Recommended for use with gasoline and non-aromatic solvents. It offers little resistance to strong oxidants and to aromatic and chlorate hydrocarbons. Temperature limits: -60 F (-50 C) to 250 F (120 C).

6.6. NITRILE (NBR)

NBR rubber is also known as Buna-N. It offers good resistance to oils, solvents, aromatic and aliphatic hydrocarbons and gasoline. It has low resistance to strong oxidant agents, chlorate hydrocarbons, ketones and esters. Temperature limits: -60 F (-50 C) to 250 F (120 C).

6.7. FLUOROELASTOMER (CFM, FVSI, FPM)

It is also known by its commercial name Viton (trademark of Du Pont). It offers excellent resistance to strong acids, oils, gasoline, chlorate solvents and aliphatic and

aromatic hydrocarbons. Not recommended for use with amines, esters, ketones and steam. Temperature limits: -40 F (-40 C) to 400 F (204 C).

6.8. SILICONE (SI)

Silicone rubber offers excellent resistance to the aging process, being unaffected by sunlight or ozone. For that reason it is often used in hot air. It has little mechanical resistance. It does not resist aliphatic and aromatic hydrocarbons or steam. Temperature limits: -150 F (-100 C) to 500 F (260 C).

6.9. ETHYLENE-PROPYLENE (EPDM)

EPDM rubber has good resistance to ozone, steam, strong acids and alkali. Not recommended for use with solvents and aromatic hydrocarbons. Temperature limits: -60 F (-50 C) to 250 F (120 C).

6.10. HYPALON (CSM)

Hypalon, similar to Neoprene rubber, offers excellent resistance to ozone, sunlight, chemical products and good resistance to oils. Temperature limits: -150 F (-100 C) to 500 F (260 C).

7. CELLULOSE FIBER SHEET

Cellulose fiber sheet is manufactured from cellulose fibers with glue and glycerin binders. It is often used in sealing low pressure and temperature oil products, gases and diverse solvents. It is available in rolls with 0.5 mm (0.020") to 1.6 mm (1/16") thick. Maximum temperature: 250 F (120 C).

8. CORK

Cork grains and rubber is bound to obtain cork compressibility, with the benefits of synthetic rubber. Largely used when the seating force is limited, as in flanges made out of thin stamped metallic sheets or fragile materials such as ceramic or glass. Recommended for service with water, lubricant oils and other oil derivative products at pressures up to 50 psi (3.5 bar). It offers little resistance to aging and is not recommended for service with inorganic acids, alkali or oxidant solutions. Temperature limits: -20 F (-30 C) to 250 F (120 C).

9. FABRIC AND TAPES

Gaskets can be made of Silica, Fiberglass, Ceramic or Aramid fabrics impregnated with Elastomers like SBR, Chloroprene, Fluoroelastomer or Silicone. To improve the mechanical resistance the fabric may be reinforced with a thin metallic wire.

Fabrics are folded and molded to form the gaskets. These gaskets are used mainly for boiler manholes and handholes, oven doors and large ducting access panels. They can

be circular, oval, square or any other form.

Its thickness can be from 1/32" (0.8 mm) to 1/8" (3.2 mm). Greater thickness can be obtained by folding layers.

10. TADPOLE

Fabrics can be rolled around a core as shown in Figure 3.1. The fabrics can be impregnated with Elastomers. The fabric overlaps the core, forming a flat lip in which holes for bolts can be cut. The circular section offers a reliable sealing for irregular surfaces subject to frequent opening and closing, such as oven doors and large ducting access panels.

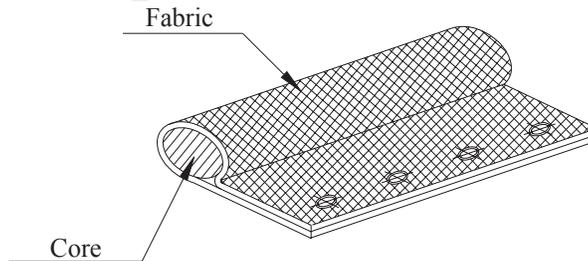


Figure 3.1

11. CERAMIC FIBER BLANKETS

In the form of blankets it is used to manufacture gaskets for use in hot gases and low pressure service. This material is also used as filler for metallic gaskets. Temperature limit: 2190 F (1200 C).

12. CERAMIC FIBER MILLBOARD

Millboards, originally designed as a thermal insulation material, can be cut into gaskets for low pressure, high temperature ducting systems. Temperature limit: 1450 F (800 C).

13. BEATER ADDITION

The Beater Addition process (BA) used in the manufacture of gasket materials is similar to the one used in paper manufacture. Synthetic, organic or mineral fibers are beaten with binders, which "open" them, providing a large contact area with the binders. This enlarged area of contact increases the mechanical resistance of the product. Several binders can be used such as Nitrile Latex and SBR rubber.

Due to its low pressure and temperature resistance it has limited use for industrial applications. Materials produced by the BA process are available in reels up to 48" (1200 mm) wide with 0.012" (0.30 mm) to 1/16" (1.6 mm) thick.

ANNEX 3.1

FLEXIBLE GRAPHITE CHEMICAL COMPATIBILITY
Annex 3.1 (continued)

Product	Maximum Temperature F (C)
Acetic acid	All
Acetic anhydride	All
Acetone	All
Air	840 (450)
Alum	All
Aluminum chloride	All
Ammonium bifluoride	All
Ammonium bisulfate	All
Ammonium hydroxide	All
Ammonium sulfate	All
Ammonium thiocyanate	Not recommended
Amyl alcohol	All
Aniline	All
Aniline hydrochloride	Not recommended
Arsenic acid	All
Arsenic trichloride	All
Benzene	All
Benzene hexachloride	All
Benzyl sulfonic acid	Not recommended
Boric acid	All
Bromine	Not recommended
Bromine water	Not recommended
Butyl alcohol	All
Butyl cellosolve	All
Calcium chlorate	Not recommended
Calcium hypochlorite	Not recommended
Carbon tetrachloride	All
Carbonic acid	All
Chloral hydrate	All
Chloroethylbenzene	All
Chloroform	All
Citric acid	All

FLEXIBLE GRAPHITE CHEMICAL COMPATIBILITY
Annex 3.1 (continued)

Copper sulfate	All
Cupric chloride	All
Deoxidine	All
Ethyl alcohol	All
Ethyl chloride	All
Ethyl mercaptan – water	All
Ethylene chlorohydrin	Not recommended
Ethylene dibromide	All
Ethylene dichloride	All
Fatty acids	All
Ferric chloride	All
Ferrous chloride	All
Ferrous sulfate	All
Formic acid	All
Fluorine	Not recommended
Folic acid	All
Gasoline	All
Glycerin	All
Heat transfer fluids	All
Hydrogen chloride	All
Hydrobromic acid	All
Hydrochloric acid	All
Hydrofluoric acid	All
Hydrofluosilicic acid	Not recommended
Hydrogen sulfide + water	All
Iodine	Not recommended
Isopropyl acetate	All
Isopropyl alcohol	All
Isopropyl ether	All
Kerosene	All
Lactic acid	All
Manganous sulfate	All
Mannitol	All

FLEXIBLE GRAPHITE CHEMICAL COMPATIBILITY
Annex 3.1 (continued)

Methyl alcohol	All
Methyl isobutyl ketone	All
Monochloroacetic acid	All
Monochlorobenzene	All
Monoethanoamine	All
Monovinyl acetate	All
Nickel chloride	All
Nitric acid	Not recommended
Octyl alcohol	All
Oxalic acid	All
Paraldehyde	All
Phosphoric acid	Not recommended
Phosphorous trichloride	Not recommended
Refrigerant fluids	All
Sodium chloride	Not recommended
Sodium chlorite	Not recommended
Sodium hydroxide	All
Sodium hypochlorite	Not recommended
Stannic chlorite	All
Steam	1200 (650)
Stearic acid	All
Sulfur dioxide	All
Sulfur monochloride	Not recommended
Sulfurous acid	All
Sulfuric acid	Not recommended
Tetrachloroethane	All
Trichloroethylene	All
Water	All
Xylene	All
Zinc ammonium chloride	All
Zinc chloride	All
Zinc sulfate	All

Annex 3.2

ELASTOMER RESISTANCE GUIDELINES

1: excellent

2: good

3: fair

4: poor

NBR: Nitrile

FPM : Fluoroelastomer

CR : Chloroprene

SBR: Styrene-Butadiene

NR : Natural

SI : Silicone

Service		NR	SBR	CR	NBR	FPM	SI
Acid	Diluted (<10%)	2	2	3	2	1	3
	Concentrated	3	4	3	4	2	4
Alkali	Diluted (<10%)	2	2	2	2	2	3
	Concentrated	3	3	2	3	4	4
Hydrocarbons	Aliphatic	4	4	3	1	1	4
	Aromatic	4	4	4	2	1	4
Flame propagation		4	4	1	4	2	4
Gas permeability		3	3	1	3	2	3
Gasoline	Aromatic	4	4	4	4	2	4
	Non Aromatic	4	4	2	3	2	2
Halogenated solvents		4	4	4	4	2	4
Ketones		4	4	4	4	4	4
Mineral oils		4	4	3	1	1	4
Ozone		4	4	3	2	2	1
Sunlight		4	4	1	4	1	1
Water		2	1	4	1	3	3

COMPRESSED FIBER GASKETS

1. TEADIT COMPRESSED FIBER GASKETS

Compressed Fiber Gaskets are cut from sheets formed by vulcanization under pressure, on large diameter rolls. These are sheets comprised of a structure containing mineral or synthetic fibers and a combination of elastomers. Because of relative low cost compared with good performance these materials are widely used to fabricate industrial gaskets. Compressed Fiber Gaskets cover a wide spectrum of applications. Their main characteristics are:

- High resistance to seating stress.
- Low creep relaxation.
- Wide range of operating temperatures and pressures.
- Resistance to an extensive range of chemical products.

2. FIBERS

Fibers provide the structural function and give the high mechanical resistance characteristic of Compressed Fiber Gaskets. The most used fibers are Aramid, Carbon, Glass, Mineral and Cellulose.

3. ELASTOMERS

The choice of elastomers, vulcanized under pressure with fibers, determines the chemical resistance of Compressed Gaskets. They also give the flexibility and elastic properties. The most used elastomers are:

- **Natural Rubber (NR):** a natural product extracted from tropical plants, it has excellent elasticity, flexibility. It has low resistance to chemical attack and high temperature.
- **Styrene-Butadiene Rubber (SBR):** also known as synthetic rubber, was developed as an alternative for natural rubber and has similar properties.
- **Chloroprene (CR):** better known by its commercial name Neoprene. It offers excellent resistance to oil, gasoline, and ozone.
- **Nitrile Rubber (NBR):** better chemical and temperature resistance when compared to SBR and CR rubbers. It has excellent resistance to oils, gasoline, aliphatic and aromatic hydrocarbonates as well as animal and vegetable oils.
- **Chlorosulfonated Polyethylene Rubber (CSM):** known by one of its brand name of Hypalon, it has excellent chemical resistance as well as resistance to acids and alkali

4. WIRE MESH

A wire mesh is used to increase the blowout resistance. Gaskets with wire mesh are recommended where it is necessary to have high mechanical strength. The wire mesh is usually made of carbon steel.

Compressed Gaskets with wire mesh insertion have less sealability because the sheet/mesh interface increases the leak rate of the gasket. It also makes it more difficult to cut the gasket; they should only be used where blowout is an issue.

5. SURFACE FINISH

The several styles of Teadit Compressed Gaskets are manufactured with two surface finishes, all of them Teadit branded; this has to do with gasket removal and subsequent flange face clean up after being in service.

- Natural
- Graphite
- Anti-stick: Teadit has developed a proprietary process that reduces the gasket adherence to the flange and its easy removal, an important characteristic when the process requires frequent disassembly of the flange. This finish also practically eliminates gasket residues sticking to the sealing surface helping the installation of the new gasket. The anti-stick finish has no detrimental effect on gasket performance. To show the effectiveness of the non-stick finish, samples manufactured from the same Compressed Fiber Gasket style with and without anti-stick finish were tested per ASTM F607 [57] showing a reduction up to 81% of the adhesion force.

6. SHEET DIMENSIONS

Teadit Compressed Gasket sheets are available in the following sizes:

- 59 in (1500 mm) by 63 in (1600 mm).
- 59 in (1500 mm) by 126 in (3200 mm).

The thickness range is from 1/64 in (0.4 mm) up to 1/8 in (3.2 mm). Some styles also are available in thickness up to 1/4 in (6.4 mm).

7. ASTM STANDARD TEST METHODS

Standardization organizations have issued several standards to assure product consistency and uniformity, as well as to compare products from different manufacturers. The most common physical tests are shown below.

The ASTM test procedures were developed to characterize gasket materials, they are used as a quality control tool, to compare and approve products. The ASTM standards are not recommended to be used as a performance indication since they do not reproduce actual field conditions. In most cases the test specimen is 1/32”(0.8 mm) thick. Most industrial applications are 1/16”(1.6mm) or thicker. ASTM standards were the first standards developed for Compressed Fiber Gaskets and are used as specification reference by all manufacturers.

7.1 COMPRESSIBILITY AND RECOVERY – ASTM F36J

Compressibility and Recovery is evaluated according to ASTM F36 Standard Test Method for Compressibility and Recovery of Gasket Materials [13]. Compressibility is the thickness reduction when the material is compressed by a load of 5000 psi (34.5 MPa). It is expressed as percentage of the original thickness.

Recovery is the increase in thickness after the load removal. It is expressed as percentage of the compressed thickness. Compressibility indicates the capacity of the material to flow and fill up flange imperfections. A higher compressibility material is easier to seat. Recovery indicates the materials capacity to resist pressure and temperature fluctuations.

7.2 SEALABILITY – ASTM F37

Sealability is measured according to ASTM F37 Standard Test Method for Sealability of Gasket Materials [14]. It indicates the material sealing performance under laboratory controlled conditions with Nitrogen or Isooctane.

7.3 LOAD RETENTION – ASTM F38

Load retention is measured according to ASTM F38 Standard Test Method for Creep Relaxation of a Gasket Material [15]. It indicates how the material retains the bolt load as a function of time. It is expressed as a percentage of the initial load. A stable material will retain a higher

residual load. On the opposite, an unstable material will show a continuous loss of load and consequently a loss of sealability. A high temperature or thickness reduces the load retention. The test parameters are initial load 3045 psi (21 MPa), temperature 212F (100C) for 22 hours.

7.4 FLUID IMMERSION – ASTM F146

This test is used to determine changes in the material when in contact with fluids in controlled conditions of temperature and time. The standard used is ASTM F146 Standard Test Method for Fluid Resistance of Gasket Materials [16]. The most used fluids are ASTM No. 3 Petroleum based oil and ASTM Fuel B which is 70% Isooctane and 30% Toluene. After the immersion, the compressibility, recovery, increase in thickness, tensile strength and increase in volume results are compared with values before the immersion.

7.5 TENSILE STRENGTH – ASTM F152

Tensile strength is measured according to ASTM F152 – 95 Standard Test Method for Tension Testing of Non-metallic Gasket Materials [17]. It is used as a quality control parameter in sheet manufacturing. Their values are not directly related to the gasket sealability.

7.6 IGNITION LOSS – ASTM F495

Tested according to ASTM F495 Standard Test Method for Weight Loss of Gasket Materials Upon Exposure to Elevated Temperature [18]. It indicates the material loss of mass with temperature.

8. EN – DIN TEST METHODS

European standards are more performance oriented to reproduce the service conditions. Test samples are 2mm (0.079 in) thick and at temperatures typical of actual field service.

8.1 GASKETS FOR GAS SERVICE TEST

The standard DIN 3535 – Gaskets for Gas Supply – Part 6: Gasket materials based on fibres, graphite or polytetrafluorethylene (PTFE) for gas valves, gas appliances and gas mains [19] establish the requirements for gaskets to be used in valves, equipment and installations for gases operating up to 150C (302 F). The test specimen is 2 mm thick. The following evaluations are performed: finishing, thickness, density, sealability, weight loss after immersion, compressibility, torque retention and recovery in both cold and hot conditions.

8.2 COMPRESSION CREEP TESTING

DIN 52913 – Testing of static gaskets for flange connections – Compression creep testing of gaskets made from sheets [20] evaluates the load loss with the time at a specified initial load and temperature. The test parameters are established in the standard according to the gasket material. The result is expressed in MPa and it is residual load on the gasket.

9. PRESSURE X TEMPERATURE DIAGRAMS

There is no internationally recognized standard to evaluate Compressed Fiber Gaskets operational limits of pressure and temperature. The Teadit Research and Development Laboratory has developed a procedure to determine the maximum recommended operating pressure as a function of the service temperature. The test fluid is Nitrogen.

10. MAXIMUM TEMPERATURE

Since there is no standard to establish the maximum temperature limit for Compressed Gaskets, Teadit has developed a test protocol to determine this property. It was presented at the ASME/JSME Pressure Vessel and Piping Conference PVP 2004 the paper Determination of Critical Temperature of Non-Asbestos Fiber Sheet Gaskets [21]. The test is performed with Nitrogen.

11. STEAM TESTS

Typical applications of Compressed Fiber Gaskets are saturated and superheated steam lines. For these services specific test procedures have been developed to determine the material suitability for each service.

11.1 SATURATED STEAM TEST

The Fluid Sealing Assiation (FSA) has developed the test protocol FSA-NMG-204-02 Standard Test Method for Perfomance of Non-Asbestos Gaskets in High Temperature Saturated Steam [22]. A minimum of 10 thermal cycles, 1000 hours at 300 C (572 F). Water leak is evaluated at each cycle by the weight loss of the test device.

11.2 SUPERHEATED STEAM TEST

To develop Compressed Fiber Gaskets for super-heated steam Teadit has developed a test for this kind of service; Superheated Steam Test Rig for Compressed Non-As-

bestos Gaskets Evaluation [23]. It was presented at the ASME Pressure Vessel and Piping Conference PVP 2004.

This evaluation is performed with 6 in – class 150 flanges with temperatures up to 400 C (752 F). The test rig can simulate several service conditions like thermal cycles, low bolt load and blowout.

11.3 REQUIREMENTS FOR POTABLE WATER, FOOD AND PHARMACEUTICAL SERVICE

Testing of raw materials and traceability is performed to ensure that the Compressed Fiber Sheet is suitable for use with food, pharmaceuticals and drinking water. There are specific standards for each of these applications as described below.

11.3.1 FOOD AND PHARMACEUTICAL SERVICE

The US Government’s Code of Federal Regulations of the US Food and Drug Administration (FDA), through its Department of Health and Human Services, issues regulatory instructions for various food products. Title 1, Volume 3, Chapter 1, Subchapter B, Section 177.2600 - Rubber articles intended for repeated use [54], sets out the criteria used in the manufacture of Compressed Fiber Sheets for food use. The raw materials employed must be those recognized as safe and approved for use in food or its packaging.

In addition to the approval of the raw materials, Compressed Fiber Sheets samples must be subjected to water and n-hexane extraction testing with maximum extractable limits. Independent laboratories issue a report confirming that the product tested meets the requirements of Section 177.200. It is important to note that the FDA does not perform tests or issue certificates.

11.3.2 POTABLE WATER SERVICE

The National Sanitary Foundation (NSF) and the American National Standards Institute (ANSI) issue standards for products used in drinking water treatment systems. The NSF / ANSI Standard 61 Drinking Water System Components - Health Effects [55] covers materials or products that come into contact with drinking water, drinking water treatment chemicals, or both.

NSF Certified Compressed Fiber Sheets is produced with approved and controlled raw materials, the final product is subjected to chromatography testing. NSF conducts periodic audits of raw materials, manufacturing, end product and stock to ensure that the requirements set forth in NSF / ANSI 61 are being met.

12. COMPRESSED FIBER GASKETS DESIGN

12.1 OPERATIONAL CONDITIONS

To initiate a gasket design it is necessary to verify the operating conditions. The service pressure and temperature must be compared with maximum values recommended for the material to be used.

Teadit has developed the Pressure x Temperature charts for each Compressed Fiber Gasket style. To verify that the product is adequate for the service conditions the design pressure and temperature must be within the recommended range. If the operating conditions fall between the curves other factors such as the product to be sealed and thermal cycles have to be considered, consult with Teadit since the material may not be recommended for the application.

12.2 CHEMICAL RESISTANCE

Before deciding on the use of a specific style of Compressed Fiber Gasket it is necessary to verify its chemical resistance to the media to be sealed. Annex 4.2 at the end of this Chapter shows the compatibility for several chemical products and Teadit Compressed Fiber Gasket. The Chemical Compatibility Tables were developed taking into account the media pure condition, laboratory tests, field experience as well as technical literature were also considered.

Important: the recommendations of Annex 4.2 are generic and the operating conditions of the application must be verified before using a specific material.

12.3 ASME FLANGE GASKET DIMENSIONS

ASME B16.21 Non-Metallic Gaskets for Pipe Flanges [25] shows gasket dimensions for use in several ASME standard flanges, including B16.5 flanges, the most used in industrial applications. Annexes 4.3 to 4.10 have the gasket dimensions for ASME flanges. The gaskets can be of two styles: Raised Face or Full Face. It is recommended to use the style RF whenever possible since it is more economical and allows greater seating stress with the same bolt load. Full face gaskets should be used in Flat Face assemblies.

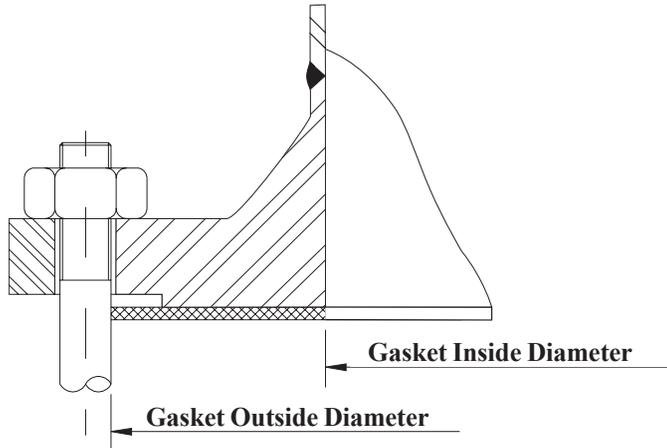


Figure 4.1

12.4 RAISED FACE (RF) - STYLE 810RF

Style 810RF: the outside diameter reaches as far as the bolts (Figure 4.1).

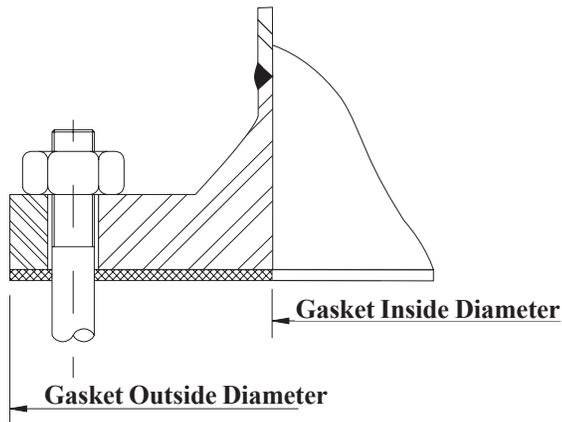


Figure 4.2

12.5 FULL FACE (FF) - STYLE 820FF

Style 820FF: the gasket outside diameter is equal to the flange outside diameter (Figure 4.2).

12.6 GASKETS FOR HEAT EXCHANGERS - STYLE 830

It is very common to use Compressed Fiber Gasket in Shell and Tube Heat Exchangers. Due the small flange width of their tongue and groove flange facings, it is recommended to control the maximum seating stress, to avoid crushing the gasket. It should be considered that TEMA – Standards of the Tubular Exchanger Manufacturers Association [24] does not recommend the use of non-metallic gaskets for some Heat Exchanger types. In most cases, Compressed Fiber Gaskets are used for hydrostatic testin, then are replaced by a metal gasket for the actual service.

12.7 NON STANDARD FLANGES

The use of sheet Compressed Fiber Gaskets in non-standard flanges is very frequent as in heat exchangers, reactors and other equipment. In this case, design recommendations of Chapter 2 must be carefully observed.

13. MANUFACTURING TOLERANCES

The manufacturing tolerances based on ASME B16.21 are shown in Table 4.1.

Table 4.1
Manufacturing Tolerances

Gasket Style	Dimension - in		Tolerance - in (mm)	
Raised Face RF	Outside Diameter	NPS 12 and smaller	-1/16(1.6)	+0.04 (1.0)
		NPS 14 and larger	-1/8 (3.2)	+1/8(3.2)
	Inside Diameter	NPS 12 and smaller	±3/32 (±2.4)	
		NPS 14 and larger	±1/8 (±3.2)	
Full Face FF	Outside Diameter	NPS 12 and smaller	-0.0	+1/16 (1.6)
		NPS 14 and larger	-0.0	+1/8 (-3.2)
	Inside Diameter	NPS 12 and smaller	±1/16 (±1.6)	
		NPS 14 and larger	±1/8 (±3.2)	
	Bolt circle diameter		±1/16 (±1.6)	
	Center to center of bolt holes		±3/64 (±1.0)	

14. LARGE DIAMETER GASKETS

When the gasket dimensions are larger than the sheet or when manufacturing in segments is recommended for economical reasons, two kinds of splicing are used: dovetail and bevelled.

14.1 DOVE-TAIL GASKETS

This splice is more frequently used in industrial applications. It can be used to make gaskets of almost any size or thickness (Figure 4.3). Each section of male and female is adjusted in such a way as to have a minimum gap between the mating parts.

It is recommended that the gasket is produced as follows:

Gaskets with a flange width (L) equal or less than 8" (200 mm), one dovetail:

$$A = L / 3$$

$$B = 1.5 (L / 3), \text{ minimum } \frac{3}{4}'' (20 \text{ mm}) \text{ to } 2'' (50 \text{ mm})$$

$$C = (L / 3) + \frac{1}{2}'' (12 \text{ mm})$$

Gaskets with a flange width (L) more than 8" (200 mm), two dovetails:

$$A = L / 5$$

$$B = 2'' (50 \text{ mm})$$

$$C = (L / 5) + \frac{1}{2}'' (12 \text{ mm})$$

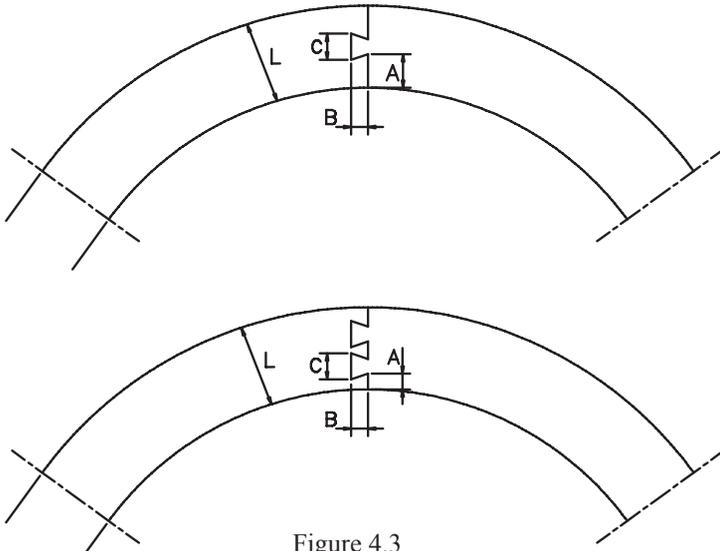


Figure 4.3

14.2 BEVELLED SPLICE

When the seating stress is not adequate for dove tailed gaskets, bevelled and bonded splices can be used (Figure 4.4). Due to manufacturing difficulty, this style of splicing can only be used for gaskets with a minimum thickness of 1/8 in (3.2 mm).

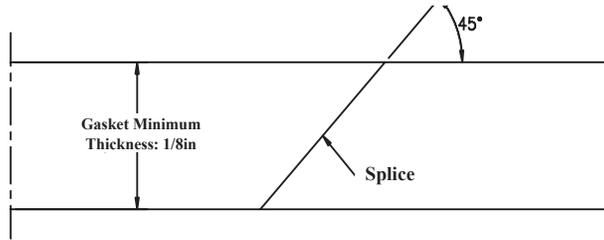


Figure 4.4

15. GASKET WIDTH AND THICKNESS

To specify the gasket thickness it is necessary to know the roughness of the flange sealing surface. As a general rule it is recommended that the gasket should be as thin as possible but capable of filling out flange irregularities. Good engineering practice recommends the following thicknesses:

- Flanges up to 10 in use 1/16" (1.6 mm).
- Flanges larger than 10 in use 1/8" (3.2 mm).

A thickness greater than 1/8" (3.2 mm) should be used only in very large, worn out or out of flatness flanges, for these cases to 1/4" (6.4 mm) gaskets can be used.

In smooth or polished flanges the minimum possible thickness should be used. But because there are no grooves or irregularities to "bite" the gasket, it can be blown out by the radial force.

ASME Section VIII, Division 1, Appendix II [5] recommends the gasket contact areas shown in Table 4.2.

Table 4.2
Recommended Minimum Gasket Contact Width

Flange Inside Diameter - ID	Gasket Contact Width
24 in (600 mm) < ID ≤ 36 in (900 mm)	1 in (25 mm)
36 in (900 mm) < ID < 60 in (1500 mm)	1 ¼ in (32 mm)
ID ≥ 60 in (1500 mm)	1 ½ in (38 mm)

16. BOLT LOAD

The bolt load must be calculated according to recommendations in Chapter 2 of this book. The "m" and "y" values for ASME Code calculation and the values for gasket installation calculations per ASME PCC-1 are in Table 4.3.

Table 4.3
ASME Code and PCC-1 Calculation Values

Style	Thickness (in)	m	y (psi)	Sg _{max} (ksi)	Sg _{min-s} (ksi)	Sg _{min-o} (psi)	φg	θg _{max}
NA1001	1/16	2.0	3500	30	11	3900	0.7	1
	1/8	2.0	3500	20	10	3900	0.7	1
1082SAN	1.6	3.0	2900	25	7	3900	0.7	1
	3.2	4.0	3600	25	7	3900	0.7	1
NA1080	1/16	3.2	3500	N/A	N/A	3900	0.7	1
	1/8	3.8	5000	N/A	N/A	3900	0.7	1
NA1081	1/16	3.0	2.900	25	7	3900	0.7	1
	1/8	4.0	3.600	25	7	3900	0.7	1
NA1085	1/16	2.5	2500	N/A	N/A	3900	0.7	1
	1/8	6.8	3500	N/A	N/A	3900	0.7	1
NA1100	1/16	2.9	3500	30	18	3900	0.7	1
	1/8	4.1	3500	22	11	3900	0.7	1
NA1122	1/16	2.6	4500	32	8	3900	0.7	1
	1/8	6.1	4500	16	10	3900	0.7	1
NA1088	1/16	2.0	2500	25	7	3900	0.7	1
	1/8	3.0	2500	25	7	3900	0.7	1
NA1035	1/16	2.5	3500	N/A	N/A	3900	0.7	1
	1/8	3.2	3000	N/A	N/A	3900	0.7	1
NA1000	1/16	2.5	2600	25	5	3900	0.7	1
	1/8	3.5	3200	25	6	3900	0.7	1
1161SAN	1/16	2.0	3000	30	5	2200	0.7	1
	1/8	2.0	3400	20	4	1450	0.7	1

N/A: the values for calculations according to the ASME-PCC-1 have not been determined at the editing time of this book.

17. GASKET FINISH

Natural finish is used the most, it has an anti-stick compound in its formulation to reduce adhesion and facilitate the gasket removal. A graphite finish should be used only when removal of the gasket is frequent.

To install Compressed Fiber Gaskets, it is not recommended to apply oil, grease, silicone, etc to the gasket surface to help its installation. These products can cause extrusion of the gasket material. Figure 12.23 shows a comparison of the Compressed Fiber Gaskets installed with the same seating stress using some of these products. The manufacturer should be consulted if it is necessary to use any of these products.

18. FINISH OF THE FLANGE SEALING SURFACE

The flange surface finish in contact with the gasket should be rough to “bite” the gasket. The Flange Surface Finish recommended by ASME PCC-1 Guidelines for Pressure Boundary Bolted Joint Assembly [6] is shown in Table 4.4.

Concentric grooves are recommended, as flanges with phonographic grooves are more difficult to seal. A leak path may result if the seating stress does not flow the gasket material up to the root of the grooves.

Radial tool marks or scratches are difficult to seal and must be avoided.

Table 4.4
Flange Surface Finish

Gasket thickness - in (mm)	Flange Surface Finish	
	μm	μin
Up to 1/16” (1.6)	3.2 to 6.4	125 to 250
Thicker than 1/16” (1.6)	3.2 to 13	125 to 500

19. STORAGE

Compressed Fiber Gaskets as well as finished gaskets should not be stored for long periods of time. The elastomer used as a binder ages changing its physical characteristics. A dry cool place without direct solar light should be used for storage. Direct contact with water, oil and chemicals should be avoided. Sheets and gaskets must be kept preferably flat, without folds or wrinkles. Also it is recommended not to hang or roll them in order to prevent permanent deformations. To determine the aging of Compressed Fiber Gaskets, Teadit has presented at the ASME PVP 2010 the paper Compressed Non-Asbestos Gaskets Shelf Life Prediction [27].

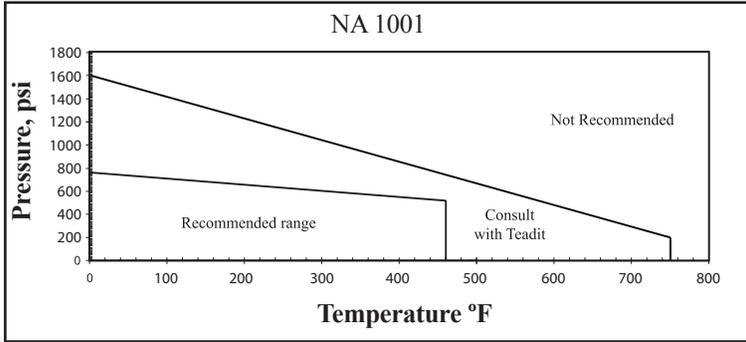
20. TEADIT COMPRESSED FIBER SHEET PRODUCTS

Teadit Compressed Fiber Sheet products for industrial applications available at the time of the publication of this book are shown in this section. Being a product in continuous development new formulations are often offered, please consult with Teadit for special application requirements.

20.1 NA 1001 – COMPRESSED FIBER SHEET WITH ARAMID FIBERS/NBR BINDER

Style NA1001 is a compressed fiber sheet gasket material produced from a combination of aramid and other synthetic fibers and bonded with nitrile rubber (NBR).

Style NA1001 is a very good general service gasket material that has numerous applications in the process industries and in the water and wastewater industry. It is also commonly used in equipment such as valves and pumps. Style NA1001 is suitable for service handling the following general media categories:

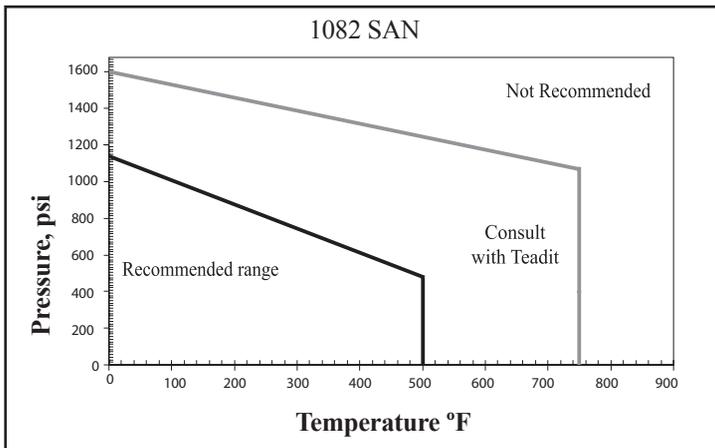


NA 1001 Pressure x Temperature diagram

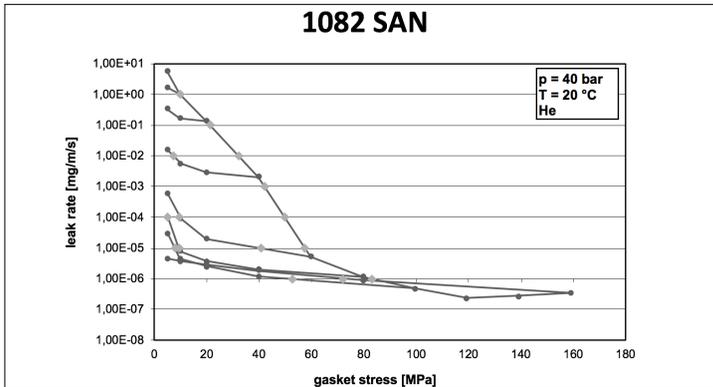
20.2. TEADIT 1082 SAN – Sanitary Service Compressed Fiber Sheet

Style 1082 SAN is specifically formulated to pass criteria established in NSF-61 for sealing materials, as well as providing excellent resistance to conductivity. Compressed Fiber Sheet technology provides mechanical and service characteristics unmatched by standard elastomeric grades.

Style 1082 SAN was developed to allow compliance for drinking water system components with NSF-61, from source to tap. Certification to NSF-61 provides assurance to a highest level that 1082 SAN is safe for use in drinking water service.



1082 SAN Pressure x Temperature diagram



1082 SAN Sealability EN 1355 with Helium at 40 bar

20.3. NA 1076 - Compressed Fiber Sheet with Aramid Fibers/Neoprene Binder

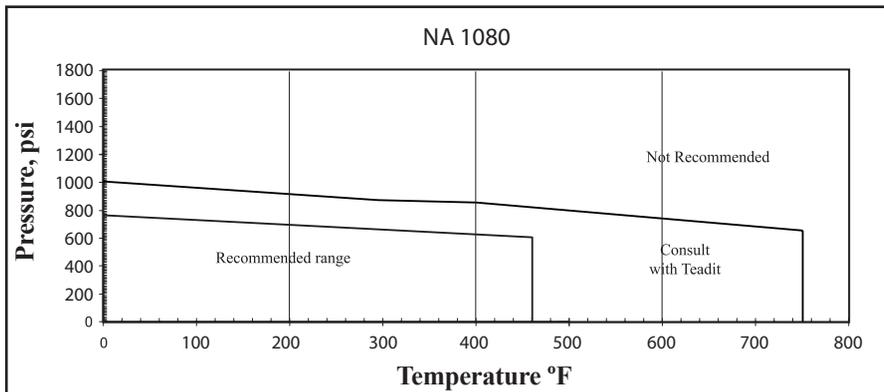
Style NA1076 is a compressed fiber sheet gasket material produced from a combination of aramid and other synthetic fibers and bonded with neoprene rubber (CR).

Style NA1076 is a good all purpose sheet that is specifically formulated to handle a broad range of refrigerants. In addition, Style 1076 is suitable for services handling water, saturated steam, oils, fuels, mild acids and alkalis.

20.4. NA1080 - Compressed Fiber Sheet with Aramid Fibers/SBR Binder

Style NA1080 is a compressed fiber sheet gasket material produced from a combination of Aramid Fiber, Inorganic Fillers and bonded with Styrene-Butadiene Rubber (SBR).

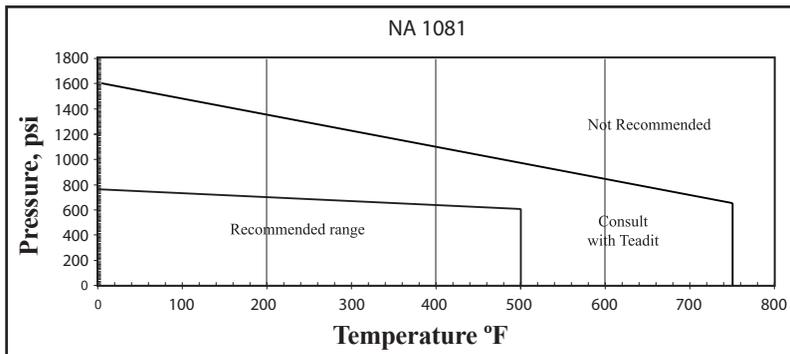
Style NA1080 has numerous applications in the process industries handling media like: mild acids and alkalis, water, brine, saturated steam, air, industrial gases, general chemicals, neutral solutions.



NA 1080 Pressure x Temperature diagram

20.5. NA1081 - Compressed Fiber Sheet with Kevlar® Fibers/NBR Binder

Style NA1081 is a compressed fiber sheet gasket material produced from a combination of Aramid Fibers, Inorganic Fillers and bonded with Nitrile Rubber (NBR). Style NA1081 has numerous applications in the process industries handling media like: mild acids and alkalis, water, hydrocarbons, oils, gasoline, steam, air, industrial gases, general chemicals, neutral solutions.

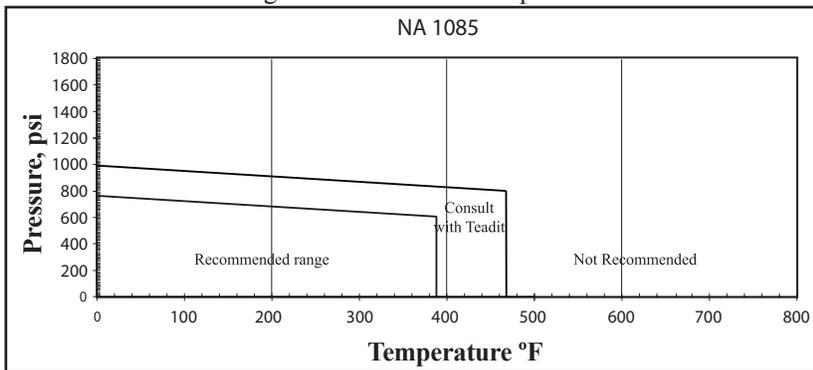


NA 1081 Pressure x Temperature diagram

20.6. NA1085 - Compressed Fiber Sheet with Aramid Fibers/Hypalon Binder

Style NA1085 is a compressed fiber sheet gasket material produced from aramid fibers and bonded with Hypalon® rubber.

Style NA1085 is a severe service non-asbestos sheet that is specifically formulated to provide an effective seal against most acids in the process industries.

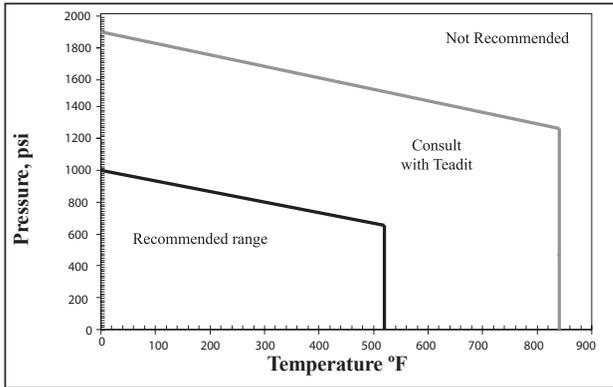


NA 1085 Pressure x Temperature diagram

20.7. NA1100 - Compressed Fiber Sheet with Carbon Fibers /NBR Binder

Style NA1100 is a compressed fiber sheet gasket material produced from carbon fibers and graphite, bonded with nitrile rubber (NBR).

Style NA1100 is a premium grade, multi-service gasket sheet, designed to handle the extremes of pressure and temperature, and it cuts very easily and cleanly. The versatility of this sheet enables a plant to standardize on one sheet for a multitude of applications and avoid the confusion of having to choose from several different sheets.

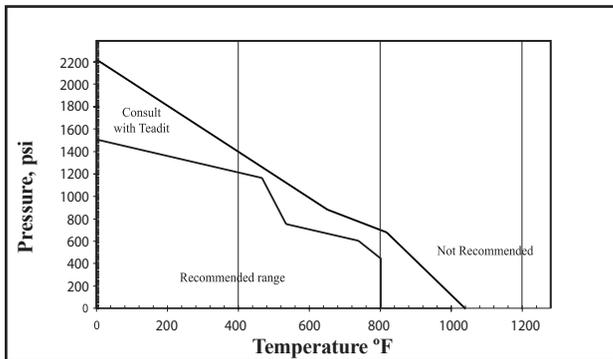


NA 1100 Pressure x Temperature diagram

20.8. NA 1122 - Compressed Fiber Sheet with Inorganic Fibers /NBR Binder

Style NA1122 is a compressed fiber sheet gasket material produced from a combination of inorganic fibers and special fillers, bonded with nitrile rubber (NBR).

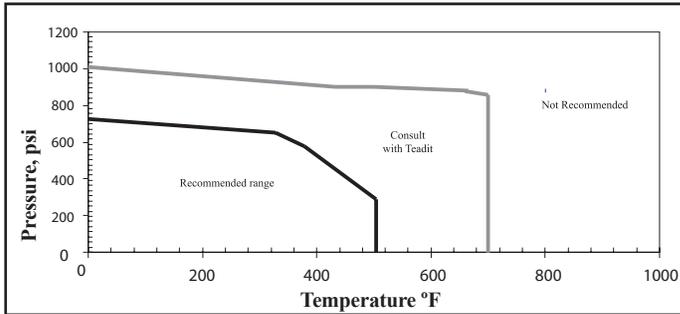
Teadit style NA1122 was developed to have superior thermal stability in order to replace compressed asbestos gasket sheets in thermal cycling applications. It is specifically recommended for saturated and superheated steam applications. Field tests have proven the results found in our laboratories and have confirmed the higher performance of the NA1122 compressed sheet in steam service.



NA 1122 Pressure x Temperature diagram

20.9 NA 1035 - Compressed Fiber Sheet with Aramid Fiber /SBR Binder

Style NA1035 is a very good general service CFS produced from a combination of Aramid Fibers, Inorganic Fillers and bonded with Styrene-Butadiene Rubber (SBR). The product has numerous applications in the process industries handling media like; mild acids and alkalis, water, brine, saturated steam, air, industrial gases, general chemicals, neutral solutions.

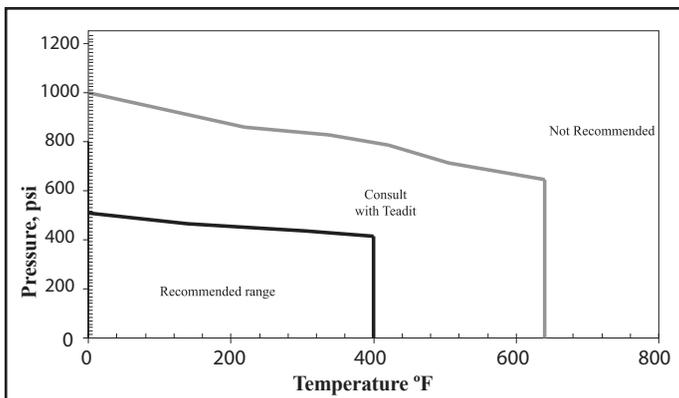


NA 1035 Pressure x Temperature diagram

20.10 NA 1088 - Compressed Fiber Sheet with Controlled Swell

Style NA1088 is a controlled swell sheet gasket material with a proprietary binder & reinforced with a synthetic/ inorganic fiber blend. It is designed for demanding applications requiring excellent sealability, torque retention, recovery, and conformability to uneven flange surfaces.

Style NA1088 is used in difficult to seal applications where inadequate bolt loading or flange surface conditions are not ideal, in low to moderate flange load conditions. The material provides a controlled swell in the presence of oils, fuels, lubricants, and water/coolant. It is used in heavy duty & industrial oil sealing applications such as diesel engine oil in Compressors, Generators, Pumps, Fuel Pumps, Gear Boxes, Cast Water Flanges, Transformers, Sight Glasses, Access Covers, Handhole/Manhole.

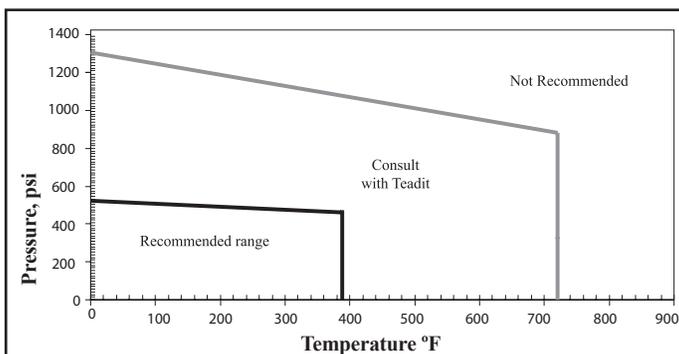


NA 1088 Pressure x Temperature diagram

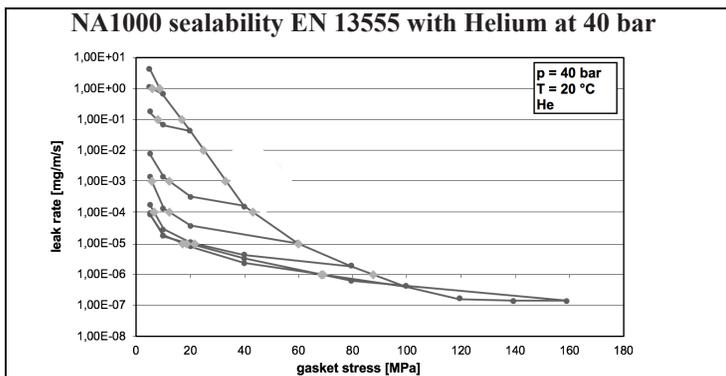
20.11 NA 1000 – Premium Compressed Fiber Sheet with Aramid Fiber /NBR Binder

Style NA1000 is a premium compressed sheet gasket material produced from a combination of aramid, inert and reinforced fillers and bonded with nitrile rubber (NBR). It is manufactured through the hot calendar process under rigorous quality control standards that are registered under ISO-9001 certification.

Style NA1000 is a premium soft gasket material that has numerous applications in the process industries and in the water and waste water industry. Style NA1000 is suitable for service handling the following general media categories: mild acids; alkalies; water; brine; air; industrial gases; animal and vegetable oils; petroleum and derivatives; neutral solutions and refrigerants..



NA1000 Pressure x Temperature diagram

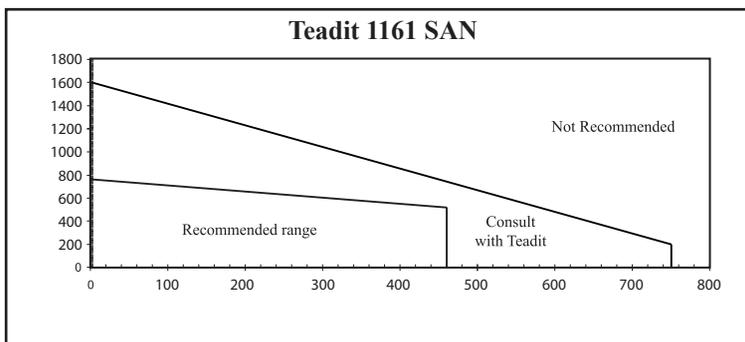


NA1000 Sealability

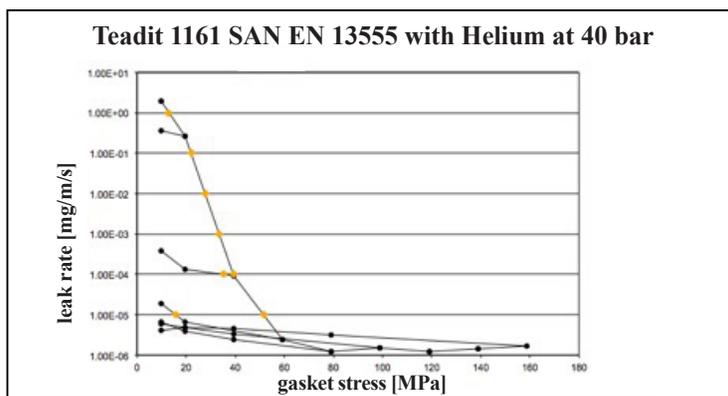
20.12 TEADIT 1161 SAN – Sanitary Service Gasket Sheet

Teadit style 1161 SAN is developed to allow compliance for drinking water system components with NSF-61, from source to tap. Certification to NSF-61 provides assurance to a highest level that 1161 SAN is safe for use in drinking water service.

Teadit style 1161 SAN is specifically formulated to pass criteria established in NSF-61 for sealing materials. Compressed Fiber Sheet technology provides mechanical and service characteristics unmatched by standard elastomeric grades, providing excellent sealability at low seating stress. This property is very important for water system piping which are usually low-pressure class flanges.



Teadit 1161 SAN Pressure x Temperature diagram



Teadit 1161 SAN Sealability

Annex 4.1
Physical properties – Tedit Compressed Fiber Sheet Materials

Physical properties			NA 1001	1082 SAN	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	NA 1000	NA 1035	NA 1088	1161SAN
Temperature Limit	Maximum	F	750	752	700	716	500	464	840	1022	716	716	650	575
		C	400	400	370	380	260	240	450	550	380	380	343	300
	Continuous Service	F	460	500	392	490	752	362	518	806	392	518	400	425
		C	240	260	200	270	400	200	270	430	200	270	205	220
Pressure Limit	Maximum	psi	1595	1160	725	1015	1160	1015	1900	2177	1305	1015	1000	1160
		bar	110	80	50	70	80	70	130	150	90	70	69	80
	Continuous Service	psi	725	1595	-	725	1595	725	1000	1480	580	725	500	290
		bar	50	110	-	50	110	50	70	100	40	50	34.5	20
Density	lb/ft ³		109	121	106	122	121	106	106	100	81	112	103	106
	g/cm ³		1.75	1.95	1.70	1.96	1.95	1.70	1.65	1.46	1.3	1.80	1.65	1.7
Compressibility – ASTM F36A - % Recovery – ASTM F36A - % , min.			7-17	5-15	7-17	7-17	5-15	5-15	5-15	12-22	15-25	7-17	10-20	10-20
Tensile Strain Across Grain - ASTM F152	psi		1670	1740	1740	2030	1740	2030	2175	1305	1885	1450	1160	1000
	MPa		11.5	12	12	14	12	14	15	9	13	10	8	7
Ignition Loss - % , max.			34	27	31	28	27	37	50	23,5	36	35	35	25
Thickness Increase ASTM F 146 - %	ASTM IRM 903		12	15	30	40	15	-	15	15	15	50	-	15
	Fuel B		10	10	20	20	10	-	15	15	15	30	-	15
Weight Increase ASTM F 146 - %	ASTM IRM 903		15	15	-	30	15	-	15	30	-	45	-	20
	Fuel B		15	10	20	30	10	-	15	20	20	20	-	20
Creep Relaxation ASTM F 38 - % , max.			25	20	20	22	20	26	22	-	48	-	22	29
Torque Retention	DIN 52913 MPa		28	36	-	37	36	28	35	43	37	32	34	29
Sealability	DIN 3535-6 - mg/s.m		0.001	0.006	-	-	0.006	-	0.003	0.1	<0.001	-	-	0.02

Annex 4.2

Chemical Compatibility Chart* Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Acetaldehyde	B	B	B	B	C	B	B	C	B	B	B
Acetamida	A	A	A	C	B	C	A	B	A	A	A
Acetic Acid (T<190F)	A	A	A	A	A	A	A	A	A	A	A
Acetic Acid (T≥190F)	C	C	C	C	-	C	C	A	C	C	C
Acetic Anhydride	C	C	C	C	B	C	C	A	C	C	C
Acetone	C	C	C	B	C	B	C	B	C	C	C
Acetonitrile	C	C	C	-	-	-	C	-	C	C	C
Acetophenone	C	C	C	C	C	C	C	C	C	C	C
Acetylene	A	A	A	A	B	A	A	B	A	C	A
Acrylic Acid	B	B	B	-	-	-	B	-	B	B	B
Acrylonitrile	C	C	C	C	C	C	C	C	C	C	C
Adipic Acid	A	A	A	B	A	B	A	A	A	A	A
Air	A	A	A	A	A	A	A	A	A	A	A
Aluminum Acetate	A	A	A	B	B	A	A	A	A	A	A
Aluminum Chloride	A	A	A	A	A	A	A	A	A	A	A
Aluminum Fluoride	B	A	A	A	A	A	A	A	A	A	A
Aluminum Nitrate	A	A	A	A	A	A	A	A	A	A	A
Aluminum Sulfate	A	A	A	B	A	B	A	A	A	A	A
Alums	A	A	A	A	-	A	A	A	A	A	A
Ammonia – Cold (Gas)	A	A	A	A	A	A	A	A	A	C	A
Ammonia – Hot (Gas)	C	C	C	C	B	C	C	B	C	C	C
Ammonia – Liquid, Anhydrous	B	B	B	C	A	C	B	B	B	B	B
Ammonium Carbonate	-	C	C	A	A	A	C	C	C	C	C
Ammonium Chloride	A	A	A	A	A	A	A	A	A	A	A
Ammonium Hydroxide 30% (T<120F)	A	A	A	C	A	C	A	A	A	A	A
Ammonium Nitrate	A	A	A	A	A	A	A	A	A	A	A
Ammonium Phosphate	A	A	A	A	A	A	A	A	A	A	A
Ammonium Sulfate	A	A	A	B	A	B	A	A	A	A	A
Amyl Acetate	B	B	B	B	C	B	B	C	B	B	B
Amyl Alcohol	B	B	B	B	B	A	B	A	B	B	B
Aniline	C	C	C	B	C	B	C	C	C	C	C
Aniline Dyes	-	C	C	B	B	B	C	B	C	C	C
Anon (Cyclohexanone)	C	C	C	C	C	C	C	C	C	C	C
Aqua Regia	C	C	C	C	C	C	C	C	C	C	C
Aroclors	C	C	C	C	B	C	C	C	C	C	C
Asphalt	B	B	B	C	B	C	B	B	B	B	B

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart*
Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Barium Chloride	A	A	A	A	A	A	A	A	A	A	A
Barium Hydroxide	A	A	A	A	A	A	A	A	A	A	A
Barium Sulfide	A	A	A	B	A	B	A	A	A	A	A
Beer	A	A	A	A	A	A	A	A	A	A	A
Benzaldehyde	C	C	C	C	C	C	C	-	C	C	C
Benzene	C	C	C	C	C	C	C	C	C	C	C
Benzoic Acid	B	B	B	B	C	B	B	B	B	B	B
Benzoyl Chloride	C	C	C	C	C	C	C	C	C	C	C
Benzyl Alcohol	C	C	C	C	B	C	C	B	C	C	C
Benzyl Chloride	C	C	C	C	C	C	C	C	C	C	C
Biphenyl	C	C	C	C	C	C	C	C	C	C	C
Blast Furnace Gas	C	C	C	C	C	C	C	C	C	C	C
Bleach (Sodium Hypochlorite)	C	C	C	C	C	C	C	B	C	C	C
Boiler Feeder Water	A	A	A	A	A	A	A	A	A	A	A
Borax	B	B	B	B	A	B	B	A	B	B	B
Boric Acid	A	A	A	A	A	A	A	A	A	A	A
Brines	A	A	A	A	A	A	A	A	A	A	A
Bromine	C	C	C	C	C	C	C	C	C	C	C
Bromine Trifluoride	C	C	C	C	C	C	C	C	C	C	C
Butadiene	C	C	C	C	C	C	C	B	C	C	C
Butane	A	A	A	C	A	C	A	A	A	C	A
Butanone (MEK)	-	C	C	C	C	C	C	C	C	C	C
Butyl Acetate	B	B	B	C	C	C	B	C	B	B	B
Butyl Alcohol (Butanol)	A	A	A	A	A	A	A	A	A	A	A
n-Butyl Amine	-	B	C	C	C	C	C	C	C	C	B
Butyl Methacrylate	C	C	C	C	-	C	C	C	C	C	C
Butyric Acid	C	C	C	C	-	C	C	C	C	C	C
Calcium Bisulfite	C	C	C	C	A	C	C	A	C	C	C
Calcium Chloride	A	A	A	A	A	A	A	A	A	A	A
Calcium Hydroxide (T<120F)	A	A	A	B	A	A	A	A	A	A	A
Calcium Hypochlorite	B	B	B	C	C	C	B	A	B	B	B
Calcium Nitrate	A	A	A	A	A	A	A	A	A	A	A
Cane Sugar Liquors	A	A	A	A	A	A	A	A	A	A	A
Carbolic Acid, Phenol	C	C	C	C	C	C	C	C	C	C	C
Carbon Dioxide, Dry	B	A	A	A	B	A	A	A	A	B	A
Carbon Dioxide, Wet	A	A	A	A	B	A	A	A	A	B	A
Carbon Disulfide	C	C	C	C	C	C	C	C	C	C	C

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart* Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Carbon Monoxide	A	A	A	B	B	B	A	B	A	B	A
Carbon Tetrachloride	B	B	B	C	C	C	B	C	B	B	B
Carbonic Acid	B	B	B	B	A	B	B	B	B	B	B
Castor Oil	A	A	A	B	A	A	A	A	A	A	A
Cetane (Hexadecane)	A	A	A	C	-	C	A	B	A	B	A
China Wood Oil	A	A	A	C	B	C	A	C	A	A	A
Chlordane	B	B	B	C	-	C	B	C	B	B	B
Chlorinated Solvents	C	C	C	C	C	C	C	C	C	C	C
Chlorine (Dry)	B	B	B	B	C	B	B	B	B	C	B
Chlorine (Wet)	C	C	C	C	C	C	C	C	C	C	C
Chlorine Dioxide	C	C	C	C	C	C	C	C	C	C	C
Chlorine Trifluoride	C	C	C	C	C	C	C	C	C	C	C
Chloroacetic Acid	C	C	C	C	C	C	C	A	C	C	C
Chlorobenzene	C	C	C	C	C	C	C	C	C	C	C
Chloroform	C	C	C	C	C	C	C	C	C	C	C
Chloroprene	C	C	C	-	-	-	C	-	C	C	C
Chlorosulfonic Acid	C	C	C	C	C	C	C	C	C	C	C
Chrome Plating Solutions	B	C	C	C	C	C	C	C	C	C	C
Chromic Acid	C	C	C	C	C	C	C	C	C	C	C
Citric Acid	A	A	A	A	A	A	A	A	A	A	A
Coke Oven Gas	C	C	C	C	C	C	C	C	C	C	C
Condensate	A	A	A	A	A	A	A	A	A	A	A
Copper Acetate	B	B	B	C	B	C	B	C	B	B	B
Copper Chloride	A	A	A	A	B	A	A	A	A	A	A
Copper Sulfate (T<120F)	A	A	A	A	A	A	A	A	A	A	A
Corn Oil	A	A	A	C	C	C	A	B	A	A	A
Cotton Seed Oil	A	A	A	C	B	C	A	B	A	A	A
Creosote	A	A	A	C	B	C	A	C	A	A	A
Cresol	B	B	B	C	C	C	B	C	B	B	B
Crude Oil	B	B	B	C	-	C	B	C	B	B	B
Cumene	C	C	C	C	C	C	C	C	C	C	C
Cyclohexane	A	A	A	C	C	C	A	C	A	A	A
Cyclohexanone	C	C	C	C	C	C	C	C	C	C	C
Cyclohexyl Alcohol	B	A	A	C	-	C	A	B	A	A	A
Decane	A	A	A	C	C	C	A	C	A	A	A
Detergent Solutions	A	A	A	B	B	B	A	B	A	A	A
Dibenzyl Ether	C	C	C	C	C	C	C	C	C	C	C
Dibromethane	C	C	C	C	-	C	C	C	C	C	C

*Please see note at the end of this table.

Annex 4.2
Chemical Compatibility Chart*
Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Dibutyl Phthalate	C	C	C	C	C	C	C	C	C	C	C
Dibutyl Sebacate	C	C	C	C	C	C	C	C	C	C	C
o-Dichlorobenzene	C	C	C	C	C	C	C	C	C	C	C
Dichloroethane (1,1 or 1,2)	C	C	C	-	-	C	C	-	C	C	C
Diesel Oil	A	A	A	C	C	C	A	B	A	A	A
Diethanolamine	A	A	A	-	-	-	A	-	A	A	A
Diethyl Ether	C	C	C	C	C	C	C	C	C	C	C
N,N-Dimethyl Aniline	C	C	C	C	C	C	C	C	C	C	C
Dimethyl Ether	A	A	A	C	C	C	A	C	A	B	A
Dimethyl Formamide	C	C	C	C	C	C	C	C	C	C	C
Dimethyl Phthalate	C	C	C	C	C	C	C	C	C	C	C
2,4-Dinitrotoluene	C	C	C	C	C	C	C	C	C	C	C
Dioxane	C	C	C	C	C	C	C	C	C	C	C
Dowtherm 4000	-	-	B	-	-	B	B	-	B	-	-
Dowtherm	C	C	C	C	C	C	C	C	C	C	C
Epichlorohydrin	C	C	C	C	C	C	C	B	C	C	C
Ethane	B	B	B	B	B	B	B	B	B	C	B
Ethers	C	C	C	C	C	C	C	C	C	C	C
Ethyl Acetate	C	C	C	C	C	C	C	C	C	C	C
Ethyl Acrylate	C	C	C	C	C	C	C	C	C	C	C
Ethyl Alcohol (Ethanol)	A	A	A	A	A	A	A	A	A	A	A
Ethyl Benzene	C	C	C	C	C	C	C	C	C	C	C
Ethyl Cellulose	B	B	B	B	B	B	B	B	B	B	B
Ethyl Chloride	B	B	B	C	C	C	B	C	B	B	B
Ethyl Ether	B	B	B	C	C	C	B	B	B	B	B
Ethylene	B	A	A	B	C	B	A	C	A	C	A
Ethylene Dibromide	C	C	C	C	-	C	C	C	C	C	C
Ethylene Dichloride	C	C	C	C	C	C	C	C	C	C	C
Ethylene Glycol	A	A	A	A	A	A	A	A	A	A	A
Ethylene Oxide	C	C	C	C	C	C	C	C	C	C	C
Ferric Chloride	A	A	A	A	A	A	A	B	A	A	A
Ferric Sulfate	A	A	A	A	A	A	A	A	A	A	A
Fluorine, Gas	C	C	C	C	-	C	C	-	C	C	C
Fluorine, Liquid	C	C	C	C	C	C	C	-	C	C	C
Fluorosilicic Acid	C	A	A	A	B	C	A	A	A	A	A
Formaldehyde	A	A	A	B	B	B	A	B	A	A	A
Formic Acid 10%	B	B	B	B	A	A	B	A	B	B	B
Formic Acid 85%	B	B	B	B	A	A	B	A	B	B	B

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart* Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Freon 12	A	A	A	A	A	A	A	A	A	C	A
Freon 22	C	C	C	A	A	A	C	A	C	C	C
Freon 32	A	A	A	A	A	A	A	A	A	C	A
Fuel Oil	A	A	A	C	B	C	A	C	A	A	A
Furfural	C	C	C	C	C	C	C	C	C	C	C
Gasoline, Refined	A	A	A	C	C	C	A	C	A	A	A
Gasoline, Sour	A	A	A	C	C	C	A	C	A	A	A
Gelatin	A	A	A	A	A	A	A	A	A	A	A
Glucose	A	A	A	A	A	A	A	A	A	A	A
Glue, Protein Base	A	A	A	A	A	A	A	A	A	A	A
Glycerine, Glycerol	A	A	A	A	A	A	A	A	A	A	A
Glycol	A	A	A	A	A	A	A	A	A	A	A
Grease	A	A	A	C	-	C	A	C	A	A	A
Green Sulfate Liquor	B	B	B	B	B	B	B	B	B	B	B
Heptane	A	A	A	C	-	C	A	B	A	A	A
Hexane	A	A	A	C	B	C	A	A	A	A	A
Hexone	B	B	B	-	-	-	B	-	B	B	B
Hydraulic Oil (Mineral)	A	A	A	C	B	C	A	B	A	A	A
Hydrazine	B	B	B	B	B	B	B	B	B	B	B
Hydrobromic Acid	-	C	C	C	C	C	C	A	C	C	C
Hydrochloric Acid 10%	A	A	A	A	C	C	A	A	A	A	A
Hydrochloric Acid 37%	C	C	C	C	C	C	C	A	C	C	C
Hydrofluoric Acid	C	C	C	C	C	C	C	C	C	C	C
Hydrofluosilicic Acid	-	C	C	C	B	C	C	A	C	C	C
Hydrogen	A	A	A	A	A	A	A	A	A	B	A
Hydrogen Fluoride	C	C	C	C	-	C	C	-	C	C	C
Hydrogen Peroxide < 30%	A	A	A	B	C	B	A	B	A	A	A
Hydrogen Sulfide, Dry or Wet	C	C	C	C	C	C	C	B	C	C	C
Hydroquinone	B	B	B	C	C	C	B	C	B	B	B
Iodine Pentafluoride	C	C	C	C	C	C	C	C	C	C	C
Isooctane	A	A	A	C	B	C	A	A	A	A	A
Isophorone	A	C	C	C	C	C	C	C	C	C	C
Isopropyl Alcohol	A	A	A	A	B	A	A	A	A	A	A
Kerosene	A	A	A	C	B	C	A	C	A	A	A
Lacquers	-	C	C	C	C	C	C	C	C	C	C
Lactic Acid 50%	A	A	A	B	-	A	A	A	A	A	A
Lactic Acid, Cold	A	A	A	A	A	A	A	A	A	A	A
Hot	C	C	C	C	C	C	C	C	C	C	C

*Please see note at the end of this table.

Annex 4.2
Chemical Compatibility Chart*
Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Lead Acetate (Sugar of Lead)	A	B	B	C	B	C	B	C	B	B	B
Linseed Oil	A	A	A	C	B	C	A	B	A	A	A
Liquified Petroleum Gas (LPG)	A	A	A	C	B	C	A	B	A	C	A
Lubricating Oils, Mineral or Petroleum Types	A	A	A	C	B	C	A	C	A	A	A
Lye	B	B	B	B	B	B	B	A	B	B	B
Magnesium Chloride	A	A	A	A	A	A	A	A	A	A	A
Magnesium Hydroxide (T<120F)	B	B	B	B	A	B	B	A	B	B	B
Magnesium Sulfate	A	A	A	A	A	A	A	A	A	A	A
Maleic Acid	C	C	C	C	C	C	C	C	C	C	C
Maleic Anhydride	C	C	C	C	C	C	C	C	C	C	C
Mercuric Chloride	A	A	A	A	A	A	A	A	A	A	A
Mercury	A	A	A	A	A	A	A	A	A	A	A
Methane	A	A	A	C	B	C	A	B	A	C	A
Methyl Alcohol (Methanol)	A	A	A	A	A	A	A	A	A	A	A
Methylacrylic Acid	C	C	C	C	B	C	C	C	C	C	C
Methyl Bromide	C	C	C	C	C	C	C	C	C	C	C
Methyl Chloride	C	C	C	C	C	C	C	C	C	C	C
Methyl Chloroform	C	C	C	-	-	-	C	-	C	C	C
Methyl Ethyl Ketone	C	C	C	C	C	C	C	C	C	C	C
Methyl Iodide	C	C	C	-	-	-	C	-	C	C	C
Methyl Isobutyl Ketone (MIBK)	C	C	C	C	C	C	C	C	C	C	C
Methyl Methacrylate	C	C	C	C	C	C	C	C	C	C	C
Methyl tert-Butyl Ether (MTBE)	A	A	A	-	-	-	A	-	A	A	A
Milk	A	A	A	A	A	A	A	A	A	A	A
Mineral Oil	A	A	A	C	B	C	A	B	A	A	A
Naphtha	A	A	A	C	C	C	A	C	A	A	A
Naphthalene	C	C	C	C	C	C	C	C	C	C	C
Natural Gas - GLP	A	A	A	B	A	B	A	A	A	C	A
Nickel Chloride	A	A	A	A	A	A	A	A	A	A	A
Nickel Sulfate	A	A	A	B	A	B	A	A	A	A	A
Nitric Acid ≤50% (T<120F)	C	C	C	C	B	C	C	A	C	C	C
Nitric Acid >50%	C	C	C	C	C	C	C	C	C	C	C
Nitric Acid Crude	C	C	C	C	C	C	C	C	C	C	C
Nitrobenzene	C	C	C	C	C	C	C	C	C	C	C
Nitrogen	A	A	A	A	A	A	A	A	A	A	A
Nitrogen Tetroxide	C	C	C	C	C	C	C	C	C	C	C
Nitromethane	C	C	C	C	B	C	C	C	C	C	C

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart* Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
2-Nitropropane	C	C	C	C	-	C	C	C	C	C	C
Octane	A	A	A	C	B	C	A	C	A	A	A
Oleic Acid	A	A	A	C	C	C	A	B	A	A	A
Orthodichlorobenzene	C	C	C	C	C	C	C	C	C	C	C
Oxalic Acid	B	B	B	B	B	B	B	B	B	B	B
Oxygen	C	C	C	C	C	C	C	B	C	C	C
Ozone	C	C	C	C	C	C	C	A	C	C	C
Palmitic Acid	A	A	A	B	B	B	A	B	A	A	A
Pentachlorophenol	A	A	A	-	-	-	A	-	A	A	A
Pentane	A	A	A	C	-	C	A	B	A	A	A
Perchloric Acid	C	C	C	C	B	C	C	C	C	C	C
Perchloroethylene	B	B	B	C	C	C	B	C	B	B	B
Petroleum	A	A	A	B	B	B	A	B	A	A	A
Petroleum Oils	A	A	A	C	B	C	A	B	A	A	A
Petroleum Ether	A	A	A	C	B	C	A	A	A	A	A
Phenol	C	C	C	C	C	C	C	C	C	C	C
Phosphoric Acid	C	C	C	C	B	C	C	C	C	C	C
Picric Acid	B	B	B	B	A	B	B	B	B	B	B
Pinene	B	B	B	C	C	C	B	C	B	B	B
Piperidine	C	C	C	C	C	C	C	C	C	C	C
Polychlorinated Biphenyls	-	B	B	-	-	-	B	-	B	-	B
Potassium Acetate	A	A	A	B	B	B	A	C	A	A	A
Potassium Chloride	A	A	A	A	A	A	A	A	A	A	A
Potassium Cyanide	A	A	A	A	A	A	A	A	A	A	A
Potassium Dichromate	A	A	A	B	A	B	A	A	A	A	A
Potassium Hydroxide (T<120F)	B	B	B	B	B	B	B	A	B	B	B
Potassium Nitrate	A	A	A	B	A	B	A	A	A	A	A
Potassium Permanganate	A	A	A	B	-	B	A	B	A	A	A
Potassium Sulfate	A	A	A	A	A	A	A	B	A	A	A
Producer Gás	A	A	A	C	B	C	A	B	A	C	A
Propane	A	A	A	C	B	C	A	B	A	B	A
Propyl Alcohol	A	A	A	A	A	A	A	A	A	A	A
Propyl Nitrate	C	C	C	C	C	C	C	C	C	C	C
Propylene	C	C	C	C	C	C	C	C	C	C	C
Propylene Oxide	C	C	C	C	C	C	C	C	C	C	C
Pyridine	C	C	C	C	C	C	C	C	C	C	C
Rapped Oil	B	B	B	C	B	C	B	C	B	B	B

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart*
Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Refrigerants											
11	B	B	B	C	C	C	B	A	B	C	B
12	A	A	A	A	A	A	A	A	A	C	A
13	A	A	A	A	A	A	A	A	A	C	A
13 B1	A	A	A	A	A	A	A	A	A	C	A
21	C	C	C	C	C	C	C	C	C	C	C
22	C	C	C	A	A	A	C	A	C	C	C
31	C	C	C	B	B	B	C	B	C	C	C
32	A	A	A	A	A	A	A	A	A	C	A
112	B	B	B	C	C	C	B	B	B	C	B
113	A	A	A	B	A	B	A	A	A	C	A
114	A	A	A	A	A	A	A	A	A	C	A
114 B2	B	B	B	C	C	C	B	A	B	C	B
115	A	A	A	A	A	A	A	A	A	C	A
142b	A	A	A	A	A	A	A	A	A	C	A
152a	A	A	A	A	A	A	A	C	A	C	A
218	A	A	A	A	A	A	A	A	A	C	A
502	B	B	B	A	A	A	B	-	B	C	B
C316	A	A	A	A	A	A	A	A	A	C	A
C318	A	A	A	A	A	A	A	A	A	C	A
Salicylic Acid	B	B	B	B	A	B	B	-	B	B	B
Salt Water	A	A	A	A	B	A	A	A	A	A	A
Sea Water	A	A	A	A	A	A	A	A	A	A	A
Sewage	A	A	A	B	B	B	A	A	A	A	A
Silicone Oil	A	A	A	A	A	A	A	A	A	A	A
Silver Nitrate	B	A	B	B	A	B	B	A	B	B	A
Skydrol 500	B	C	C	C	C	C	C	C	C	C	C
Soap Solutions	A	A	A	A	B	A	A	A	A	A	A
Soda Ash	A	A	A	A	A	A	A	A	A	A	A
Sodium Bicarbonate	A	A	A	B	A	B	A	A	A	A	A
Sodium Bisulfate, Dry	A	A	A	B	-	B	A	A	A	A	A
Sodium Bisulfite	A	A	A	A	A	A	A	A	A	A	A
Sodium Carbonate	A	A	A	A	-	A	A	A	A	A	A
Sodium Chloride (T<120F)	A	A	A	A	A	A	A	A	A	A	A
Sodium Cyanide	C	A	A	A	A	A	A	A	A	A	A
Sodium Hydroxide (T≥120F)	C	C	C	C	C	C	C	C	C	C	C
Sodium Hydroxide (T<120F)	B	B	B	B	A	B	B	A	B	B	B
Sodium Hypochlorite	C	C	C	C	C	C	C	C	C	C	C

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart* Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Sodium Metaphosphate	A	A	A	A	B	A	A	B	A	A	A
Sodium Nitrate	B	B	B	B	B	B	B	A	B	B	B
Sodium Perborate	B	B	B	B	B	B	B	B	B	B	B
Sodium Peroxide	B	B	B	B	B	B	B	B	B	B	B
Sodium Phosphate	A	A	A	A	B	A	A	A	A	A	A
Sodium Silicate	B	A	A	A	A	A	A	A	A	A	A
Sodium Sulfate	A	A	A	A	A	A	A	A	A	A	A
Sodium Sulfide	A	A	A	A	-	A	A	A	A	A	A
Sodium Thiosulfate	B	B	B	B	A	B	B	A	B	B	B
Soybean Oil	A	A	A	C	-	C	A	C	A	A	A
Stannic Chloride	A	A	A	A	B	A	A	-	A	A	A
Steam	A	A	A	B	B	A	A	B	A	A	A
Stearic Acid	A	A	A	A	B	A	A	B	A	A	A
Stoddard Solvent	A	A	A	C	B	C	A	C	A	-	A
Styrene	C	C	C	C	C	C	C	C	C	C	C
Styrene Oxide	C	C	C	C	-	C	C	C	C	C	C
Sulfur Chloride	C	C	C	C	C	C	C	C	C	C	C
Sulfur Dioxide	C	C	C	B	C	B	C	A	C	C	C
Sulfur, Molten	C	C	C	C	-	C	C	C	C	C	C
Sulfur Trioxide	C	C	C	C	C	C	C	C	C	C	C
Sulfuric Acid, oleum	C	C	C	C	C	C	C	C	C	C	C
Sulfuric Acid ≤ 90%	C	C	C	C	C	C	C	A	C	C	C
Sulfuric Acid 95%	C	C	C	C	C	C	C	B	C	C	C
Sulfuric Acid, Fuming	C	C	C	C	C	C	C	C	C	C	C
Sulfurous Acid	B	B	B	B	B	B	B	A	B	B	B
Tannic Acid	A	A	A	A	A	A	A	A	A	A	A
Tar (Asphalt)	B	B	B	C	C	C	B	C	B	B	B
Tartaric Acid	A	A	A	A	B	A	A	A	A	A	A
Tetrabromoethane	C	C	C	C	C	C	C	C	C	C	C
Tetrachloroethane	B	B	B	C	-	C	B	C	B	B	B
Tetrachloroethylene	C	C	C	C	C	C	C	C	C	C	C
Tetrahydrofuran, THF	C	C	C	C	C	C	C	C	C	C	C
Thionyl Chloride	C	C	C	C	C	C	C	C	C	C	C
Titanium Tetrachloride	B	B	B	C	C	C	B	C	B	B	B
Toluene	C	C	C	C	C	C	C	C	C	C	C
2,4-Toluenediisocyanate	C	C	C	C	C	C	C	C	C	C	C
Transformer Oil	A	A	A	C	B	C	A	B	A	B	A
Transmission Fluid A	A	A	A	C	B	C	A	C	A	A	A

*Please see note at the end of this table.

Annex 4.2

Chemical Compatibility Chart*
Teadit Compressed Fiber Gasket Materials

A: Suitable B: Consult with TEADIT C: Not recommended

FLUIDS	NA 1000	NA 1001	1082 SAN	NA 1035	NA 1076	NA 1080	NA 1081	NA 1085	NA 1100	NA 1122	1161 SAN
Trichloroacetic Acid	B	B	B	C	C	C	B	C	B	B	B
1,1,2-Trichloroethane	C	C	C	C	C	C	C	C	C	C	C
Trichloroethylene	C	C	C	C	C	C	C	C	C	C	C
Trichlorotrifluoroethane	A	A	A	C	-	C	A	C	A	C	A
Tricresylphosphate	C	C	C	C	C	C	C	C	C	C	C
Triethanolamine – TEA	B	B	B	B	A	B	B	A	B	B	B
Triethyl Aluminum	C	C	C	C	C	C	C	C	C	C	C
Triethylamine	C	C	C	-	-	-	C	-	C	C	C
Tung Oil	A	A	A	C	B	C	A	C	A	A	A
Turpentine	A	A	A	C	C	C	A	C	A	A	A
Varnish	C	C	C	C	C	C	C	C	C	C	C
Vegetable Oil	A	A	A	C	C	C	A	B	A	A	A
Vinegar	B	B	B	B	B	B	B	A	B	B	B
Vinyl Acetate	B	B	B	-	-	-	B	-	B	B	B
Vinyl Chloride	C	C	C	C	C	C	C	C	C	C	C
Vinylidene Chloride	C	C	C	C	-	C	C	C	C	C	C
Vinyl Methacrylate	C	C	C	C	-	C	C	C	C	C	C
Water, Oxidizing Salt	A	A	A	A	A	A	A	A	A	A	A
No Oxidizing Salt	A	A	A	A	A	A	A	A	A	A	A
Water, Distilled	A	A	A	A	A	A	A	A	A	A	A
Whiskey and Wines	A	A	A	A	A	A	A	A	A	A	A
Xylene	C	C	C	C	C	C	C	C	C	C	C
Zinc Chloride	A	A	A	A	A	A	A	A	A	A	A
Zinc Sulfate	A	A	A	B	A	B	A	A	A	A	A

NOTE: Properties and application parameters shown throughout this Compressed Fiber Gasket Materials Chemical Compatibility Chart are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult with TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications subject to change without notice; this edition cancels all previous issues.

Annex 4.3

FF and RF gasket dimensions per ASME B16.21 for ASME 16.5 flanges Pressure Class 150 and 300 - dimensions in inches

Nominal Diameter	Style	Inside Diameter	Outside Diameter		Bolt Circle		N°. of Bolts		Hole Diameter	
			150 psi	300 psi	150 psi	300 psi	150 psi	300 psi	150 psi	300 psi
1/2	FF	0.84	3.50	3.75	2.38	2.62	4	4	0.62	5/8
	RF		1.88	2.12						
3/4	FF	1.06	3.88	4.62	2.75	3.25	4	4	0.62	3/4
	RF		2.25	2.62						
1	FF	1.31	4.25	4.88	3.12	3.50	4	4	0.62	3/4
	RF		2.62	2.88						
1 1/4	FF	1.66	4.63	5.25	3.50	3.88	4	4	0.62	3/4
	RF		3.00	3.25						
1 1/2	FF	1.91	5.00	6.12	3.88	4.50	4	4	0.62	7/8
	RF		3.38	3.75						
2	FF	2.38	6.00	6.50	4.75	5.00	4	8	0.75	3/4
	RF		4.12	4.38						
2 1/2	FF	2.88	7.00	7.50	5.50	5.88	4	8	0.75	7/8
	RF		4.88	5.12						
3	FF	3.50	7.50	8.25	6.00	6.62	4	8	0.75	7/8
	RF		5.38	5.88						
3 1/2	FF	4.00	8.50	9.00	7.00	7.25	8	8	0.75	7/8
	RF		6.38	6.50						
4	FF	4.50	9.00	10.00	7.50	7.88	8	8	0.75	7/8
	RF		6.88	7.12						
5	FF	5.56	10.00	11.00	8.50	9.25	8	8	0.88	7/8
	RF		7.75	8.50						
6	FF	6.62	11.00	12.50	9.50	10.62	8	12	0.88	7/8
	RF		8.75	9.88						
8	FF	8.62	13.50	15.00	11.75	13.00	8	12	0.88	1
	RF		11.00	12.12						
10	FF	10.75	16.00	17.50	14.25	15.25	12	16	1.00	1 1/8
	RF		13.38	14.25						
12	FF	12.75	19.00	20.50	17.00	17.75	12	16	1.00	1 ¼
	RF		16.13	16.62						
14	FF	14.00	21.00	23.00	18.75	20.25	12	20	1.12	1 ¼
	RF		17.75	19.12						
16	FF	16.00	23.50	25.50	21.25	22.50	16	20	1.12	1 3/8
	RF		20.25	21.25						
18	FF	18.00	25.00	28.00	22.75	24.75	16	24	1.25	1 3/8
	RF		21.62	23.50						
20	FF	20.00	27.50	30.50	25.00	27.00	20	24	1.25	1 3/8
	RF		23.88	25.75						
24	FF	24.00	32.00	36.00	29.50	32.00	20	24	1.38	1 5/8
	RF		28.25	30.50						

Annex 4.4

**RF Gasket dimensions per ASME B16.21 for ASME B16.5 flanges
Pressure Class 400, 600 and 900 - dimensions in inches**

Nominal Diameter	Inside Diameter	Outside Diameter		
		400	600	900
1/2	0.84	2.12	2.12	2.50
3/4	1.06	2.62	2.62	2.75
1	1.31	2.88	2.88	3.12
1 1/4	1.66	3.25	3.25	3.50
1 1/2	1.91	3.75	3.75	3.88
2	2.38	4.38	4.38	5.62
2 1/2	2.88	5.12	5.12	6.50
3	3.50	5.88	5.88	6.62
3 1/2	4.00	6.38	6.38	-
4	4.50	7.00	7.62	8.12
5	5.56	8.38	9.50	9.75
6	6.62	9.75	10.50	11.38
8	8.62	12.00	12.62	14.12
10	10.75	14.12	15.75	17.12
12	12.75	16.50	18.00	19.62
14	14.00	19.00	19.38	20.50
16	16.00	21.12	22.25	22.62
18	18.00	23.38	24.12	25.12
20	20.00	25.50	26.88	27.50
24	24.00	30.25	31.12	33.00

Annex 4.5

FF Gasket dimensions per ASME B16.21 for ASME B16.24 flanges Cast Copper Alloy Flanges

Nominal Diameter	Inside Diameter	Pressure Class 150				Pressure Class 300			
		Outside Diameter	N°. of Bolts	Hole Diameter	Bolt Circle	Outside Diameter	N°. of Bolts	Hole Diameter	Bolt Circle
1/2	0.84	3.50	4	0.62	2.38	3.75	4	0.62	2.62
3/4	1.06	3.88	4	0.62	2.75	4.62	4	0.75	3.25
1	1.31	4.25	4	0.62	3.12	4.88	4	0.75	3.50
1 1/4	1.66	4.62	4	0.62	3.50	5.25	4	0.75	3.88
1 1/2	1.91	5.00	4	0.62	3.88	6.12	4	0.88	4.50
2	2.38	6.00	4	0.75	4.75	6.50	8	0.75	5.00
2 1/2	2.88	7.00	4	0.75	5.50	7.50	8	0.88	5.88
3	3.50	7.50	4	0.75	6.00	8.25	8	0.88	6.62
3 1/2	4.00	8.50	8	0.75	7.00	9.00	8	0.88	7.25
4	4.50	9.00	8	0.75	7.50	10.00	8	0.88	7.88
5	5.56	10.00	8	0.88	8.50	11.00	8	0.88	9.25
6	6.62	11.00	8	0.88	9.50	12.50	12	0.88	10.63
8	8.62	13.50	8	0.88	11.75	15.00	12	1.00	13.00
10	10.75	16.00	12	1.00	14.25	-	-	-	-
12	12.75	19.00	12	1.00	17.00	-	-	-	-

Annex 4.6

**RF Gaskets per ASME B16.21 for ASME B16.47 Series A flanges
Classes 150, 300, 400 and 600 - Dimensions in inches**

Nominal Diameter	Inside Diameter	Outside Diameter			
		150	300	400	600
22 (1)	22.00	26.00	27.75	27.63	28.88
26	26.00	30.50	32.88	32.75	34.12
28	28.00	32.75	35.38	35.12	36.00
30	30.00	34.75	37.50	37.25	38.25
32	32.00	37.00	39.62	39.50	40.25
34	34.00	39.00	41.62	41.50	42.25
36	36.00	41.25	44.00	44.00	44.50
38	38.00	43.75	41.50	42.26	43.50
40	40.00	45.75	43.88	44.58	45.50
42	42.00	48.00	45.88	46.38	48.00
44	44.00	50.25	48.00	48.50	50.00
46	46.00	52.25	50.12	50.75	52.26
48	48.00	54.50	52.12	53.00	54.75
50	50.00	56.50	54.25	55.25	57.00
52	52.00	58.75	56.25	57.26	59.00
54	54.00	61.00	58.75	59.75	61.25
56	56.00	63.25	60.75	61.75	63.50
58	58.00	65.50	62.75	63.75	65.50
60	60.00	67.50	64.75	66.25	67.75

Note 1: NPS 22 for reference only. Size not listed in ASME B16.47.

Annex 4.7

**RF Gaskets per ASME B16.21 for ASME B16.47 Series B flanges
Pressure Class 75, 150, 300, 400 and 600 - dimensions in inches**

Nominal Diameter	Inside Diameter	Outside Diameter				
		75	150	300	400	600
26	26.00	27.88	28.56	30.38	29.38	30.12
28	28.00	29.88	30.56	32.50	31.50	32.25
30	30.00	31.88	32.56	34.88	33.75	34.62
32	32.00	33.88	34.69	37.00	35.88	36.75
34	34.00	35.88	36.81	39.12	37.88	39.25
36	36.00	38.31	38.88	41.25	40.25	41.25
38	38.00	40.31	41.12	43.25	-	-
40	40.00	42.31	43.12	45.25	-	-
42	42.00	44.31	45.12	47.25	-	-
44	44.00	46.50	47.12	49.25	-	-
46	46.00	48.50	49.44	51.88	-	-
48	48.00	50.50	51.44	53.88	-	-
50	50.00	52.50	53.44	55.88	-	-
52	52.00	54.62	55.44	57.88	-	-
54	54.00	56.62	57.62	61.25	-	-
56	56.00	58.88	59.62	62.75	-	-
58	58.00	60.88	62.19	65.19	-	-
60	60.00	62.88	64.19	67.12	-	-

Annex 4.8

FF Gasket dimensions per ASME B16.21 for MSS SP-51 flanges

Class 150LW - dimensions in inches

Nominal Diameter	Inside Diameter	Outside Diameter	Number of Bolts	Hole Diameter	Bolt Circle Diameter
1/4	0.56	2.50	4	0.44	1.69
3/8	0.69	2.50	4	0.44	1.69
1/2	0.84	3.50	4	0.62	2.38
3/4	1.06	3.88	4	0.62	2.75
1	1.31	4.25	4	0.62	3.12
1 1/4	1.66	4.62	4	0.62	3.50
1 1/2	1.91	5.00	4	0.62	3.88
2	2.38	6.00	4	0.75	4.75
2 1/2	2.88	7.00	4	0.75	5.50
3	3.50	7.50	4	0.75	6.00
4	4.50	9.00	8	0.75	7.50
5	5.56	10.00	8	0.88	8.50
6	6.62	11.00	8	0.88	9.50
8	8.62	13.60	8	0.88	11.75
10	10.75	16.00	12	1.00	14.25
12	12.75	19.00	12	1.00	17.00
14	14.00	21.00	12	1.12	18.75
16	16.00	23.50	16	1.12	21.25
18	18.00	25.00	16	1.25	22.75
20	20.00	27.50	20	1.25	25.00
24	24.00	32.00	20	1.38	29.50

Annex 4.9

**Gasket dimensions per ASME B16.21 for ASME B16.1
Class 25 Cast Iron Flanges - dimensions in inches**

Nominal Diameter	Inside Diameter	RF gaskets	FF gaskets			
		Outside Diameter	Outside Diameter	Number of Bolts	Hole Diameter	Bolt Circle
4	4.50	6.88	9.00	8	0.75	7.50
5	5.56	7.88	10.00	8	0.75	8.50
6	6.62	8.88	11.00	8	0.75	9.50
8	8.62	11.12	13.50	8	0.75	11.75
10	10.75	13.62	16.00	12	0.75	14.25
12	12.75	16.38	19.00	12	0.75	17.00
14	14.00	18.00	21.00	12	0.88	18.75
16	16.00	20.50	23.50	16	0.88	21.25
18	18.00	22.00	25.00	16	0.88	22.75
20	20.00	24.25	27.50	20	0.88	25.00
24	24.00	28.75	32.00	20	0.88	29.50
30	30.00	35.12	38.75	28	1.00	36.00
36	36.00	41.88	46.00	32	1.00	42.75
42	42.00	48.50	53.00	36	1.12	49.50
48	48.00	55.00	59.50	44	1.12	56.00
54	54.00	61.75	66.25	44	1.12	62.75
60	60.00	68.12	73.00	52	1.25	69.25
72	72.00	81.38	86.50	60	1.25	82.50
84	84.00	94.25	99.75	64	1.38	95.50
96	96.00	107.25	113.25	68	1.38	108.50

Annex 4.10

**Gasket dimensions per ASME B16.21 for ASME B16.1
Class 125 Cast Iron Flanges - dimensions in inches**

Nominal Diameter	Inside Diameter	RF Gaskets	FF Gaskets			
		Outside Diameter	Outside Diameter	Number of Bolts	Hole Diameter	Bolt Circle
1	1.31	2.62	4.25	4	0.62	3.12
1 ¼	1.66	3.00	4.62	4	0.62	3.50
1 ½	1.91	3.38	5.00	4	0.62	3.88
2	2.38	4.12	6.00	4	0.75	4.75
2 ½	2.88	4.88	7.00	4	0.75	5.50
3	3.50	5.38	7.50	4	0.75	6.00
3 ½	4.00	6.38	8.50	8	0.75	7.00
4	4.50	6.88	9.00	8	0.75	7.50
5	5.56	7.75	10.00	8	0.88	8.50
6	6.62	8.75	11.00	8	0.88	9.50
8	8.62	11.00	13.50	8	0.88	11.75
10	10.75	13.88	16.00	12	1.00	14.25
12	12.75	16.12	19.00	12	1.00	17.00
14	14.00	17.75	21.00	12	1.12	18.75
16	16.00	20.25	23.50	16	1.12	21.25
18	18.00	21.62	25.00	16	1.25	22.75
20	20.00	23.88	27.50	20	1.25	25.00
24	24.00	28.25	32.00	20	1.38	29.50
30	30.00	34.75	38.75	28	1.38	36.00
36	36.00	41.25	46.00	32	1.62	42.75
42	42.00	48.00	53.00	36	1.62	49.50
48	48.00	54.50	59.50	44	1.62	56.00

PTFE GASKETS

1. POLYTETRAFLUORETHYLENE (PTFE)

A polymer with exceptional chemical resistance, Polytetrafluorethylene – PTFE, is the most widely used plastic for industrial sealing. The only media products that chemically attack PTFE are liquid alkaline metals and free fluorine. It also has excellent properties for electrical insulation, anti-stick, impact resistance and low friction coefficient.

Extruding, lamination and sintering pure PTFE or mixed with other materials, obtains gasket products with distinct physical and chemical properties to meet the needs of each application.

2. STYLES OF PTFE SHEETS

PTFE gaskets are used in services where it is necessary to have a high chemical resistance. As with any fluid sealing material there is some overlapping between each other. Several materials can be used successfully in the same application. The most popular materials, with specific applications, characteristics and advantages are discussed in the following paragraphs.

2.1. MOLDED SINTERED PTFE SHEET

Molded Sintered PTFE sheets were the first products introduced in the market. They are manufactured from virgin or reprocessed PTFE resin, without fillers, in a process of molding, compressing and sintering. As any plastic product PTFE exhibits a characteristic of creep when subjected to a compression force. This characteristic is very detrimental to the gasket performance since it requires frequent retightening of the gasket to avoid or reduce leaks. This creep behavior is increased with the temperature.

2.2. SKIVED PTFE SHEET

This sheet material is manufactured from virgin or reprocessed PTFE resin, without fillers, in a process of skiving a sintered PTFE billet. This process was developed to overcome manufacturing deficiencies of the Molded Process, however its products have the same creep behavior problems. The main advantages of skived PTFE sheets are the low cost, ample market availability and high chemical resistance.

2.3. MOLDED OR SKIVED FILLED PTFE SHEET

To reduce the creep behavior of Molded or Skived PTFE sheets, mineral fillers or fibers are added to reduce it. However, due to the manufacturing process (molding or skiving) this reduction is not enough to produce a long-term effective seal.

2.4. RESTRUCTURED FILLED PTFE SHEET (rPTFE)

To reduce the creep a manufacturing process was developed to produce Filled PTFE sheets. The material is subjected to a lamination before sintering, creating a highly bi-directional fibrillated structure. Creep at both room and high temperature is substantially reduced. To meet the chemical service needs several mineral or artificial fillers are used, like Barite, Mineral and Synthetic Silica, Barium Sulphate or Hollow Glass Micro-Spheres. Each filler has a specific service application but there is a major overlapping of all of them for normal applications. The most used fillers are:

- Barite: mineral used to produce sheets for strong caustic service. It is one of the most commonly used filler; it has a wide range of service applications including strong acids and general chemical products.
- Mineral Silica: used to produce sheets for strong acidic service. Is also used as a general service sheet since it has a broad range of applications including mild caustic solutions.
- Hollow Glass Micro-Spheres: this filler produces a sheet with a high compressibility for use with fragile or glass lined flanges replacing PTFE envelope gaskets. It is not recommended for either strong or hot caustic service.

2.5. EXPANDED PTFE (ePTFE)

As an alternative to overcome the creep of PTFE is the hot expansion of it before sintering. Gasket products expanded in one direction (cords or tapes) or bi-axially (tapes or sheets) can be produced. Expanded PTFE has a high chemical resistance; it also exhibits a very high compressibility and is ideal for use with fragile or glass lined flanges. Its main drawback is the handling and installation of large gaskets or when it is not possible to separate the flanges. It is often used as a replacement for the Hollow Glass Micro-Spheres sheet.

3. TEALON® RESTRUCTURED FILLED PTFE SHEET

Tealon® gasket sheets were developed to meet the highest demands for PTFE gaskets. Its lamination process before sintering creates a highly fibrillated structure, which combined with a selected choice of fillers, results in a product with reduced creep at both room and high temperature. To meet the chemical service needs fillers are: Barite, Mineral Silica and Hollow Glass Micro-Spheres.

3.1. TEADIT TEALON® STYLE TF1570 SHEETS

Tealon® TF1570 is produced with virgin Teflon resin filled with Hollow Glass Micro-Spheres. Table 5.1 shows the characteristics of Style TF1570 Sheets.

Due to its filler characteristics this product exhibits high compressibility and is recommended for use in fragile or lined flanges, for service handling strong acids, moderate caustic, chlorine dioxide, gases, solvents, water, steam, hydrocarbons and chemical products. It is not recommended for strong and hot caustic media since it can attack the Hollow Glass Micro-Spheres.

It is available in sheets 59" x 59" (1500 mm x 1500 mm), thickness range 1/16" (1.6 mm) to 1/4" (6.4 mm), blue dyed.

3.2. TEADIT TEALON® STYLE TF1580 SHEETS

Tealon® TF 1580 is produced with virgin PTFE resin filled with Barite. Table 5.1 shows the characteristics of Style TF1580 Sheets.

Due to its exceptional resistance it is recommended for strong and hot caustic service, solvents, gases, water, steam, hydrocarbons and chemical products. It also meets the requirements of the Food and Drug Administration (FDA) for use in food and pharmaceutical applications. It has no dyes and can be used when color contamination is an issue.

It is available in sheets 59" x 59" (1500 mm x 1500 mm), thickness range 1/16" (1.6 mm) to 1/4" (6.4 mm).

3.3. TEADIT TEALON® STYLE TF1590 SHEETS

Tealon® TF 1590 is produced with virgin PTFE resin filled with Mineral Silica. Table 5.1 shows the characteristics of Style TF1590 Sheets.

Tealon® TF1590 is General Service Sheet recommended for service handling strong acids (except hydrofluoric), moderate caustic, gases, solvents, water, steam, hydrocarbons and chemical products.

It is available in sheets 59" x 59" (1500 mm x 1500 mm), thickness range 1/16" (1.6 mm) to 1/4" (6.4 mm), fawn dyed.

Table 5.1
Typical Characteristics of Tealon® Sheets

Physical Characteristics		Test Method	TF1570	TF1580	TF1590
Minimum Temperature	C	-	-268	-268	-268
	F	-	-450	-450	-450
Maximum Temperature	C	-	260	260	260
	F	-	500	500	500
Maximum Pressure	bar	-	55	83	83
	psi	-	800	1200	1200
pH Range		-	0 - 14	0 - 14	0 - 14
P x T Factor	bar x C	1.5 mm thick	12 000	12 000	12 000
		3 mm thick	-	8 600	8 600
	psi x F	1/16" thick	350 000	350 000	350 000
		1/8" mm thick	-	250 000	250 000
Compressibility, %		ASTM F 36 A	25-40	4-10	5-15
Recovery, %		ASTM F 36 A	30	40	40
Tensile Strength	MPa	ASTM 152	14	14	14
	psi		2000	2000	2000
Specific Gravity	g/cm ³	ASTM F1315	1.55	2.90	2.20
	lb/cu.ft		106	181	131
Creep Relaxation, %		ASTM F 38	40	15	18
Sealability, ml/hr (.7 bar) 1000 psi		ASTM F 37 A	0.12	0.04	0.20
Gas Permeability, cm ³ /min		DIN 3535	< 0.015	< 0.015	< 0.015
ASTM CALLOUT		ASTM	F456999A9B7E99M6	F451999A9B2E99M6	F451999A9B4E99M6

ASTM tests are based on 0.80mm thickness sheets and DIN tests on 2.0mm thickness sheets.

3.4 TEALON PERFORMANCE TESTS

To show its outstanding properties, Tealon sheets were performance tested as shown in the following paragraphs.

3.4.1. HOT COMPRESSION TEST

Gaskets produced from Tealon® and from skived PTFE sheets were subjected to a compression stress of 1500 psi (10 MPa) at 500F (260C) for 1 hour. Figure 5.1 shows the test result. It can clearly be seen that the Tealon gasket has retained its shape. Due to its high creep behavior the skived PTFE has lost its initial shape.

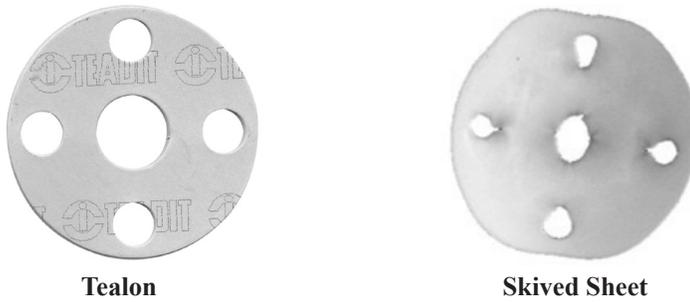


Figure 5.1

3.4.2. HOT CAUSTIC SODA IMMERSION

To verify the performance samples of Tealon were immersed in Caustic Soda, 33% concentration at 230F (110C), for 24 days. Figure 5.2 shows the weight change.

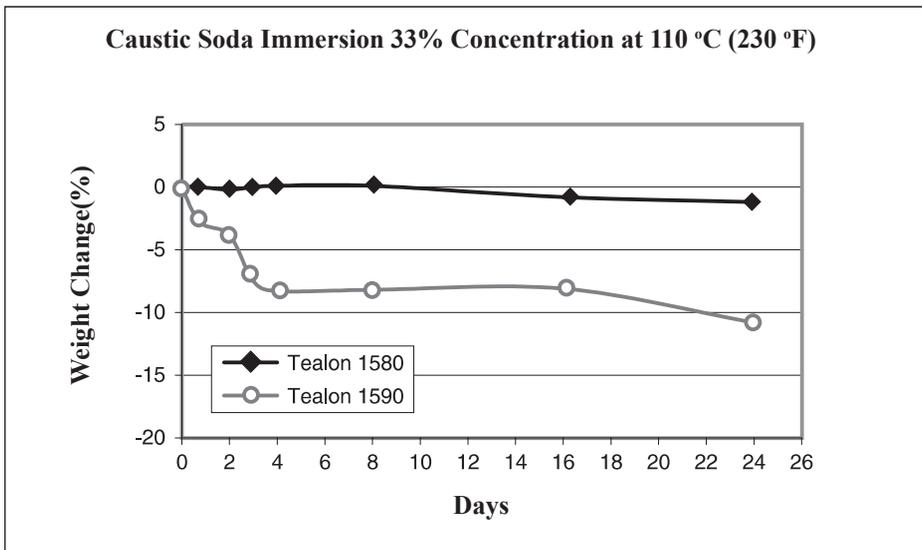


Figure 5.2

The TF1580 Barite filled product showed the lowest change of the tested sheets. The TF1590 Silica filled sheet on the other hand showed severe weight loss. A visual inspection of the samples after 24 days of immersion showed the Silica filled sheets had some discoloration and pitting. The TF1580 filled sheets showed no evidence of chemical attack and for this reason is the recommended product for caustic media.

3.4.3. SULPHURIC ACID IMMERSION

To verify the performance in acidic services samples of Tealon Restructured Sheets were immersed in Sulphuric Acid, 20% concentration at 185F (85C), for 8 days. Figure 5.3 shows the weight change.

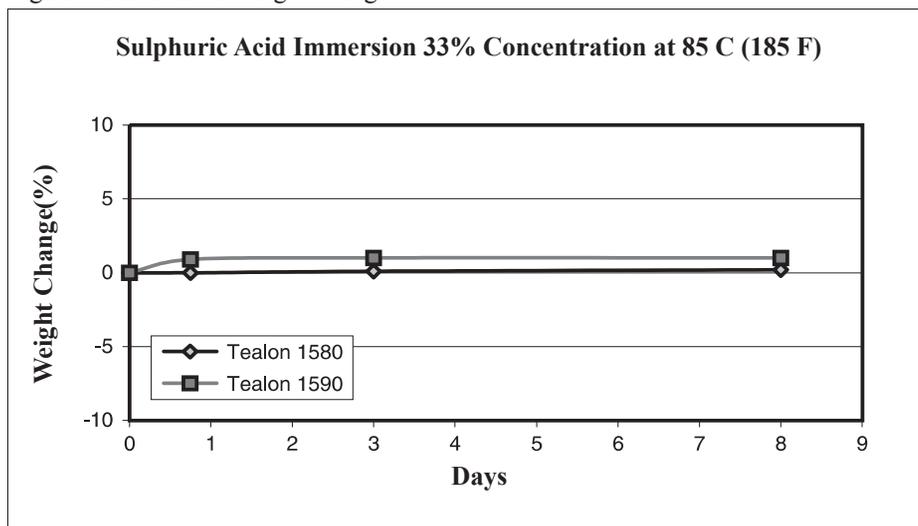


Figure 5.3

Both TF1580 Barite and TF1590 Silica filled sheets had only a small weight increase under these test conditions. A visual inspection of the samples showed no evidence of chemical attack.

3.4.4. PRESSURE LOSS WITH THERMAL CYCLING

Gaskets made of Tealon TF1570 and PTFE Skived Sheet were tested under thermal cycling conditions. The objective of the test was to compare the pressure loss (leak rate) of both gaskets. The Test Protocol used is as follows:

- Install the gasket with a seating stress of 5000 psi (35 MPa).
- Wait 30 minutes for the initial relaxation and increase the seating stress again to 5000 psi (35 MPa).
- Increase the temperature to 392F (200C).
- Pressurize the Test Bench with 600 psi (42 bar). The gas inlet is then closed for the remaining of the test.
- The temperature is kept constant at 392F (200C) for 4 hours.
- Turn the heating system off and let the Test Bench cool down.
- When the temperature reaches 86F (30C) it is increased to 392F (200C).
- The temperature is kept constant at 392F (200C) for 30 minutes.
- This cycle is repeated 2 times.
- The pressure, temperature and seating stress are recorded throughout the test.

The test results are shown in Figures 5.4 and 5.5.

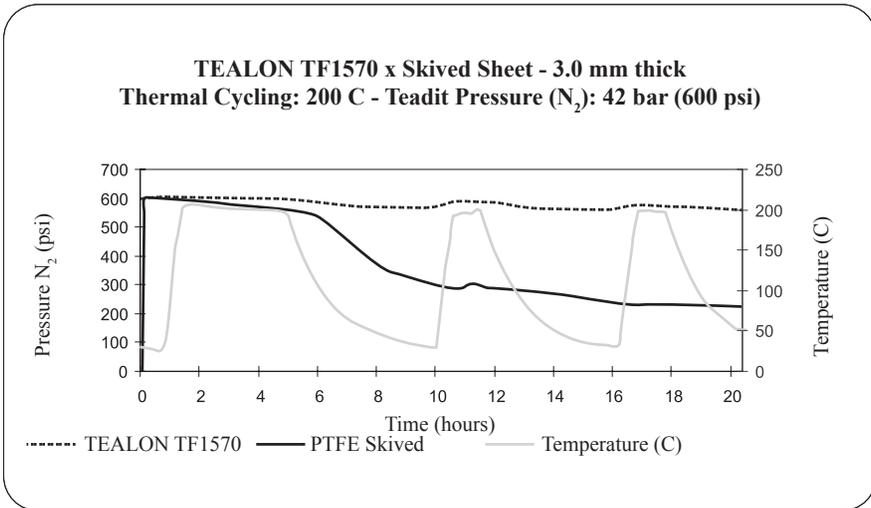


Figure 5.4

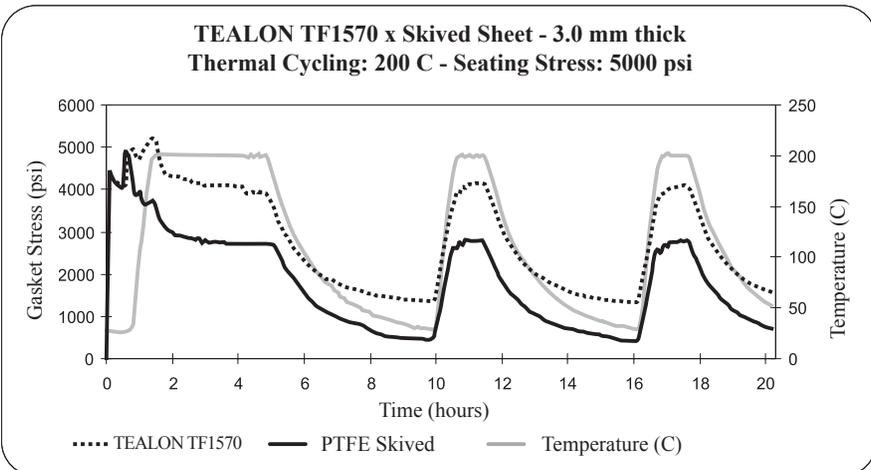


Figure 5.5

This test is a good example of the difference between a skived sheet and restructured PTFE sheets like Tealon. As shown in Figure 5.5, the PTFE Skived Sheet loses 44% of its initial seating stress as the gaskets thermocycle. This loss of seating stress is the cause of the higher pressure loss for the PTFE Skived Sheet gasket as shown in Figure 5.4 and is typical for this kind of product. Restructured PTFE products like Tealon, due to its fibrillated structure, have a better retention of the initial seating stress and maintain a higher sealability.

3.4.5. HOT BLOW OUT TEST (HOBT-2)

To verify the pressure resistance at elevated temperatures, samples of Tealon were tested at the TTRL (Tightness Testing and Research Laboratory) of the University of Montreal, Canada and by the CETIM (Centre de Industries Mechaniques), Nantes, France. A summary of the test protocol known as HOBT-2 is as follows:

- Flanges ASME B16.5 DN 3”- Class 150 psi.
- Test Media: Helium.
- Test Pressure: 435 psi.
- Seating Stress: 5000 psi (34.5 MPa).
- Test procedure: install gasket and pressurize the test bench. Increase the temperature until the gasket blows out or it reaches 680F (360C).

Test results are as follows:

- TF1570: reached 529F (276C)
- TF1580: reached 595F (313C).
- TF1590: the test reached its the test maximum temperature of 680F (360C) without a gasket failure.

3.4.6. HOT GAS SERVICE

Tealon gaskets have been approved by the DVGW – Deutscher Verein des Gasund Wasserfaches e.V. (Germany) per DIN 3535 for hot gas service.

3.4.7. OXYGEN SERVICE

Tealon TF1580 has been approved by the Bundesansalt für Materialforschung und –prüfung (BAM), Berlin, Germany, for Oxygen service in pressures up to 1200 psi (83 bar) and 482F (250C).

3.4.8. TA-LUFT APPROVAL FOR REFINERY AND CHEMICAL SERVICE

Tealon gaskets have been approved by the Staatliche Materialprüfungsanstalt – Universität Stuttgart (MPA), Germany, according to the VDI 2440, for service in Refineries, Petrochemical and Chemical plants. The maximum allowed leak rate is 10 4 mbar-l/(s·m). The test results are shown in Table 5.2:

Table 5.2
Tealon® TA-Luft Test Results

Product	Leak Rate - mbar·l/(s·m)
TF1570	$3.7 \cdot 10^{-6}$
TF1580	$5.9 \cdot 10^{-7}$
TF1590	$1.1 \cdot 10^{-6}$

3.5 TEALON CHEMICAL COMPATIBILITY

Annex 5.1 shows the Chemical Compatibility of the Tealon sheets with several chemical products.

3.6 BOLTING CALCULATIONS

The Tealon gasket properties for ASME calculations are shown in Table 5.3.

Table 5.3
Tealon ASME Gasket Properties

Property	TF1570		TF1580		TF1590	
	Thickness - in		Thickness - in		Thickness - in	
	1/16	1/8	1/16	1/8	1/16	1/8
m	2	2	2	2	4.4	3.5
y - psi	1 500	1 500	1 800	1 500	2 500	2 000
Sg _{max} – Maximum Seating Stress – MPa (psi)	140 (20 000)	100 (14 500)	140 (20 000)	100 (14 500)	140 (20 000)	100 (14 500)
Sg _{min-s} – Minimum Assembly Stress – MPa (psi)	15 (2180)	20 (2900)	25 (3600)	20 (2900)	25 (3600)	22 (3200)
Sg _{min-o} – Minimum Operating Stress – MPa (psi)	10 (1450)	10 (1450)	7 (1020)	10 (1450)	10 (1450)	8 (1160)
Relaxation fraction at 80 MPa/100C – ϕ_g	0.66	0.57	0.58	0.58	0.69	0.64
Maximum rotation – $\Theta_{g_{max}}$	0.7	0.7	0.7	0.7	0.7	0.7

4. TEADIT TF1510

Teadit® TF1510 is a high compressibility PTFE sheet made through a unique lamination process with a high level of fibrillation, which provides reduced creep, deficiency typical to skived or molded PTFE sheets in the market.

Due to the PTFE chemical properties, Teadit® TF1510 is suitable for a wide variety of chemically aggressive fluids. The manufacturing process provides a rigid and high compressibility sheet. Teadit® TF1510 gaskets are rigid allowing them to be installed even in places that are difficult to access and with little space to separate the flanges. Its high compressibility also enables Teadit® TF1510 gaskets to be applied on worn flanges or uneven surfaces. Its non-stick properties make it easy to remove gaskets after use without any material residue left on the flanges.

Teadit TF1510 main properties are in Table 5.4 and the gasket properties for ASME calculations are in Table 5.5.

It is available in sheets 59” x 59” (1500 mm x 1500 mm), thickness range 1/16” (1.6 mm) to 1/4” (6.4 mm).

Table 5.4
Typical Characteristics of Tedit® TF1510

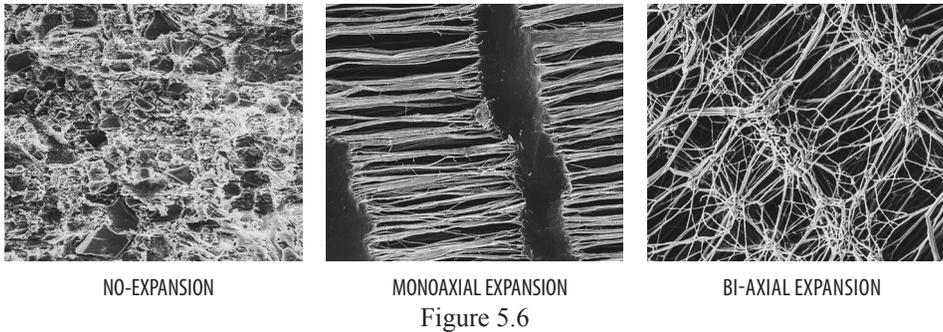
Physical Characteristics		Tedit® TF1510	
Minimum Temperature	C	-268	
	F	-450	
Maximum Temperature	C	260	
	F	500	
Maximum Pressure	bar	55	
	psi	800	
pH Range		0 - 14	
P x T Factor	bar x C	1.5 mm thick	12 000
		3 mm thick	8 600
	psi x F	1/16" thick	350 000
		1/8" mm thick	250 000
Color		White	
Selalability(ml/h)		ASTM F 37A < 0.025	
Relaxation (%)		ASTM F 38 45	
Compressibility(%)		ASTM F 36A 50	
Recovery Min. (%)		ASTM F 36A 16	
Tensile Streght (MPa)		ASTM F 152 8	
Torque Retention (MPa)		DIN 52913 13	

Table 5.5
Tedit® TF1510 ASME Gasket Properties

Property	Thickness – in (mm)	
	1/16 (1.6)	1/8 (3.2)
m	1.8	5.9
y - psi	3000	5500
Sg _{max} – Maximum Seating Stress – MPa (psi)	172 (25 000)	172 (25 000)
Sg _{mins} – Minimum Assembly Stress – MPa (psi)	25 (3600)	25 (3600)
Sg _{min-o} – Minimum Operating Stress – MPa (psi)	10 (1450)	11 (1600)
Relaxation fraction at 80 MPa/100C – φg	0.6	0.54
Maximum rotation – θg _{max}	0.7	0.7

5. EXPANDED PTFE (ePTFE)

The exceptional properties which distinguish expanded PTFE products are the result of a special stretching process which produces a highly fibrillated microstructure with millions of fibrils connected with each other. This gives the material its unique strength and pressure resistance, without the cold flow and creep characteristics of sintered PTFE. Expanded PTFE Products have outstanding plastic malleability and flexibility; they conform easily to irregular and rough surfaces. At the same time they withstand high flange loads and high internal pressures.



5.1. SERVICE CHARACTERISTICS

The most important service characteristics are as follows:

- Pure PTFE without fillers or additives for better chemical resistance, pH ranges from 0 to 14. Not recommended for molten alkali and elemental fluorine)
- Temperature range -450 F (-268 C) to 500 F (+260 C), for continuous service and up to 590 F (310 C) for short periods.
- Pressure range from full vacuum to 2900 psi (200 bar).
- Low creep not requiring frequent retightening of bolts like sintered PTFE.
- High compressibility recommended for fragile flange materials like ceramic, glass or plastic.
- Conforms easily to irregular and rough surfaces. .
- Physiologically harmless up to 500 F (+270 C). It has no smell and is tasteless.
- It is non-toxic and does not contaminate.
- Microorganisms or fungi do not influence it.
- Approved by the FDA (Food and Drug Administration) for use with foods and drugs.
- It contains no extractable substances.
- Unlimited shelf life, it is non-aging.
- Atmospheric agents like sunlight, ozone and ultraviolet light (UV) do not attack it.
- The research paper “The Influence of Elevated Temperature in Creep Relaxation of Various PTFE Gaskets Production Methods” [56] presented at the ASME/PVP 2018 shows the properties differences among several PTFE gaskets.

5.1.1. High Temperature Gasket Relaxation (PQR) – EU Standard EN 13555

The European Standard EN 13555 defines test methods for determining various gasket properties, including high temperature relaxation. The factor PQR is the ratio of the residual and the original loads from a relaxation test in a compression press used in the displacement-controlled mode with a known stiffness. The test procedure consists of loading the test gasket at the defined rate until the required loading and surface pressure is reached. The loading is then held for 5 min, at this stage the gasket thickness is recorded as the original gasket thickness after which the temperature of the rig is raised at the rate specified until the required temperature is reached. The temperature is then held constant for a period of 4 hours. After the 4-hour period the remaining load being imposed by the press and the final gasket thickness are recorded. PQR is then calculated as the ratio of the

residual load to the original load Expanded PTFE products (ePTFE) have higher PQR values when compared to molded or skived PTFE products as shown in Figure 5.7.

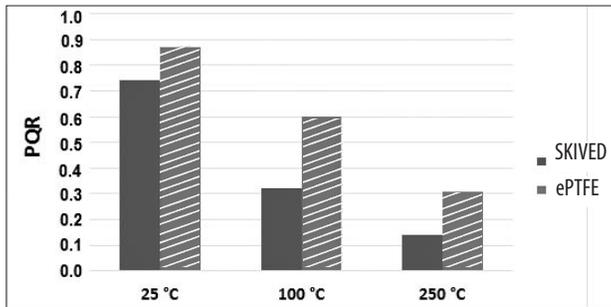


Figure 5.7

It is important to notice that the PQR values of ePTFE products from different manufacturers may differ significantly depending on the PTFE resin quality and production process employed. Figure 5.8 compares samples obtained in the market. As it can be observed the differences are accentuated as the temperature increases.

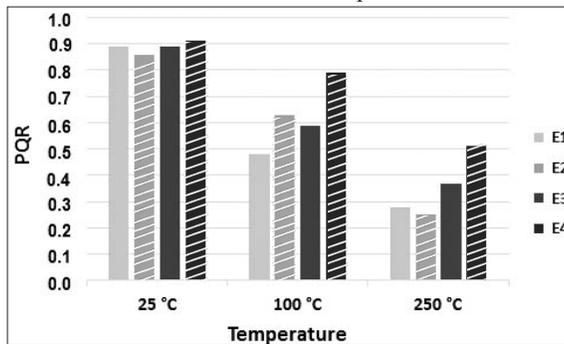


Figure 5.8

5.1.2. Maximum Surface Pressure (Q_{smax}) - EU Standard EN 13555

EN 13555 also defines the procedure for determining the maximum surface pressure (Q_{smax}) that can be safely imposed upon the gasket at the service temperature without damage or to seal satisfactorily.

The test procedure consists of raising the temperature of the gasket to the required value under an initial surface pressure and then carrying out cyclic compression/recovery loadings on the gasket at progressively higher surface pressures until the gasket collapses or the maximum load of the test machine or the maximum surface pressure specified by the manufacturer is reached.

For ePTFE gaskets, the test procedure for determining Q_{smax} is to raise the gasket temperature at a rate of 2 K/min to the test temperature value. Keeping the temperature constant, the stress on the gasket is raised and reduced progressively in cycles, as shown in Table 5.6.

The surface pressure of the loading cycle prior to collapse is taken to be the Q_{smax} value

for that temperature. The parameter Q_{smax} for sheet materials is very thickness dependent and the values determined are only relevant for the thicknesses of gaskets tested.

In the context of the above the term collapse is defined as when the thickness decrement per unit of surface pressure increase rises sharply above the trend set by the previous values to the extent that it cannot be considered to be just a consequence of the inherent variation around the trend.

Table 5.6
Loading/Unloading

Step	Loading (MPa)	Unloading (MPa)
1°	20	6.7
2°	30	10.0
3°	40	13.3
4°	50	16.7
5°	60	20.0
etc	Each 20 MPa	Each 6.7 MPa

The ePTFE products show a higher Q_{smax} when compared with molded or skived PTFE sheets, as shown in Figure 5.9.

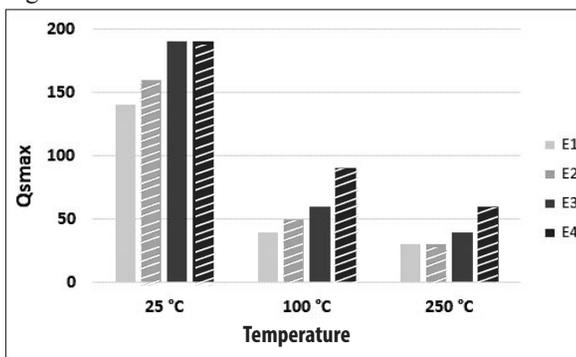


Figure 5.9

Therefore, proper selection of the ePTFE gasket which includes both the proper resin type and the manufacturing process, is essential to provide a reliable seal, especially when the process requires high temperature. It is recommended that the properties of the gasket to be installed be evaluated according to the service requirements of the application.

5.2. EXPANDED PTFE TAPES AND SHEETS

Sheets and tapes are manufactured by expanding virgin PTFE using a proprietary process that produces a uniform and highly fibrillated microstructure with equal tensile strength in all directions. The resulting product exhibits characteristics significantly different than conventional PTFE. It is softer and more flexible, conforming easily to irregular and rough surfaces. It is also easier to compress and has a reduced cold flow and creep. It is ideally suited to cut or punch gaskets, for flanges with a narrow sealing area or where a defined gasket width after seating is needed.

5.2.1 TEADIT STYLE 24B JOINT SEALANT

The most common form of Expanded PTFE is a tape with an adhesive strip on one side. This tape is placed over the sealing surface of one of the flanges. The adhesive strip backing makes the installation very easy as shown in Figure 5.10, even for irregular shaped flanges.

After seating, Expanded PTFE gaskets are reduced to a very thin cross section with high tensile strength. This very thin cross section reduces the gasket tendency to blowout increasing its pressure resistance.

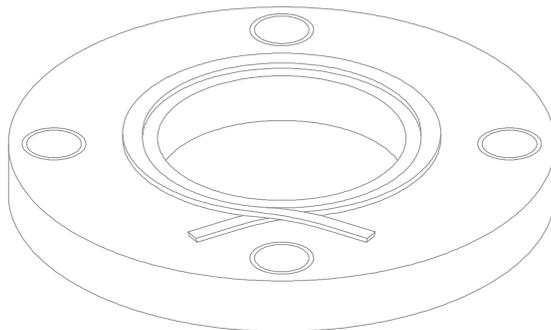


Figure 5.10

For standard size flanges the size recommendations are in Table 5.7. For non-standard flanges the recommended width is 1/3 to 1/2 of the flange sealing surface. For flanges with scratches, tool marks and other irregularities choose the thickest possible size.

Table 5.7
Size Recommendations

Flange Nominal Diameter - in	Style 24B size - in
Up to 1/2	1/8
3/4 to 1 1/2	3/16
2 to 4	1/4
5 to 8	3/8
10 to 16	1/2
18 to 24	5/8
24 to 36	3/4
36 and up	1

Table 5.8
Teadit 24B Standard Sizes – feet per roll

Thickness in	Width - in						
	1/2	3/4	1	2	4	6	8
1/64	100	100	100	100	-	-	-
1/32	50	50	50	50	50	50	50
1/16	25	25	25	25	25	25	25
1/8	25	25	25	25	25	25	25

5.2.2. TEADIT STYLE 24SH EXPANDED PTFE SHEET

Teadit 24 SH gasket sheet is manufactured by expanding 100% virgin PTFE using a proprietary process that produces a uniform and highly fibrillated microstructure with equal tensile strength in all directions. The resulting product exhibits characteristics significantly different than conventional PTFE sheet. This style is much softer and more flexible than regular PTFE sheet and thus conforms easily to irregular and rough surfaces. In addition, the material is easier to compress and minimizes creep and cold flow.

It is available in sheets 59" x 59" (1500 mm x 1500 mm), thickness range 1/64" (0.4 mm) to 1/4" (6.4 mm).

5.2.2.1. TEADIT STYLE 24SH PROPERTIES

- Color: white
- Temperature range: -400F (-268) up to 500F (+260C). For short periods up to 600F (315C).
- Chemical resistance: chemically inert against all substances (pH 0-14), including the most aggressive acids and lyes. The only exceptions are molten alkali metals and elemental fluorine at high temperature and pressure.
- Operating pressure: from vacuum up to 200 bar.
- Ageing: is not subject to aging or weathering. It can be stored indefinitely.
- Safety: complies to FDA regulations for food, it is physiologically harmless.
- Suitable for oxygen applications.

The Style 24SH gasket properties for ASME calculations are shown in Table 5.9.

Table 5.9
24SH ASME Gasket Properties

Property	Thickness - in	
	1/16	1/8
m	2	2
y (psi)	2 800	2 800
SG _{max} - Maximum Seating Stress - MPa (psi)	238 (345000)	190 (27500)
SG _{min-s} - Minimum Assembly Stress - MPa (psi)	30 (4350)	35 (5075)
SG _{min-o} - Minimum Operating Stress - MPa (psi)	12 (1740)	10 (1450)
Relaxation fraction at 100 MPa/150C φg	0,60	0,48
Maximum rotation Θ _{gmax}	0.7	0.7

5.2.3. TEADIT STYLE 24BB EXPANDED PTFE GASKET TAPE

Teadit Style 24BB gasket tape is produced by expanding 100% virgin PTFE into a highly fibrillated structure which is softer and more flexible than regular PTFE and thus conforms easily to irregular and rough surfaces. In addition, the expanded material is easier to compress and exhibits excellent resistance to creep and cold flow.

The exceptional malleability of expanded PTFE can compensate for out-of-parallel and/or damaged sealing surfaces and allows use with stress sensitive connections and applications where only a limited flange load is available, e.g. plastic flanges, glass flanges, etc. Gaskets can be cut and/or punched from Teadit 24 BB, which can be installed in areas

where there is not enough room to install a gasket tape like Teadit 24B. Typical applications are the sealing of flanges, housings of pumps, gearboxes and compressors, handholes and manholes, air ducts, compensators, heat exchangers, chemical reactors.

Teadit 24BB gasket tape is supplied as a continuous tape with a self-adhesive backing strip to facilitate easy installation, as shown in Table 5.10.

Table 5.10
Teadit 24BB Standard Dimensions

Standard Sizes							
Thickness - in	Width (feet per roll)						
	1/2"	3/4"	1"	2"	4"	6"	8"
1/8	25	25	25	25	25	25	25
1/16	25	25	25	25	25	25	25
1/32	50	50	50	50	50	50	50
1/64	100	100	100	100	-	-	-

5.2.4. TEADIT STYLE 25BI EXPANDED PTFE GASKET TAPE

Teadit Style 25BI is a multidirectionally expanded gasket-tape, produced from 100% pure PTFE. Due to its excellent malleability and adaptability – it is particularly well suited to compensate for irregularities or damages on the sealing areas, as well as for all stress-sensitive joints.

A special manufacturing process results in almost equal tensile strength in both the longitudinal and cross direction. As a result of this, it does not change its width under compression. This is in stark contrast to normal expanded PTFE tapes. Teadit 25BI, because of this property, is extremely well suited as a gasket material for narrow sealing areas and in all applications where a defined gasket width (under load) is required. Typical applications are enamelled and glass flanges, heat exchangers, large flanges and containers, pressure vessels, suction filters and strainers, etc.

5.2.4.1. TEADIT STYLE 25BI PROPERTIES

- Thermal stability: from -450 °F (-268 °C) to 500 °F (+260 °C). Up to 590 F (310 C) for short periods
- Chemical resistance: chemically inert against most substances (pH 0 –14), including the most aggressive acids and lyes. The only exceptions are molten alkali metals and elemental fluorine at high temperatures and pressures.
- Ageing: does not age and can be stored indefinitely. (Please note: adhesive tape has a limited shelf life)
- Pressure: from vacuum up to 200 bar
- Minimum stress to seal Q_{min}/L (EN 13555 He, 40 bar):
 - $L[mg/s*m] 10^{-2} Q_{min}/L [MPa] = 23$
 - $L[mg/s*m] 10^{-3} Q_{min}/L [MPa] = 31$
- Maximal applicable gasket stress $SG_{max} = 130 \text{ MPa}$ (acc. EN 13555)

- Color: white
- Recovery: 10 % (ASTM F36)
- Compressibility: 70 % (ASTM F36)

5.2.5 TEADIT STYLE 30SH

To meet the recent demands of European standards, Teadit 30SH ePTFE sheet has been developed, it provides reduced relaxation and higher maximum stress at elevated temperature.

The latest edition of the EN 1591-1 Flanges and their joints – Design rules for gasketed circular flange connections requires improved mechanical properties of gasket materials. In particular, for PTFE gaskets, relaxation and maximum gasket stress are of great importance in the new calculation method.

The standards EN 13555 [50], EN 1591-1 [51] and VCI Guideline for Gasket Installation [58] require PTFE gaskets to have the following characteristics:

- Relaxation value, P_{QR} , greater than 0.75 at room temperature and 0.45 at operating temperature, starting from initial seating stress of 30 MPa.
- Maximum allowable leakage with 40 bar Helium of 0,01 mg / (s.m), with 30 MPa seating stress.
- Maximum gasket stress (Q_{smax}) greater than 150 MPa at room temperature.

Commercial ePTFE gaskets do not meet the requirements of these standards. This requires high molecular weight PTFE resins and a dedicated technology manufacturing process. The new Teadit 30SH product features greater and more homogeneous fibrillation in its molecular structure. The VCI Guideline for Gasket Installation requires in its “Appendix C” the minimum P_{QR} value of 0.45 at operating temperature, for Teadit 30SH this temperature is 500F (260C). The exceptional mechanical properties of Teadit 30SH allows the calculation of flanges according to EN 1591-1 in a wide range of dimensions.

The main properties of Teadit 30SH are as follows.

Table 5.11
 Q_s values for Teadit 30SH

Minimum stress to seal $Q_{min/L}$ (at assembly), $Q_{Smin/L}$ (after off-loading) for $p=40$ bar $Q_{Smin/L}$ [MPa]							
L [mg/(s*m)]	$Q_{min/L}$ [MPa]	$Q_A = 20$ MPa	$Q_A = 30$ MPa	$Q_A = 40$ MPa	$Q_A = 60$ MPa	$Q_A = 80$ MPa	$Q_A = 100$ MPa
10^0	14	10	10	10	10	10	10
10^{-1}	25		10	10	10	10	10
10^{-2}	36			10	10	10	10
10^{-3}	45				10	10	10
10^{-4}	54				10	10	10
10^{-5}	71					33	18

Sealability chart per EN 13555, Helium, 40 bar

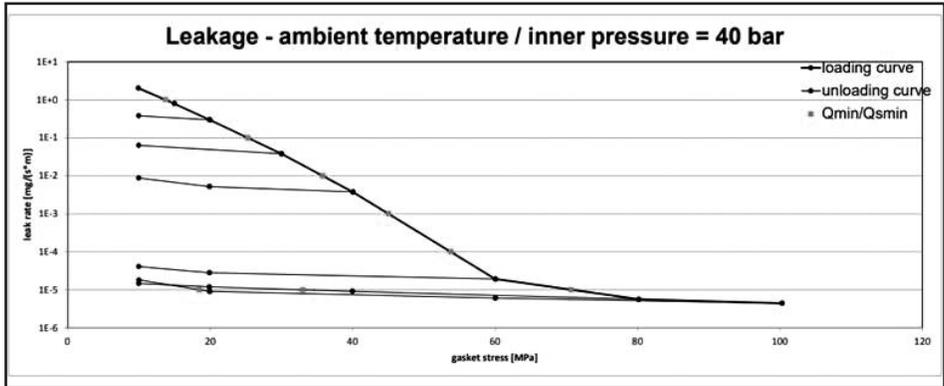


Table 5.12
 P_{QR} and $Q_{S_{MAX}}$ for Teadit 30SH

Relaxation ratio P_{QR} for stiffness $C = 500$ kN/mm						
Gasket Stress	Temperature 1 [21°C]		Temperature 2 [150°C]		Temperature 3 [230°C]	
	P_{QR}	Δe_{Gc} [mm]	P_{QR}	Δe_{Gc} [mm]	P_{QR}	Δe_{Gc} [mm]
Stress Level 1 [30 MPa]	0.91	0.024	0.71	0.073	0.55	0.113
Stress Level 2 [50 MPa]	0.95	0.021	0.63	0.157	0.51	0.206
P_{QR} and Δe_{Gc} at maximal applicable gasket stress $Q_{S_{max}}$						
P_{QR} at $Q_{S_{max}}$	0.97	0.048	0.65	0.235	0.55	0.229
$Q_{S_{max}}$	190 MPa		80 MPa		60 MPa	

Table 5.13
Teadit 30SH Properties

Technical Parameters	Unit	TEADIT 30 SH
Thickness	[mm]	0,50 - 9,00
Sheet dimensions	[mm]	1500 x 1500
Purity ePTFE	[%]	100
Color material		plain white
Color printing		red (or embossed)
Operating Temperature Range	[°C]	- 268 to + 260
Operating pressure	[bar]	Vacuum to 200
Gasket factors acc. DIN28090-2		
Compression (room temperature) εKSW	[%]	35 - 40
Creep relaxation (room temperature) εKRW	[%]	>3
Compression (elevated temperature) εWSW	[%]	<15
Gasket factors acc. ASTM		
Compressibility ASTM F 36M (34,5 MPa)	[%]	>45
Recovery ASTM F 36M (34,5 MPa)	[%]	>10
Creep ASTM F 38 (100 °C)	[%]	≤22
Other Properties		
Residual stress DIN 52913	MPa	>18
Leakage rate TA Luft / VDI 2240	mbar ^{1/2} /(s*m)	8,3*10 ⁻⁷
Leakage rate DIN 3535-6 (40bar, N2)	ml/min	<0,01
Tensile strength ASTM F 152	MPa	>25
Gasket factor "m" ASTM		2
Minimum gasket stress "y Stress" ASTM	psi	2800

The Style 30SH gasket properties for ASME calculations are shown in Table 5.14.

Table 5.14
30SH ASME Gasket Properties

m	2
y (psi)	2 800
SG _{max} - Maximum Seating Stress - MPa (psi)	190 (27500)
SG _{min-s} - Minimum Assembly Stress - MPa (psi)	40 (6525)
SG _{min-o} - Minimum Operating Stress - MPa (psi)	10 (1450)
Relaxation fraction at 100 MPa/150C φg	0,58
Maximum rotation Θg _{max}	0.7

5.2.6 TEADIT STYLE 28LS-LE

Teadit Style 28LS-LE is a new generation of gaskets produced from 100% pure, multi-directionally expanded PTFE. The biocompatible gaskets are designed for use in the pharmaceutical, chemical and food industry. A diffusion barrier ensures extraordinarily high sealability at very low gasket stress. They are therefore ideal for - but not limited to - sealing connections where only very low surface pressure can be applied, i.e. on plastic or glass flanges.

Teadit 28LS-LE gaskets have exceptional mechanical strength, which allows operation with minimal creep at elevated temperatures and are dimensionally stable, i.e. they do not get wider when compressed. The diffusion barrier on the inner diameter significantly increases the sealability of the gaskets and reduces cross contamination and migration.

Teadit 28LS-LE gaskets are manufactured according to *Good manufacturing Practices* (GMP) requirements, with full supply chain integrity and traceability. FDA and EU 1935/2004 certificates, issued by the Fraunhofer Institute, confirm its usability in the food and pharmaceutical Industry. They are not subject to aging or weathering and can be stored indefinitely. Gaskets can be easily identified by the embossed labelling, showing both type and dimension.

5.2.6.1. TEADIT 28LS-LE PROPERTIES

- Color: white
- Thickness: 1/16” (1.6 mm), 1/8” (3.2 mm) and ¼” (6 mm)
- Sizes: EN 1514-1 and ASME B 16.21
- Temperature range: -400 F (-240 C) up to 518 F (270 C). For short periods up to 600 F (315 C).
- Chemical resistance: chemically inert against all substances (pH 0-14), including the most aggressive acids and lyes. The only exceptions are molten alkali metals and elemental fluorine
- Operating pressure: from vacuum up to 200 bar

Gasket Parameters are shown in Table 5.15 to 5.17 and the sealing properties chart in Figure 5.12.

Table 5.15
Teadit 28LS-LE Gasket Parameters

TEADIT 28LS-LE			
Property	Test Method	Nominal Value	Parameters
Density - g/cm ³	ASTM D792	0.9	-
Compressibility - ε KSW(%)	DIN 28090-2	41	σ = 20 MPa
Recovery - ε KRW(%)	DIN 28090-2	10	σ = 20 MPa
Tensile Strength - MPa	ASTM F152	31	Room temperature
Stress Retention - MPa	DIN 52913	15	30 MPa - 150C -16h
Q min - 0.01	EN13555	<5	He - 40 bar
Qsmin - 0.01	EN13555	<5	He - 40 bar
Q min - 0.001	EN13555	8	He - 40 bar
Qsmin - 0.001	EN13555	8	He - 40 bar
Qsmax	EN13555	>140	Room temperature

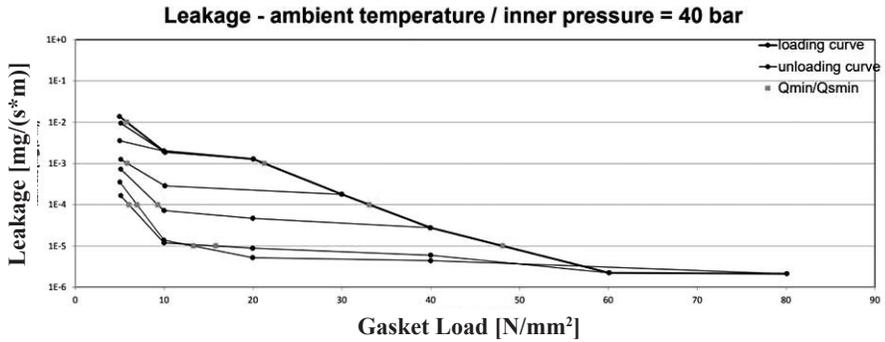


Figure 5.12

Table 5.16

Relaxation ratio PQR for stiffness C = 500 kN/mm						
Gasket Stress	Ambient Temperature		Temperature 1 [150°C]		Temperature 2 [230°C]	
	P_{QR}	Δe_{Gc}	P_{QR}	Δe_{Gc}	P_{QR}	Δe_{Gc}
Stress Level 1 [30 MPa]	0.92	0.020	0.71	0.073	0.55	0.113
Stress Level 2 [50 MPa]	0.94	0.025	0.64	0.151	0.51	0.206
P_{QR} and Δe_{Gc} at maximal applicable gasket stress Q_{Smax}						
P_{QR} at Q_{Smax}	0.96	0.064	0.64	0.242	0.54	0.232
Q_{Smax}	190 MPa		80 MPa		60 MPa	

Table 5.17

Minimum stress to seal $Q_{min/L}$ (at assembly), $Q_{Smin/L}$ (after off-loading) for p= 40 bar							
L [mg/(s*m)]	$Q_{Smin/L}$ [MPa]						
	$Q_{min/L}$	$Q_A = 10$ MPa	$Q_A = 20$ MPa	$Q_A = 30$ MPa	$Q_A = 40$ MPa	$Q_A = 60$ MPa	$Q_A = 80$ MPa
10^0	5	5	5	5	5	5	5
10^{-1}	5	5	5	5	5	5	5
10^{-2}	6	5	5	5	5	5	5
10^{-3}	21			6	5	5	5
10^{-4}	33				9	6	7
10^{-5}	48					16	13

6. PTFE SPIRAL WOUND GASKETS - ORIGIN® TECHNOLOGY

In a continuous search for better performance and sustainability, Teadit has developed the Origin® technology to manufacture PTFE gaskets [63]. This process has received an international patent WO 2017 / 049054A1 [64]. The gaskets are made from a sintered and wound PTFE tape. Tapes may be with or without fillers, expanded or not, with or without pigments. These possibilities make it possible to create infinite combinations to have the most suitable gasket product for each application. Different additives can be used in different regions of the gasket to have specific characteristics, including varying colors to identify these properties. Additionally, this technology allows the manufacture of thicker or large diameters gaskets without splices.

Another feature of this technology is the reduction of waste, the fabrication of gaskets from the cutting of sheets is extremely inefficient causing waste that can reach more than 60%. Origin® technology reduces process losses to virtually zero while substantially reducing environmental impact.

In 2018, Origin® technology was recognized by The Chemours Company receiving the Plunkett Award, which highlights innovations based on the use of fluoropolymers. New applications are gradually being developed, as this book is being edited the following gaskets are being marketed.

6.1. RAIL CAR MANWAY GASKET – ORIGIN® RC510

The RC510 gaskets were developed from Origin® technology. It is a PTFE with hollow glass microspheres gasket for rail tank cars manway dome lids, as shown in Figure 5.13.

Its high compressibility, torque retention and reusability are key features for this application. The RC510 allows extended use in multiple cycles without leaks.

Typical applications are the transport of ethanol, petroleum and its derivatives and chemically aggressive acids or caustics. It can be stored indefinitely without aging. They are available for most common domes such as AAR-1, TRN-1, UTC-1, etc.



Figure 5.13.

RC510 gaskets were installed on dome lids and compared to similar market products. Typical tests are performed by installing gaskets with 250lb-ft torque and pressurized with air at 35 psi. Then, a leak assessment is performed. After 1 hour, the dome is opened and, without changing the gasket, it is closed again and pressurized. The cycle is repeated 8 times, then pressurized for 16 hours, and then a new leak assessment is performed. The RC510 gasket retained sealability even after 40 cycles, which is superior to all other gaskets tested. The test result is shown in Table 5.17.

Table 5.18

Gasket	Number of cycles to failure
Origin RC510	More than 40
Competitor A	20
Competitor B	20
Competitor C	30
Competitor D	10

The result of the sealability test is shown in Figure 5.14.

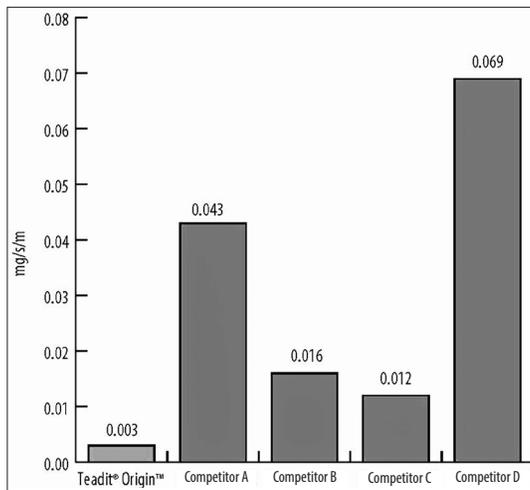


Figure 5.14

6.2. GASKETS FOR SULFURIC ACID PIPING - ORIGIN® APF-510

The Origin® APF-510 is a soft gasket with a sealing barrier for sulfuric acid process piping applications, as shown in Figure 5.15. They are designed to meet the specific conditions of this type of piping where the flanges have scratches or irregularities. The flange is threaded to the pipe which does not provide a leak free connection between them. Traditional gaskets do not seal satisfactorily under these conditions.

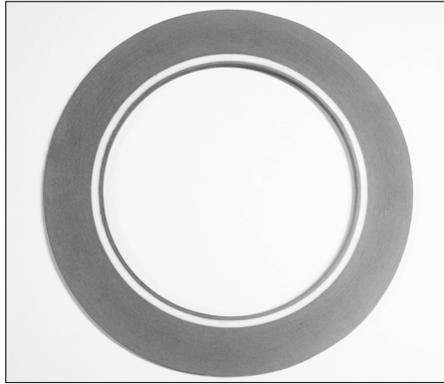


Figure 5.15

The Origin[®] APF-510 gaskets are produced from expanded PTFE tape with hollow glass microspheres, resulting in an extremely compressible gasket that conforms to flange irregularities. To ensure sealability, a low porosity pure PTFE barrier is located to seal the thread region. The location of the various PTFE tapes has been carefully studied to be compressed in the thread area ensuring a safe and reliable seal.

7. PTFE ENVELOPE GASKETS

PTFE Envelope gaskets are manufactured from a Compressed Sheet gasket core with a PTFE protection envelope.

They combine the mechanical strength, resilience and bolt load retention of Compressed Gasket Sheet with the chemical resistance of PTFE. They are used in equipment with glass; ceramic or glass coated steel flanges. Maximum service temperature is 500 F (260 C), the limit for PTFE. A Beater Addition core or Rubber core can also be used.

The main problem with PTFE envelope gaskets is that the envelope has a tendency to crack under stress. When this occur the media penetrates into the core which is not chemically resistant causing gasket failure.

7.1. STYLE 933-V

It is the most common and economical style (Figure 5.16). Its total thickness is limited to approximately 1/8 in (3.2 mm). Due to the high cost of PTFE the envelope is normally manufactured in raised face dimensions. In some applications to help the assembly of the gasket, the sheet core can be made with the same drilling pattern as the flange.

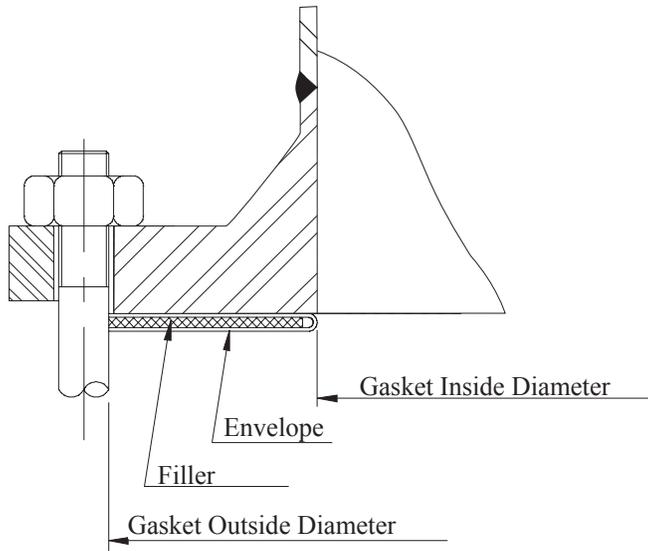


Figure 5.16

7.2. STYLE 933-U

When a gasket capable of absorbing more irregularities or with higher resiliency is desired, a corrugated stainless steel core is added to the core as shown in Figure 5.17.

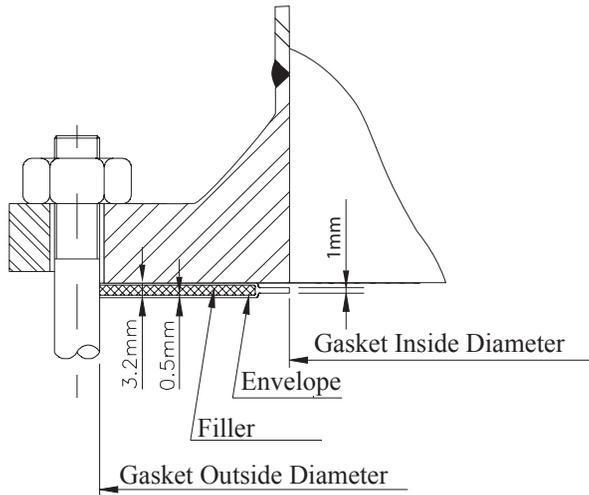


Figure 5.17

Annex 5.1
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Abietic Acid	A	A	A	A
Acetaldehyde	A	A	A	A
Acetamide	A	A	A	A
Acetic Acid (Crude,Glacial,Pure)	A	A	A	A
Acetic Anhydride	A	A	A	A
Acetone	A	A	A	A
Acetonitrile	A	A	A	A
Acetophenone	A	A	A	A
2-Acetylaminofluorene	A	A	A	A
Acetylene	A	A	A	A
Acrolein	B	B	B	A
Acrylamide	B	B	B	A
Acrylic Acid	B	B	B	A
Acrylic Anhydride	A	A	A	A
Acrylonitrile	B	B	B	A
Adipic Acid	A	A	A	A
Air	A	A	A	A
Allyl Acetate	A	A	A	A
Allyl Chloride	A	A	A	A
Allyl Methacrylate	A	A	A	A
Aluminum Acetate	A	A	A	A
Aluminum Chloride	A	A	A	A
Aluminum Fluoride	B	A	C	A
Aluminum Hydroxide (Solid)	A	A	A	A
Aluminum Nitrate	A	A	A	A
Aluminum Sulfate	A	A	A	A
Alums	A	A	A	A
4-Aminodiphenyl	A	A	A	A
Ammonium Carbonate	A	A	A	A
Ammonia, Liquid or Gas	A	A	A	A
Ammonium Chloride	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Ammonium Hydroxide	A	A	A	A
Ammonium Nitrate	A	A	A	A
Ammonium Phosphate, Dibasic	A	A	A	A
Ammonium Phosphate, Monobasic	A	A	A	A
Ammonium Phosphate, Tribasic	A	A	A	A
Ammonium Sulfate	A	A	A	A
Amyl Acetate	A	A	A	A
Amyl Alcohol	A	A	A	A
Aniline Dyes	A	A	A	A
Aniline, Aniline Oil	A	A	A	A
Aqua Regia	A	A	A	A
Aroclors	A	A	A	A
Asphalt	A	A	A	A
Aviation Gasoline	A	A	A	A
Barium Chloride	A	A	A	A
Barium Hydroxide	A	A	A	A
Barium Sulfide	A	A	A	A
Beer	A	A	A	A
Benzaldehyde	A	A	A	A
Benzene, Benzol	A	A	A	A
Benzidine	A	A	A	A
Benzoic Acid	A	A	A	A
Benzonitrile	A	A	A	A
Benzotrichloride	A	A	A	A
Benzoyl Chloride	A	A	A	A
Benzyl Alcohol	A	A	A	A
Benzyl Chloride	A	A	A	A
Beta-Propiolactone	A	A	A	A
Biphenyl	A	A	A	A
Bis(2-chloroethyl)ether	A	A	A	A
Bis(2-ethylhexyl)phthalate	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Bis(chloromethyl)ether	A	A	A	A
Black Sulfate Liquor	B	A	C	A
Blast Furnace Gas	A	A	A	A
Bleach (Sodium Hypochlorite)	A	A	A	A
Boiler Feed Water	A	A	A	A
Bórax	A	A	A	A
Boric Acid	A	A	A	A
Brine (Sodium Chloride)	A	A	A	A
Bromine	A	A	A	A
Bromine Trifluoride	C	C	C	C
Bromoform	A	A	A	A
Bromomethane	A	A	A	A
Butadiene	B	B	B	A
Butane	A	A	A	A
2-Butanone	A	A	A	A
Butyl Acetate	A	A	A	A
Butyl Alcohol, Butanol	A	A	A	A
Butyl Methacrylate	B	B	B	A
Butyric Acid	A	A	A	A
Calcium Bisulfite	A	A	A	A
Calcium Chloride	A	A	A	A
Calcium Cyanamide	A	A	A	A
Calcium Hydroxide	A	A	B	A
Calcium Hypochlorite	A	A	A	A
Calcium Nitrate	A	A	A	A
Calcium Sulphate	A	A	A	A
Calflo AF	A	A	A	A
Calflo FG	A	A	A	A
Calflo HTF	A	A	A	A
Calflo LT	A	A	A	A
Cane Sugar Liquors	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Tedit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Caprolactam	A	A	A	A
Captan	A	A	A	A
Carbaryl	A	A	A	A
Carbolic Acid,Phenol	A	A	A	A
Carbon Dioxide,Dry or Wet	A	A	A	A
Carbon Disulfide	A	A	A	A
Carbon Monoxide	A	A	A	A
Carbon Tetrachloride	A	A	A	A
Carbonic Acid	A	A	A	A
Carbonyl Sulfide	A	A	A	A
Castor Oil	A	A	A	A
Catechol	A	A	A	A
Cetane (Hexadecane)	A	A	A	A
China Wood Oil	A	A	A	A
Chloramben	A	A	A	A
Chlordane	A	A	A	A
Chlordane	A	A	A	A
Chlorinated Solvents,Dry or Wet	A	A	A	A
Chlorine Dioxide	A	A	A	A
Chlorine Trifluoride	C	C	C	C
Chlorine, Dry or Wet	A	A	A	A
Chloroacetic Acid	A	A	A	A
2-Chloroacetophenone	A	A	A	A
Chloroazotic Acid (Aqua Regia)	A	A	A	A
Chlorobenzene	A	A	A	A
Chlorobenzilate	A	A	A	A
Chloroethane	A	A	A	A
Chloroethylene	A	A	A	A
Chloroform	A	A	A	A
Chloromethyl Methyl Ether	A	A	A	A
Chloronitrous Acid (Aqua Regia)	A	A	A	A
Chloroprene	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Chlorosulfonic Acid	A	A	A	A
Chrome Plating Solutions	B	A	B	A
Chromic Acid	A	A	A	A
Chromic Anhydride	A	A	A	A
Chromium Trioxide	A	A	A	A
Citric Acid	A	A	A	A
Coke Oven Gas	A	A	A	A
Copper Acetate	A	A	A	A
Copper Chloride	A	A	A	A
Copper Sulfate	A	A	A	A
Corn Oil	A	A	A	A
Cotton Seed Oil	A	A	A	A
Creosote	A	A	A	A
Cresols, Cresylic Acid	A	A	A	A
Crotonic Acid	A	A	A	A
Crude Oil	A	A	A	A
Cumene	A	A	A	A
Cyclohexane	A	A	A	A
Cyclohexanol	B	B	B	B
Cyclohexanone	A	A	A	A
2,4-D, Salts and Esters	A	A	A	A
Detergent Solutions	B	A	B	A
Diazomethane	A	A	A	A
Dibenzofuran	A	A	A	A
Dibenzylether	A	A	A	A
1,2-Dibromo-3-chloropropane	A	A	A	A
Dibromoethane	A	A	A	A
Dibutyl Phthalate	A	A	A	A
Dibutyl Sebacate	A	A	A	A
1,4-Dichlorobenzene	A	A	A	A
3,3-Dichlorobenzidene	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Dichloroethane (1,1 or 1,2)	A	A	A	A
Dichloroethyl Ether	A	A	A	A
1,1-Dichloroethylene	B	B	B	A
Dichloromethane	A	A	A	A
1,2-Dichloropropane	A	A	A	A
1,3-Dichloropropene	A	A	A	A
Dichlorvos	A	A	A	A
Diesel Oil	A	A	A	A
Diethanolamine	A	A	A	A
Diethyl Carbonate	A	A	A	A
Diethyl Sulfate	A	A	A	A
3,3-Dimethoxybenzidene	A	A	A	A
Dimethyl Carbamoyl Chloride	A	A	A	A
Dimethyl Ether	A	A	A	A
Dimethyl Hydrazine, Unsymmetrical	A	A	A	A
Dimethyl Phthalate	A	A	A	A
Dimethyl Sulfate	A	A	A	A
Dimethylaminoazobenzene	A	A	A	A
3,3-Dimethylbenzidine	A	A	A	A
Dimethylformamide	A	A	A	A
4,6-Dinitro-o-Cresol and Salts	A	A	A	A
2,4-Dinitrophenol	A	A	A	A
2,4-Dinitrotoluene	A	A	A	A
Dioxane	A	A	A	A
1,2-Diphenylhydrazine	A	A	A	A
Diphyl DT	A	A	A	A
Dowfrost	A	A	A	A
Dowfrost HD	A	A	A	A
Dowtherm 4000	A	A	A	A
Dowtherm A	A	A	A	A
Dowtherm E	A	A	A	A
Dowtherm G	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Dowtherm HT	A	A	A	A
Dowtherm J	A	A	A	A
Dowtherm Q	A	A	A	A
Dowtherm SR-1	A	A	A	A
Epichlorohydrin	A	A	A	A
1,2-Epoxybutane	A	A	A	A
Ethane	A	A	A	A
Ethers	A	A	A	A
Ethyl Acetate	A	A	A	A
Ethyl Acrylate	B	B	B	A
Ethyl Alcohol	A	A	A	A
Ethyl Carbamate	A	A	A	A
Ethyl Cellulose	A	A	A	A
Ethyl Chloride	A	A	A	A
Ethyl Ether	A	A	A	A
Ethyl Hexoate	A	A	A	A
Ethylbenzene	A	A	A	A
Ethylene	A	A	A	A
Ethylene Bromide	A	A	A	A
Ethylene Dibromide	A	A	A	A
Ethylene Dichloride	A	A	A	A
Ethylene Glycol	A	A	A	A
Ethylene Oxide	B	B	B	A
Ethylene Thiourea	A	A	A	A
Ethyleneimine	B	A	B	A
Ethylidine Chloride	A	A	A	A
Ferric Chloride	A	A	A	A
Ferric Phosphate	A	A	A	A
Ferric Sulfate	A	A	A	A
Fluorine Dioxide	C	C	C	C
Fluorine, Gas	C	C	C	C

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Tedit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Fluorine, Liquid	C	C	C	C
Formaldehyde	A	A	A	A
Formamid	A	A	A	A
Formic Acid	A	A	A	A
Freon 12, Frigen 12, Arcton 12	A	A	A	A
Freon 22, Frigen 22, Arcton 22	A	A	A	A
Fuel Oil	A	A	A	A
Fuel Oil, Acid	A	A	A	A
Furfural	A	A	A	A
Gasoline, Refined	A	A	A	A
Gasoline, Sour	A	A	A	A
Gelatin	A	A	A	A
Generator Gas	A	A	A	A
Glucose	A	A	A	A
Glue, Protein Base	A	A	A	A
Glycerine, Glycerol	A	A	A	A
Glycol	A	A	A	A
Grain Alcohol	A	A	A	A
Grease, Petroleum Base	A	A	A	A
Green Sulfate Liquor	B	A	C	A
Heptachlor	A	A	A	A
Heptane	A	A	A	A
Hexachlorobenzene	A	A	A	A
Hexachlorobutadiene	A	A	A	A
Hexachlorocyclopentadiene	A	A	A	A
Hexachloroethane	A	A	A	A
Hexadecane	A	A	A	A
Hexamethylene Diisocyanate	A	A	A	A
Hexamethylphosphoramide	A	A	A	A
Hexane	A	A	A	A
Hexone	A	A	A	A
Hydraulic Oil, Mineral	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Tedit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Hydraulic Oil, Synthetic	A	A	A	A
Hydrazine	A	A	A	A
Hydrobromic Acid	A	A	A	A
Hydrochloric Acid	A	A	A	A
Hydrocyanic Acid	A	A	A	A
Hydrofluoric Acid, < 65% > 150°F	C	A	C	A
Hydrofluoric Acid, = 150°F	C	A	C	A
Hydrofluoric Acid, 65% to Anhydrous, > 150°F	C	B	C	A
Hydrofluoric Acid, Anhydrous	C	C	C	A
Hydrofluorosilicic Acid	C	A	C	A
Hydrogen	A	A	A	A
Hydrogen Bromide	A	A	A	A
Hydrogen chloride (dry)	A	A	A	A
Hydrogen Fluoride	C	C	C	A
Hydrogen Peroxide,10-90%	A	A	A	A
Hydrogen Sulfide,Dry or Wet	A	A	A	A
Hydroquinone	A	A	A	A
Iodine Pentafluoride	B	B	B	B
Iodomethane	A	A	A	A
Isobutane	A	A	A	A
Isooctane	A	A	A	A
Isophorone	A	A	A	A
Isopropyl Alcohol	A	A	A	A
Jet Fuels (JP Types)	A	A	A	A
Kerosene	A	A	A	A
Lacquer Solvents	A	A	A	A
Lacquers	A	A	A	A
Lactic Acid, Above 150°F	A	A	A	A
Lactic Acid, 150°F and below	A	A	A	A
Lead Acetate	A	A	A	A
Lead Arsenate	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Lime Saltpeter (Calcium Nitrates)	A	A	A	A
Lindane	A	A	A	A
Linseed Oil	A	A	A	A
Liquefied petroleum gas	A	A	A	A
Lithium Bromide	A	A	A	A
Lithium, Elemental	C	C	C	A
Lubricating Oils, Refined	A	A	A	A
Lubricating Oils, Sour	A	A	A	A
Lubricating Oils, Mineral or Petroleum Types	A	A	A	A
Lye	B	B	C	A
Magnesium Chloride	A	A	A	A
Magnesium Hydroxide	A	A	A	A
Magnesium Sulfate	A	A	A	A
Maleic Acid	A	A	A	A
Maleic Anhydride	A	A	A	A
Mercuric Chloride	A	A	A	A
Mercury	A	A	A	A
Methane	A	A	A	A
Methanol, Methyl Alcohol	A	A	A	A
Methoxychlor	A	A	A	A
Methyl Alcohol	A	A	A	A
Methyl Bromide	A	A	A	A
Methyl Chloride	A	A	A	A
Methyl Chloroform	A	A	A	A
Methyl Ethyl Ketone	A	A	A	A
Methyl Hydrazine	A	A	A	A
Methyl Iodide	A	A	A	A
Methyl Isobutyl Ketone (MIBK)	A	A	A	A
Methyl Isocyanate	A	A	A	A
Methyl Methacrylate	B	B	B	A
Methyl Tert. Butyl Ether (MTBE)	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Methylacrylic Acid	A	A	A	A
2-Methylaziridine	B	A	B	A
4,4 Methylene Bis (2-chloroaniline)	A	A	A	A
Methylene Chloride	A	A	A	A
4,4-Methylene Dianiline	A	A	A	A
Methylene Diphenyldiisocyanate	A	A	A	A
Milk	A	A	A	A
Mineral Oils	A	A	A	A
Mobiltherm 600	A	A	A	A
Mobiltherm 603	A	A	A	A
Mobiltherm 605	A	A	A	A
Mobiltherm Light	A	A	A	A
Molten Alkali Metals	C	C	C	C
Monomethylamine	A	A	A	A
MultiTherm 100	A	A	A	A
MultiTherm 503	A	A	A	A
MultiTherm IG-2	A	A	A	A
MultiTherm PG-1	A	A	A	A
Muriatic Acid	A	A	A	A
N,N-Diethylaniline	A	A	A	A
N,N-Dimethyl Aniline	A	A	A	A
Naphtha	A	A	A	A
Naphthalene	A	A	A	A
Naphthols	A	A	A	A
Natural Gas	A	A	A	A
n-Butyl Amine	A	A	A	A
Nickel Chloride	A	A	A	A
Nickel Sulfate	A	A	A	A
Nitric Acid, Above 0,3	A	A	A	A
Nitric Acid, Crude	A	A	A	A
Nitric Acid, Less than 0,3	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Nitric Acid, Red Fuming	A	A	A	A
2-Nitro-2-Methyl Propanol	A	A	A	A
Nitrobenzene	A	A	A	A
4-Nitrobiphenyl	A	A	A	A
2-Nitro-Butanol	A	A	A	A
Nitrocalcite (Calcium Nitrate)	A	A	A	A
Nitrogen	A	A	A	A
Nitrogen Tetroxide	A	A	A	A
Nitrohydrochloric Acid (Aqua Regia)	A	A	A	A
Nitromethane	A	A	A	A
Nitromuriatic Acid (Aqua Regia)	A	A	A	A
4-Nitrophenol	A	A	A	A
2-Nitropropane	A	A	A	A
N-Methyl-2-Pyrrolidone	A	A	A	A
N-Nitrosodimethylamine	A	A	A	A
N-Nitrosomorpholine	A	A	A	A
N-Nitroso-N-Methylurea	A	A	A	A
N-Octadecyl Alcohol	A	A	A	A
Norge Niter (Calcium Nitrate)	A	A	A	A
Norwegian Saltpeter (Calcium Nitrate)	A	A	A	A
o-Anisidine	A	A	A	A
Octane	A	A	A	A
o-Dichlorobenzene	A	A	A	A
Oil, Petroleum	A	A	A	A
Oils, Animal and Vegetable	A	A	A	A
Oleic Acid	A	A	A	A
Oleum	B	C	A	A
Orthodichlorobenzene	B	A	A	A
o-Toluidine	A	A	A	A
Oxalic Acid	B	A	A	A
Oxygen, Gas	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Ozone	A	A	A	A
Palmitic Acid	A	A	A	A
Paraffin	A	A	A	A
Paratherm HE	A	A	A	A
Paratherm NF	A	A	A	A
Parathion	A	A	A	A
Paraxylene	A	A	A	A
Pentachloronitrobenzene	A	A	A	A
Pentachlorophenol	A	A	A	A
Pentane	A	A	A	A
Perchloric Acid	A	A	A	A
Perchloroethylene	A	A	A	A
Petroleum Oils, Refined	A	A	A	A
Petroleum Oils,Crude	A	A	A	A
Phenol	A	A	A	A
Phosgene	A	A	A	A
Phosphate Esters	A	A	A	A
Phosphine	A	A	A	A
Phosphoric Acid, Pure Less than 45%	A	A	A	A
Phosphoric Acid, Pure Above 45%, 150°F and below	B	A	C	A
Phosphoric Acid Pure, Above 45%, Above 150°F	B	A	B	A
Phosphoric Acid,Crude	C	A	C	A
Phosphorus Pentachloride	A	A	A	A
Phosphorus, Elemental	A	A	A	A
Phthalic Acid	A	A	A	A
Phthalic Anhydride	A	A	A	A
Picric Acid, Molten	B	B	B	B
Picric Acid, Water Solution	A	A	A	A
Pinene	A	A	A	A
Piperidine	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Tedit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Polyacrylonitrile	A	A	A	A
Polychlorinated Biphenyls	A	A	A	A
Potash, Potassium Carbonate	A	A	A	A
Potassium Acetate	A	A	A	A
Potassium Bichromate	A	A	A	A
Potassium chlorate	A	A	A	A
Potassium chloride	A	A	A	A
Potassium Chromate, Red	A	A	A	A
Potassium Cyanide	A	A	A	A
Potassium Dichromate	A	A	A	A
Potassium Hydroxide	B	B	C	A
Potassium Hypochlorite	A	A	A	A
Potassium iodide	A	A	A	A
Potassium Nitrate	A	A	A	A
Potassium Permanganate	A	A	A	A
Potassium Sulfate	A	A	A	A
Potassium, Elemental	C	C	C	C
p-Phenylenediamine	A	A	A	A
Producer Gas	A	A	A	A
Propane	A	A	A	A
1,3-Propane Sultone	A	A	A	A
Propionaldehyde	A	A	A	A
Propoxur (Baygon)	A	A	A	A
Propyl alcohol	A	A	A	A
Propyl Nitrate	A	A	A	A
Propylene	A	A	A	A
Propylene Dichloride	A	A	A	A
Propylene Glycol	A	A	A	A
Propylene Oxide	A	A	A	A
1,2-Propylenimine	B	A	B	A
Prussic Acid, Hydrocyanic Acid	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Pyridine	A	A	A	A
Quinoline	A	A	A	A
Quinone	A	A	A	A
Rapeseed oil	A	A	A	A
Refrigerant, 10	A	A	A	A
Refrigerant, 218	A	A	A	A
Refrigerant, 11	A	A	A	A
Refrigerant, 112	A	A	A	A
Refrigerant, 113	A	A	A	A
Refrigerant, 114	A	A	A	A
Refrigerant, 114B2	A	A	A	A
Refrigerant, 115	A	A	A	A
Refrigerant, 12	A	A	A	A
Refrigerant, 123	A	A	A	A
Refrigerant, 124	A	A	A	A
Refrigerant, 125	A	A	A	A
Refrigerant, 13	A	A	A	A
Refrigerant, 134a	A	A	A	A
Refrigerant, 13B1	A	A	A	A
Refrigerant, 141b	A	A	A	A
Refrigerant, 142b	A	A	A	A
Refrigerant, 143a	A	A	A	A
Refrigerant, 152a	A	A	A	A
Refrigerant, 21	A	A	A	A
Refrigerant, 22	A	A	A	A
Refrigerant, 23	A	A	A	A
Refrigerant, 290	A	A	A	A
Refrigerant, 31	A	A	A	A
Refrigerant, 32	A	A	A	A
Refrigerant, 500	A	A	A	A
Refrigerant, 502	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Refrigerant, 503	A	A	A	A
Refrigerant, 507	A	A	A	A
Refrigerant, 744 (Carbon dioxide)	A	A	A	A
Refrigerant, 777 (Ammonia)	A	A	A	A
Refrigerant, C316	A	A	A	A
Refrigerant, C318	A	A	A	A
Refrigerant, HP62	A	A	A	A
Refrigerant, HP80	A	A	A	A
Refrigerant, HP81	A	A	A	A
Salicylic Acid	A	A	A	A
Salicylic Acid, 10%, = 150°F	A	A	A	A
Salt Water	A	A	A	A
Saltpeter, Potassium Nitrate	A	A	A	A
Sewage	A	A	A	A
Silicone Oil	A	A	A	A
Silver Nitrate	A	A	A	A
Skydrols	A	A	A	A
Soap Solutions	A	A	A	A
Soda Ash, Sodium Carbonate	A	A	A	A
Sodium Aluminate	A	A	A	A
Sodium Bicarbonate, Baking Soda	A	A	A	A
Sodium Bisulfate, Dry	A	A	A	A
Sodium Bisulfite	A	A	A	A
Sodium Chlorate	A	A	A	A
Sodium Chloride	A	A	A	A
Sodium Cyanide	C	A	C	A
Sodium Hydroxide	B	A	C	A
Sodium Hypochlorite	A	A	A	A
Sodium Metaborate Peroxyhydrate	A	A	A	A
Sodium Metaphosphate	A	A	B	A
Sodium Nitrate	A	A	A	A
Sodium Perborate	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Sodium Peroxide	A	A	A	A
Sodium Phosphate, Dibasic	B	A	B	A
Sodium Phosphate, Monobasic	A	A	A	A
Sodium Phosphate, Tribasic	B	A	C	A
Sodium Silicate	B	A	B	A
Sodium Sulfate	A	A	A	A
Sodium Sulfide	A	A	A	A
Sodium Superoxide	A	A	A	A
Sodium Thiosulfate, Hypo	A	A	A	A
Sodium, Elemental	C	C	C	C
Soybean Oil10	A	A	A	A
Stannic Chloride	A	A	A	A
Starch	A	A	A	A
Steam	A	A	A	A
Stearic Acid	A	A	A	A
Styrene	B	B	B	A
Styrene Oxide	A	A	A	A
Sugar	A	A	A	A
Sulfur Chloride	A	A	A	A
Sulfur Dioxide	A	A	A	A
Sulfur Trioxide, Dry or Wet	A	A	A	A
Sulfur, Molten	A	A	A	A
Sulfuric Acid, 10%, Above 150°F	A	A	A	A
Sulfuric Acid, 10-75%, 500°F and below	A	A	A	A
Sulfuric Acid, 75-98%, 150°F and below	A	B	A	A
Sulfuric Acid, 75-98%, 150°F to 500°F	B	B	A	A
Sulfuric Acid, Fuming	B	C	A	A
Sulfurous Acid	A	A	A	A
Syltherm 800	A	A	A	A
Syltherm XLT	A	A	A	A
Tannic Acid	A	A	A	A
Tar	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Tartaric Acid	A	A	A	A
2,3,7,8-TCDB-p-Dioxin	A	A	A	A
tert-Butyl Amine	A	A	A	A
Tetrabromoethane	A	A	A	A
Tetrachlorethane	A	A	A	A
Tetrachloroethylene	A	A	A	A
Tetrahydrofuran, THF	A	A	A	A
Therminol 44	A	A	A	A
Therminol 55	A	A	A	A
Therminol 59	A	A	A	A
Therminol 60	A	A	A	A
Therminol 66	A	A	A	A
Therminol 75	A	A	A	A
Therminol D12	A	A	A	A
Therminol LT	A	A	A	A
Therminol VP-1	A	A	A	A
Therminol XP	A	A	A	A
Thionyl Chloride	A	A	A	A
Titanium Sulfate	A	A	A	A
Titanium Tetrachloride	A	A	A	A
Toluene	A	A	A	A
Toluene Sulfonic Acid	A	A	A	A
2,4-Toluenediamine	A	A	A	A
2,4-Toluenediisocyanate	A	A	A	A
Toxaphine	A	A	A	A
Transformer Oil (Mineral Type)	A	A	A	A
Transmission Fluid	A	A	A	A
Trichloroacetic Acid	A	A	A	A
Trichlorobenzene	A	A	A	A
1,2,4- Trichlorobenzene	A	A	A	A
1,1,2-Trichloroethane	A	A	A	A
Trichloroethylene	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
2,4,5-Trichlorophenol	A	A	A	A
2,4,6-Trichlorophenol	A	A	A	A
Tricresylphosphate	A	A	A	A
Triethanolamine	A	A	A	A
Triethyl Aluminum	A	A	A	A
Triethylamine	A	A	A	A
Trifluralin	A	A	A	A
2,2,4-Trimethylpentane	A	A	A	A
Tung Oil	A	A	A	A
Turpentine	A	A	A	A
Turpentine	A	A	A	A
UCON Heat Transfer Fluid 500	A	A	A	A
UCON Process Fluid WS	A	A	A	A
Urea, = 65°C	A	A	A	A
Urea, > 65°C	A	A	A	A
Varnish	A	A	A	A
Vinegar10	A	A	A	A
Vinyl Acetate	B	B	B	A
Vinyl Bromide	B	B	B	A
Vinyl Chloride	B	B	B	A
Vinyl Methacrylate	A	A	A	A
Vinylidene Chloride	B	B	B	A
Water chlorinated	A	A	A	A
Water, Acid Mine, with Oxidizing Salt	A	A	A	A
Water, Acid Mine, No Oxidizing Salts	A	A	A	A
Water, Distilled	A	A	A	A
Water, Return Condensate	A	A	A	A
Water, Seawater	A	A	A	A
Water, Tap	A	A	A	A
Whiskey and Wines	A	A	A	A
Wood Alcohol	A	A	A	A

* See note at the end of the table

Annex 5.1 (Continued)
PTFE Chemical Compatibility Chart*

A: recommended

B: consult with Teadit

C: not recommended

PRODUCT	TF1510 TF1570	TF1580	TF1590	24 SH, 24 B, 25 BI, 28 LS-LE, 30 SH
Xceltherm 550	A	A	A	A
Xceltherm 600	A	A	A	A
Xceltherm MK1	A	A	A	A
Xceltyherm XT	A	A	A	A
Xylene	A	A	A	A
Zinc Chloride	A	A	A	A
Zinc Sulfate	A	A	A	A

* See note at the end of the table

NOTE: Properties and application parameters shown throughout this PTFE Chemical Compatibility Chart are typical. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult with TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury. Specifications subject to change without notice; this edition cancels all previous issues.

MATERIALS FOR METALLIC GASKETS

1. PRELIMINARY CONSIDERATIONS

On specifying the material for a metallic gasket, we must analyze the metal or alloy properties and its reactions under stress and temperature. Special attention must be given to:

- **Stress Corrosion:** stainless steel 18-8 can show stress corrosion in the presence of certain fluids. Table 6.1 shows products that can cause stress corrosion in the most frequently used alloys for industrial gaskets.

- **Intergranular Corrosion:** some chemical products can precipitate carbides in austenitic stainless steel in temperatures between 790F (420C) and 1490F (810C). This precipitation is known as Intergranular Corrosion. Table 6.2 shows products, which induce Intergranular Corrosion.

- **Fluid Compatibility:** the gasket should resist deterioration or corrosive action by the sealed product and at the same time avoid its contamination. Table 6.3 presents recommendations for most frequently used metallic gasket materials.

Following are the most widely used alloys in manufacturing industrial gaskets, their major characteristics, temperature limits and approximate hardness.

2 . CARBON STEEL

Material frequently used in manufacturing jacketed gaskets and Ring Joints. Due to its low resistance to corrosion it should not be used in water, diluted acids or saline solutions. It may be used in alkalis and concentrated acids. Temperature limit is 900F (500C). Hardness: 56 HRB.

3. STAINLESS STEEL AISI 304

Alloy with 18% Cr and 8% Ni is the material most used in the manufacturing of industrial gaskets due to its excellent resistance to corrosion, low cost and availability in the market. Its maximum operating temperature is 1400F (760C). Due to stress and intergranular corrosion, its continuous service temperature is limited to 790F (420C). Hardness: 68 HRB.

4. STAINLESS STEEL AISI 304L

It has the same resistance to corrosion as the AISI 304. Since its Carbon content is limited to 0.03%, it has less intergranular Carbon precipitation and therefore less intergranular corrosion. Its operational limit for continuous service is 1400F (760C). It is susceptible to Stress Corrosion. Hardness: 68 HRB.

5. STAINLESS STEEL AISI 316

This alloy with 18% Ni, 13% Cr and 2% Mo, offers excellent resistance to corrosion. It can have carbonate precipitation at temperatures between 860F (460C) and 1650F (900C), under severe corrosion conditions. Maximum recommended temperature for continuous service is 1400F (760C). Hardness: 68 HRB.

6. STAINLESS STEEL AISI 316L

It has the same chemical composition as the AISI 316 but its Carbon content is limited to 0.03%, which inhibits intergranular carbon precipitation and consequently, the intergranular corrosion. The maximum service temperature is 1400F (760C). Hardness: 68 HRB.

7. STAINLESS STEEL AISI 321

Austenitic stainless steel alloy with 18% Cr and 10% Ni stabilized with Ti, which reduces the intergranular carbon precipitation and also the intergranular corrosion. It can be used in temperatures up to 1500F (815C). Hardness: 68 HRB.

8. STAINLESS STEEL AISI 347

Alloy similar to the AISI 304 stabilized with Cb and Ta to reduce carbonate precipitation and intergranular corrosion. It is subject to Stress Corrosion. Has good performance in high temperature corrosive service. Maximum temperature: 1550F (815C). Hardness: 68 HRB.

9. MONEL

Alloy with 67% Ni and 30% Cu, it offers excellent resistance to the majority of acids and alkalis, except to extremely oxidant acids. Subject to stress corrosion and therefore should not be used in the presence of fluorine-silicon acid and Mercury. In combination with PTFE, it is used frequently in Spiral Wound gaskets for severe corrosion services. Operating maximum temperature: 1500F (815C). Hardness: 70 HRB.

10. NICKEL 200

Alloy with 99% Ni, offers great resistance to caustic solutions, even though it does not have the same global resistance of Monel. It is also used in Spiral Wound and jacketed gaskets for special applications. Maximum operating temperature: 1400F (760C). Hardness: 45 HRB.

11. COPPER

Material often used in small dimension gaskets, where the maximum seating stress is limited. Maximum operating temperature: 500F (260C). Hardness: 50 HRF.

12. ALUMINUM

Due to its excellent resistance to corrosion and easy handling it is very often used in manufacturing gaskets. Maximum service temperature: 860F (460C). Hardness: 15 HV.

13. INCONEL

Alloy with 70% Ni, 15% Cr and 7% Fe, it has excellent resistance from cryogenic to high temperatures. Temperature limit: 2000F (1100C). Hardness: 99 HRB.

14. TITANIUM

Metal with excellent corrosion properties in elevated temperatures, oxidant service, Nitric acid and caustic solutions. Temperature limit: 2000F (1100C). Hardness: 90 HRB.

Besides these materials , which are the most commonly used in industrial applications, there are many others like Hastelloy, Carpenter, etc depending on the operational circumstances. They are not analyzed in this book due to the fact that their application is restricted to very special situations when the use of an alternative material is not possible.

TABLE 6.1

STRESS CORROSION CHART

A: Aluminum
B : Brass

C: Carbon Steel
M: Monel

S : Stainless Steel 18-8
N: Nickel

SERVICE	C	S	B	M	N	A
Ammonium Chloride	X					
Ammonia - diluted			X			
Ammonia - pure	X					
Ammonium Nitrate	X	X				
Butane + Sulfur Dioxide			X			
Calcium Bromide	X					
Chloridic Acid		X				
Chromic Acid	X					
Cresylic Acid vapor	X					
Cyanogen	X					
Fluoridric Acid		X		X	X	
Fluorsilicic Acid				X		
Hydrogen Chloride + water	X	X				
Hydrogen Cyanide + water	X					
Hydrogen Sulfide + water	X					
Hydrofluoric Acid	X			X	X	
Inorganic Chlorides + water		X				
Inorganic Nitrates	X					
Mercurous Nitrate				X		
Mercury				X		
Nitric Acid diluted		X				
Nitric Acid vapor			X			
Nitric Acid + Magnesium Chloride	X					
Oleum	X					
Organic Chlorides + water		X				
Pickling Acids		X				
Potassium Hydroxide	X	X		X		
Potassium Permanganate	X					
Salt water + Oxygen						X

TABLE 6.1 (continued)

STRESS CORROSION CHART

A: Aluminum
B : Brass

C: Carbon Steel
M: Monel

S : Stainless Steel 18-8
N: Nickel

SERVICE	C	S	B	M	N	A
Silicofluoride Salts				X		
Sodium Hydroxide	X	X		X	X	
Steam				X	X	
Sulfate Liquor (white)	X	X				
Sulfide Liquor		X				
Sulfuric Acid + Nitric Acid	X					
Sulfur Compounds					X	

TABLE 6.2

**PRODUCTS THAT CAN INDUCE INTERGRANULAR CORROSION IN
AUSTENITIC STAINLESS STEELS**

PRODUCT
Acetic Acid
Acetic Acid + Salicylic Acid
Ammonium Nitrate
Ammonium Sulfate
Ammonium Sulfate + Sulfuric Acid
Beet Juice
Cyanidric Acid
Cyanidric Acid + Sulfur Dioxide
Calcium Nitrate
Chromic Acid
Chromium Chloride
Copper Sulfate
Crude Oil
Fatty Acids
Ferric Chloride
Ferric Sulfate
Formic Acid
Hydrocyanic Acid
Hydrocyanic Acid + Sulfur Dioxide
Hydrocyanic Acid + Hydrofluoric Acid
Lactic Acid
Lactic Acid + Nitric Acid
Maleic Acid
Nitric Acid + Hydrochloric Acid
Nitric Acid + Hydrofluoric Acid
Oxalic Acid
Phenol + Naphthenic Acid
Phosphoric Acid
Phthalic Acid

TABLE 6.2 (continued)

**PRODUCTS THAT CAN INDUCE INTERGRANULAR CORROSION IN
AUSTENITIC STAINLESS STEELS**

PRODUCT
Salt spray
Sea Water
Silver Nitrate + Acetic Acid
Sodium Bisulfate
Sodium Hydroxide + Sodium Sulfide
Sodium Hypochlorite
Sulfide Cooking Liquor
Sulfide Digester Acid
Sulfamic Acid
Sulfur Dioxide + water
Sulfuric Acid
Sulfuric Acid + Acetic Acid
Sulfuric Acid + Copper Sulfate
Sulfuric Acid + Ferrous Sulfate
Sulfuric Acid + Methanol
Sulfuric Acid + Nitric Acid
Sulfurous Acid
Water + Starch + Sulfur Dioxide
Water + Aluminum Sulfate

TABLE 6.3

CORROSION RESISTANCE OF GASKET METALS

S: satisfactory
F: fair

U: unsatisfactory
-: no information

C : Copper

A : Aluminum

M: Monel

N : Nickel

S : Iron and Carbon Steel

4: 304 Stainless Steel

6: 316 Stainless Steel

7: 347 Stainless Steel

SERVICE	C	A	M	N	S	4	6	7
Acetic Acid	F	S	S	F	U	F	F	-
Acetic Anhydride	U	S	S	-	-	F	F	F
Acetone	S	S	S	S	S	S	S	S
Acetylene	-	S	S	-	S	S	S	-
Air	S	S	S	S	S	S	S	S
Aluminum Chloride	F	U	S	-	F	U	U	F
Aluminum Sulphate	F	-	F	-	U	F	F	F
Alums	F	-	F	-	U	F	F	F
Ammonia	U	S	S	-	S	S	S	-
Ammonium Chloride	U	U	F	F	-	F	F	-
Ammonium Hydroxide	U	F	-	-	S	S	S	S
Ammonium Nitrate	U	F	-	-	S	S	S	S
Ammonium Phosphate	F	F	S	S	F	S	S	-
Ammonium Sulphate	F	-	S	-	S	S	S	S
Amyl Acetate	F	F	S	-	-	S	S	S
Amyl Alcohol	S	-	S	-	-	-	-	-
Aniline	U	U	S	-	-	S	-	-
Asphalt	S	-	S	-	S	S	-	-
Barium Chloride	-	U	-	S	-	F	S	-
Barium Hydroxide	U	U	-	S	-	S	-	-
Barium Sulphide	U	-	S	-	-	S	S	S
Beer	S	S	S	-	S	S	S	-
Beet Sugar Liquors	S	S	S	-	S	S	S	-
Benzene	S	S	S	-	S	S	S	-
Benzine	S	S	S	-	S	S	S	-
Black Sulphate Liquor	F	-	S	-	S	S	-	-
Blast Furnace Gas	U	-	-	-	S	-	-	S

TABLE 6.3 (continued)

CORROSION RESISTANCE OF GASKET METALS

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SERVICE		C	A	M	N	S	4	6	7
Borax		F	F	S	S	S	S	S	S
Boric Acid		F	S	S	S	U	S	S	S
Bromine		U	-	-	-	U	U	U	U
Butane		-	S	S	-	S	-	S	-
Butanol		S	-	S	-	S	-	-	-
Butyl Acetate		S	S	-	-	-	S	S	S
Calcium Bisulphide		U	-	U	-	U	-	S	S
Calcium Chloride		S	-	F	-	S	-	-	-
Calcium Hydroxide		-	-	S	S	S	F	F	-
Caliche Liquors		-	-	S	-	S	S	-	-
Cane Sugar Liquors		S	S	S	-	S	S	S	-
Carbolic Acid		U	S	S	-	-	S	S	-
Carbon Dioxide	Dry	S	S	S	-	S	S	S	-
	Wet	F	F	S	-	F	S	S	-
Carbon Bisulphide		U	S	S	-	S	S	S	-
Carbon Monoxide		U	-	-	-	S	S	S	S
Carbon Tetrachloride		-	-	S	-	-	-	-	-
Castor Oil		-	S	S	-	S	S	-	-
Chlorine	Dry	S	S	S	-	S	S	S	-
	Wet	U	U	U	-	U	U	-	-
Chlorinated Solvents	Dry	S	S	S	-	S	S	-	-
	Wet	U	U	S	-	U	-	-	-
Chloroacetic Acid		U	U	-	F	U	U	U	U
Chlorosulphonic Acid		-	-	F	-	-	F	-	-
Chromic Acid		U	U	F	-	-	-	S	-
Citric Acid		S	S	S	-	U	S	S	-

TABLE 6.3 (continued)

CORROSION RESISTANCE OF GASKET METALS

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SERVICE		C	A	M	N	S	4	6	7
Coke Oven Gas		S	-	S	-	S	-	S	-
Copper Chloride		-	U	F	-	F	U	U	-
Copper Sulphate		-	U	S	-	U	S	S	-
Corn Oil		-	S	S	-	S	S	S	-
Cotton Seed Oil		-	S	S	-	S	S	S	-
Creosote		S	S	S	-	S	S	S	-
Cresylic Acid		S	S	F	-	F	-	S	-
Dowtherm	A	U	S	-	-	S	-	-	-
	E	S	U	-	-	S	-	-	-
Ethers		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
Ferric Chloride		U	U	U	U	U	U	U	U
Ferric Sulphate		U	U	U	U	U	F	S	-
Formaldehyde		F	F	S	-	F	S	S	-
Formic Acid		F	U	-	-	U	F	F	-
Freon		S	S	S	-	-	-	-	-
Fuel Oil		S	-	S	-	S	S	-	-
Furfural		S	S	S	-	S	S	S	-
Gasoline		S	S	S	-	S	S	S	-
Gelatin		-	S	S	-	-	S	S	-
Glucose		S	S	S	-	S	S	S	-
Glycerin		-	S	S	-	S	S	S	-
Glycerol		F	S	S	-	S	S	S	-

TABLE 6.3 (continued)

CORROSION RESISTANCE OF GASKET METALS

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S : Iron and Carbon Steel

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6: 316 Stainless Steel

7: 347 Stainless Steel

SERVICE			C	A	M	N	S	4	6	7
Green Sulphate Liquor			-	-	S	-	S	-	-	-
Hydrobromic Acid			-	U	-	-	U	-	-	-
Hydrochloric Acid			U	U	-	-	U	U	U	-
Hydrocyanic Acid			-	-	S	-	-	S	S	-
Hydrofluoric Acid	Cold	Less than 65%	-	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
		More than 65%	F	U	S	-	-	U	U	U
Hydrofluosilicic Acid			-	-	-	-	U	U	U	U
Hydrogen			S	S	S	S	S	S	S	S
Hydrogen Peroxide			U	S	F	F	U	S	S	-
Hydrogen Sulphide	Dry	Cold	U	S	S	S	S	S	S	S
		Hot	U	S	U	U	U	-	-	S
	Wet	Cold	U	S	S	S	-	S	S	S
		Hot	U	S	U	U	U	-	-	S
Kerosene			S	-	S	-	S	S	S	-
Lacquers, Lacquer Solvents			-	S	S	-	-	S	S	-
Lactic Acid-			-	-	S	S	-	-	F	F
Linseed Oil			S	S	S	-	S	S	S	-
Lubricating Oils			S	S	S	-	S	S	S	S
Magnesium Chloride			F	U	F	F	F	F	F	-
Magnesium Hydroxide			U	U	S	S	S	S	S	-
Magnesium Sulphate			S	-	S	-	S	S	S	-
Mercuric Chloride			U	U	U	U	-	U	U	U
Mercury			U	U	S	-	S	S	S	-
Methanol			S	S	S	-	S	S	S	-

TABLE 6.3 (continued)

CORROSION RESISTANCE OF GASKET METALS

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7: 347 Stainless Steel

SERVICE		C	A	M	N	S	4	6	7
Methyl Chloride		S	-	S	-	S	-	-	-
Milk		-	S	S	S	S	-	S	-
Mineral Oils		S	S	S	-	S	S	S	-
Natural Gas		-	S	S	-	S	S	S	-
Nickel Chloride		U	U	-	-	-	F	F	-
Nickel Sulphate		U	U	-	-	-	S	S	-
Nitric Acid	Concentrated	U	S	U	U	U	F	F	-
	Diluted	U	U	U	U	U	S	S	-
Nitrobenzene		F	-	-	-	S	-	S	-
Oleic Acid		U	S	S	S	-	S	S	-
Oleum Spirits		S	-	S	-	S	-	-	-
Oxalic Acid		-	S	S	-	-	-	-	-
Oxygen	Cold	S	S	S	-	S	S	S	S
	Hot	U	-	S	-	S	S	S	S
Palmitic Acid		S	S	S	-	S	S	S	-
Petroleum Oils		U	S	U	U	S	S	S	S
Phosphoric Acid	Less than 45%	F	-	F	-	U	S	S	-
	More than 45%	F	U	-	-	U	S	S	-
Picric Acid		U	F	U	U	S	S	S	-
Potassium Chloride		S	-	S	S	S	S	S	-
Potassium Cyanide		U	U	S	-	S	S	S	-
Potassium Hydroxide		U	U	S	S	-	F	F	-
Potassium Sulphate		S	S	S	S	S	F	F	-
Propane		-	-	S	-	S	S	S	-
Seawater		-	U	S	-	-	F	F	-
Sewage		-	F	S	-	F	F	F	-

TABLE 6.3 (continued)

CORROSION RESISTANCE OF GASKET METALS

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7: 347 Stainless Steel

SERVICE		C	A	M	N	S	4	6	7
Soap Solutions		-	-	S	-	S	S	-	-
Sodium Bicarbonate		-	U	S	S	-	S	S	-
Sodium Bisulphate		F	-	S	S	U	-	-	-
Sodium Carbonate		-	U	S	-	S	S	S	-
Sodium Chloride		F	U	S	S	S	F	S	-
Sodium Cyanide		U	U	F	-	S	-	S	-
Sodium Hydroxide		U	U	S	S	S	F	F	-
Sodium Hypochlorite		-	U	-	-	U	U	U	-
Sodium Metaphosphate		-	S	S	S	-	S	-	-
Sodium Nitrate		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	U	U	S	S	S	-	S	-
Sodium Silicate		-	U	S	S	S	-	S	-
Sodium Sulphate		S	-	S	S	S	S	S	S
Sodium Sulphide		U	U	F	F	S	S	S	S
Sodium Thiosulphate		U	U	-	-	-	S	S	-
Soybean Oil		-	--	-	-	-	S	S	-
Stannic Chloride		U	U	U	U	-	-	-	-
Steam		S	S	S	S	S	S	S	S
Stearic Acid		-	-	S	S	-	S	S	-
Sulphur		U	S	U	U	S	F	F	-
Sulphur Chloride		U	-	-	-	-	-	-	-
Sulphur Dioxide, dry		S	S	S	S	S	S	S	-
Sulphur Trioxide, dry		S	S	S	-	S	S	-	-

TABLE 6.3 (continued)**CORROSION RESISTANCE OF GASKET METALS**S: satisfactory
F: fairU: unsatisfactory
-: no information

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M: Monel

N : Nickel

S : Iron and Carbon Steel

4: 304 Stainless Steel

6: 316 Stainless Steel

7: 347 Stainless Steel

SERVICE			C	A	M	N	S	4	6	7
Sulphuric Acid	Less than 10%	Cold	-	-	-	-	U	F	F	-
		Hot	U	-	-	U	U	U	F	-
	10% to 75%	Cold	U	-	-	-	U	U	F	-
		Hot	U	U	-	U	U	U	U	-
	75% to 95%	Cold	U	-	-	-	-	S	S	-
		Hot	U	U	-	U	F	U	U	-
Fuming		U	-	U	U	-	-	F	-	
Sulphurous Acid			-	-	U	U	S	U	-	-
Tannic Acid			S	U	S	S	-	F	F	-
Tar			-	S	-	-	S	S	-	-
Tartaric Acid			-	S	-	-	U	-	S	-
Toluene			-	S	S	-	S	-	-	-
Trichloroethylene			-	-	S	-	-	-	-	-
Turpentine			-	S	S	-	-	S	S	-
Vinegar			-	-	S	-	-	F	S	-
Water			S	S	S	S	S	S	S	S
Whiskey and Wines			S	-	S	-	U	F	S	-
Zinc Chloride			U	U	S	-	-	U	U	-
Zinc Sulphate			U	-	S	-	-	S	S	-

SPIRAL WOUND GASKETS

1. SPIRAL WOUND GASKETS

Spiral Wound gaskets are made of a preformed metal strip and a soft filler wound together under pressure (Figure 7.1). When the gasket is seated, the filler flows, filling up the imperfections of the flanges. The metal strip holds the filler, giving mechanical resistance and resiliency to the gasket. Its “V” shape acts as a Chevron Ring reacting to changes in pressure and temperature.

Spiral wound gaskets can be manufactured in several combinations of materials, and a wide range of dimensions and shapes. They are widely utilized covering an ample range of applications. ASME B16.5 flanges spiral wound gaskets are standardized and produced in high volumes at competitive price when compared with other gasket styles of same performance.

This Chapter presents the styles, design values, materials and other information related to Spiral Wound gaskets.

Figure 7.1 shows a Spiral Wound gasket with both inner and centering rings.

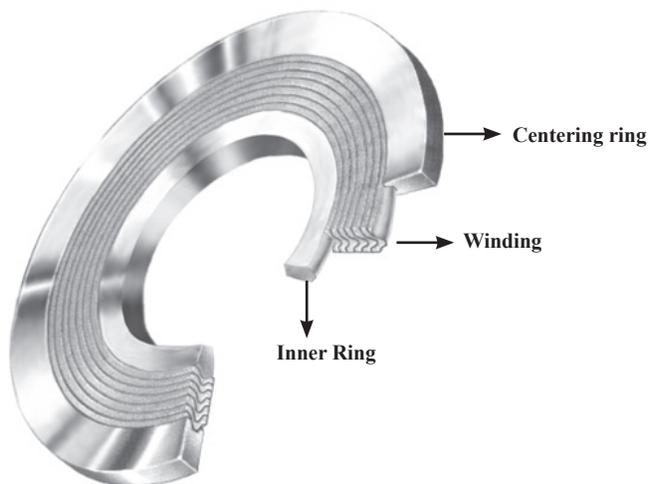


Figure 7.1

2. MATERIALS

2.1. METAL STRIP

The metal strip has a standardized thickness of 0.008 in (0.19 mm) and the width according to the thickness of the gasket. Metals normally available on the market in strip form are adequate for the manufacture of spiral wound gaskets. However the most common metals are:

- Stainless steel AISI 304 and 304L: are the most widely used materials as a result of their price and good resistance to corrosion.
- Stainless steel AISI 316 and 316L for chemical service.
- Stainless steel AISI 321 for high temperature service.
- Monel.
- Nickel
- Inconel.
- Titanium

The characteristics and recommended uses of these metals are in Chapter 6 of this book.

2.2. FILLER

The filler material provides the sealability of the gasket. It is recommended that the edge of the filler be above the metal strip. It should never be flush or below the metal.

2.2.1. FLEXIBLE GRAPHITE

The main characteristics of Flexible Graphite are shown in Chapter 3 of this book. Having high temperature resistance and being confined by the metal strip Spiral Wound Gaskets are “fire safe” and used for services with flammable products such as fuels and hydrocarbons in general. Spiral Wound gaskets with 304L and Flexible Graphite windings are one of the most used piping gaskets by the process industry like refineries, chemical, petrochemical and pulp and paper industries in temperatures up to 840F (450C). For temperatures above this value with oxidizing service, including air, degrade the material. In this case, it is necessary to avoid the direct contact of the flexible graphite with the oxidizing media. For gaskets with direct contact with the air and temperature above 840F (450C) the Flexible Graphite reacts with oxygen in the air, the gasket loses its filler gradually until it leaks.

2.2.2. HIGH TEMPERATURE FLEXIBLE GRAPHITE (FG-HT)

For high temperature service oxidation inhibitors are added to the Flexible Graphite during its production process increasing its service temperature up to 1200F (650C). The other properties remain the same.

2.2.3. PTFE

PTFE is used as filler when higher chemical resistance is needed. The service temperature range is from cryogenic up to 500F (260C). PTFE filled gaskets should be confined in a grooved flange or with an inner reinforcing ring to increase its mechanical resistance and avoid inward buckling of the winding.

2.2.4. PHLOGOPITE MICA - TERMICA

The TerMica filler is manufactured from mica tapes with an inorganic binder. Mica filled Spiral Wound gaskets service temperature is up to 1832F (1000C). It is resistant to most chemicals such as solvents, acids, caustics, hydrocarbons and organic products. However, Mica filled Spiral Wound gaskets do not exhibit the same level of sealability. For this reason, mica is typically used together with high temperature Flexible Graphite, combining its excellent sealability with high temperature resistance of Mica, which acts as an oxidation barrier.

2.3. CENTERING RING

The centering ring, since it does not come into direct contact with contained fluid, is normally made of carbon steel AISI 1008/1011. Carbon steel centering rings are electroplated or painted to avoid corrosion. Alloy centering rings should be used when flanges are in non-carbon assemblies steel to avoid contamination, also for extremely aggressive and cryogenic services or off-shore applications.

2.4. INNER RING

Inner rings are used to avoid inward buckling of the spiral and turbulence in the transition region between flanges. Initially, Spiral Wound gaskets were produced mostly without inner rings. However, field accident reports and studies [29, 30] showed that without an inner ring, there is no safe way to avoid buckling regardless of size or pressure class of the gasket. The buckling of the spiral is when it protrudes towards the inside of the pipe as shown in Figure 12.29. The gasket, after buckling, loses seating stress and sealability. The inner ring is an effective way to prevent inward buckling in raised face flanges.

The inner ring also provides greater stability to the gasket, especially in larger ones, which are very unstable making it difficult to transport, handle and install. The thickness of the inner ring is the same as the centering ring and usually manufactured in the same material as the winding metal.

3. GASKET DENSITY

In the spiral gasket manufacturing process, the metal tape and the filler are wrapped under pressure. By combining this manufacturing pressure and the thickness of the filler, different density gaskets can be manufactured. This is a very important feature for gasket performance.

To address the Fugitive Emissions maximum values required by the hydrocarbon processing, research was performed on the density of spiral wound gaskets, the result of this research was presented at the 2011 ASME Congress PVP under the title, “The Influence of Winding Density in the Sealing Behavior of Spiral Wound Gaskets” [28].

The density of a spiral wound gasket is defined as the number of wraps of metal and filler per millimeter width of the gasket. Gaskets on the market at the time of the research typically had a density of 0.80 wraps per millimeter (w/mm) to 1.35 w/mm.

The graph in Figure 7.2 shows the test result with gaskets of density 0.869 w/mm, 0.994 w/mm and 1.132 w/mm. As can be seen from the graph there is a large leak reduction as the gasket density increases (higher number of wraps per mm).

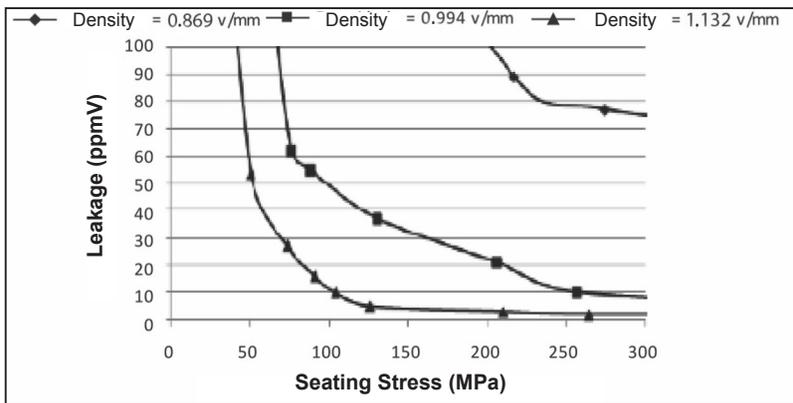


Figure 7.2

Another feature of the low-density gasket is that the sealing surfaces of the flanges make contact with the centering ring. This feature limits the tightness of the gasket and therefore reduces its sealability. When making contact with the flange the centering ring acts as a fulcrum causing the flange to rotate in the plane perpendicular to the pipe axis as shown in Figure 7.3. In this situation, there is a reduction in the seating stress in the gasket bore region further reducing its sealability.

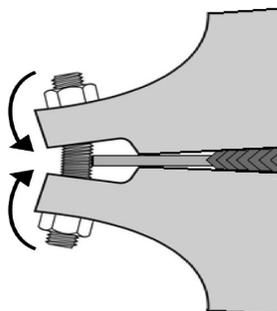


Figure 7.3

The height of filler protruding beyond the metal tape is another important feature. If this feature is not controlled the gaskets need a very high seating stress to seal. Figure 7.4 shows a graph of a gasket fabricated with the filler flush with the metal strip. As can be seen, the gasket only begins to seal above 140 MPa (20000 psi) of tightening, values that are impossible to reach in most of the existing flanges in the industries.

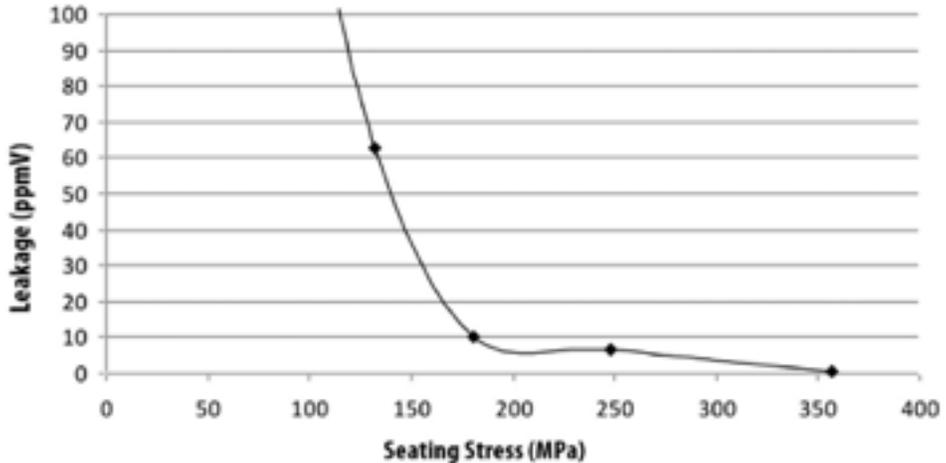


Figure 7.4

4. GASKET DIMENSIONS

Spiral Wound gaskets should be designed in such a way that the winding is always in contact with the sealing surface of the flanges. If the winding is smaller than the inside diameter or larger than the outside diameter of the flange it can break, losing its sealability. If the winding protrudes into the inside diameter, pieces of the gasket can be carried out by the fluid, damaging the equipment.

The following recommendation should be used in dimensioning non-standard gaskets.

- ***Gaskets confined by the inside and outside diameters***

Gasket inside diameter = inside diameter of the groove plus 1/16 in (1.6 mm).

Outside diameter of the gasket = outside diameter of the groove less 1/16 in (1.6 mm).

- ***Gaskets confined only by the outside diameter:***

Inside diameter of the gasket = inside diameter of the female plus a minimum of ¼ in (6.4 mm).

Outside diameter of the gasket = outside diameter of the male less 1/16 in (1.6 mm).

- ***Gaskets for raised or flat faced flanges:***

Inside diameter of the gasket = inside diameter of the face plus a minimum of ¼ in (6.4 mm).

Outside diameter of the gasket = outside diameter of the face less a minimum of ¼ in (6.4mm).

The gasket outside and inside diameters should be adjusted in order to meet the seating and operating stress recommendations in Chapter 2 of this book.

5. THICKNESS

The standard manufacturing thickness for spiral wound gaskets are 1/8 in (3.2 mm), 0.175 in (4.45 mm), 3/16 in (4.76 mm) and ¼ in (6.4 mm).

The recommended thickness after seating should be in accordance with Table 7.1. The final thickness indicated is what experience demonstrates to be the best for maximum gasket resiliency.

Table 7.1
Gasket Thickness

Manufacturing Thickness - in (mm)	Thickness after Seating - in (mm)
1/8 (3.2)	0.090 to 0.100 (2.3 to 2.5)
0.175 (4.45)	0.125 to 0.135 (3.2 to 3.4)
3/16 (4.76)	0.125 to 0.145 (3.2 to 3.4)
¼ (6.4)	0.180 to 0.200 (4.6 to 5.1)

6. DIMENSIONAL AND THICKNESS LIMITATIONS

Spiral wound gaskets can be manufactured in diameters ranging from ½ in (12 mm) up to 150 in (3800 mm). Table 7.2 shows maximum diameter and flange width as a function of the gasket thickness. These limitations are generic and can vary according to the winding metal and the filler. Gaskets with dimensions other than shown are unstable and difficult to manufacture and handle.

Table 7.2
Dimensional Limits

Thickness in (mm)	Maximum Inside Diameter in (mm)	Maximum Width in (mm)
1/8 (3.2)	40 (1000)	1/2 (13)
0.175 (4.45) or 3/16 (4.76)	70 (1800)	1 (25)
¼ (6.4)	150 (3800)	1 ¼ (32)

PTFE filled gaskets are less stable and can unwind during shipping and handling. They have dimensional limits as shown in Table 7.3.

Table 7.3
Dimensional Limits for PTFE Filled Gaskets

Thickness in (mm)	Maximum Inside Diameter in (mm)	Maximum Width in (mm)
1/8 (3.2)	20 (500)	5/8 (16)
0.175 (4.45) or 3/16 (4.76)	45 (1100)	3/4 (20)
¼ (6.4)	118 (3000)	¾ (20)

7. MANUFACTURING TOLERANCES

The manufacturing tolerances for the inside and outside diameters of spiral wound gaskets are indicated in Table 7.4.

Table 7.4
Manufacturing Tolerances

Inside Diameter in (mm)	Diameter Tolerance – in (mm)	
	Inside	Outside
Up to 12 (250)	-1/32 (-0.8) +1/16 (1.6)	-1/16 (1.6) +1/32 (0.8)
12 to 27 (250 to 700)	-1/32 (-0.8) +1/16 (1.6)	-1/16 (-1.6) +1/32 (0.8)
Over 27 (700)	± 1/16 (± 1.6)	± 1/16 (± 1.6)

The tolerance of the winding thickness is plus or minus 0.005 in (0.13 mm), measured across the metal winding. In gaskets with PTFE filler or with an internal diameter less than 1 in (25 mm) or with a flange thickness greater than 1 in (25 mm) the winding thickness tolerance is +0.010 in (0.25 mm), -0.005 in (0.13 mm).

8. FINISH OF THE FLANGE SEALING SURFACE

As explained early in this Chapter, spiral wound gaskets depend on the combined action of both metal and filler for efficient sealing. When the gasket is compressed, the filler flows, filling up the flange irregularities. The metal provides mechanical resistance and resiliency. Proper finishing of the sealing surface is very important for good sealing. A scratched surface will be difficult to seal. A smooth and polished surface can cause the gasket inward buckling.

Although most of commercial flange finishes can be used, the experience indicates that the values shown in Table 7.5 are the most appropriate.

Table 7.5
Finish of the Flange Sealing Surface

Media	Flange Sealing Surface Finish - Ra	
	$\mu\text{ m}$	$\mu\text{ in}$
General use	6.3	250
Dangerous Service and gases	3.2	125
Vacuum service	2.0	80

Important: The sealing surfaces of flanges cannot have scratches or radial tool marks going from the inside to the outside diameter. These irregularities make the sealing very difficult for any style of gasket and, especially, for spiral wound gaskets.

9. SPIRAL WOUND GASKETS BOLTING CALCULATIONS

The “m” and “y” values for ASME Code calculation are shown in Table 7.6 and the values for gasket installation calculations per ASME PCC-1 are in Table 7.7.

Table 7.6
ASME Gasket Factors

m	y
3	10 000

Table 7.7
ASME PCC-1 Values

Property	Value (psi)
Minimum Installation Stress ($S_{g_{min-s}}$)	10 000
Minimum Gasket Operating Stress ($S_{g_{min-o}}$)	3 900
Maximum Permissible Gasket Stress ($S_{g_{max}}$)	43 000
Fraction of gasket load remaining after relaxation (ϕ_g)	0.80
Maximum permissible flange rotation ($\theta_{g_{max}}$)	1

It is recommended that after the calculations per ASME Code, to verify if the Maximum Seating and Operational Stress are lower are indicated in Table 7.7 to avoid crushing the gasket.

10. GASKET STYLES

Spiral wound gaskets are manufactured in several geometrical forms such as circular, oval, diamond, square, rectangular and others.

Centering rings or inner rings can be incorporated to the gaskets to better meet specific service requirements.

11. STYLE 911 GASKETS

This is the simplest style of spiral wound gasket, consisting of a circular winding without centering or inner rings. Spiral wound gaskets Style 911 are mainly used in tongue and groove (Figure 7.5) or male and female. They are also used in equipment with space and weight limitations.

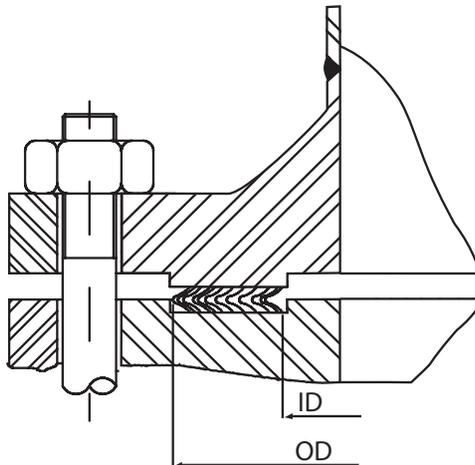


Figure 7.5

11.1. DIMENSIONS

The dimensions of the gaskets for flanges ASME B16.5 [46] are in Annex 7.5 and 7.6 at the end of this Chapter. For other applications, when it is necessary to have non-standard dimensions, the winding should be designed to be totally under compression between the flanges. The recommendations of Section 4 of this Chapter should be carefully followed.

11.2. THICKNESS

The standard thickness for style 911 gaskets is 1/8 in (3.2 mm). For large diameters they can be manufactured in thickness of 3/16 in (4.76 mm) and 1/4 in (6.4mm).

11.3. STYLE 911-M

A style 911-M gasket is a sealing winding with an inner ring (Figure 7.6). The purpose of this ring is to fill out the space between the flanges, avoiding turbulence in the flow of the fluid or as a protection against corrosion or erosion. It is also used as a compression limit when the seating stress is greater than 30000 psi (210 MPa).

Gaskets with PTFE filler have a tendency to inward buckle thus the use of an inner ring is recommended if the gasket is to be installed with a non-confined inside diameter.

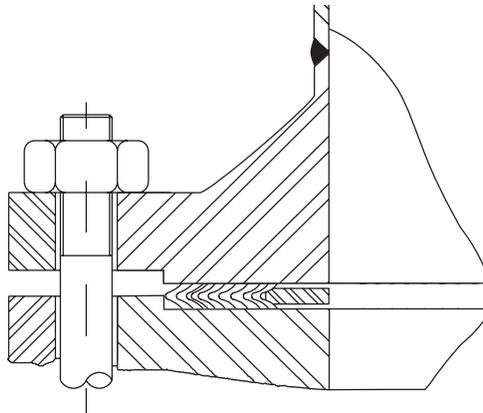


Figure 7.6

11.4. STYLE 911-T

Double-jacketed pass partition bars are welded into the winding (Figure 7.7). They are used in shell and tube heat exchangers potentially with several passes. The bars are manufactured in the same material and are plasma or spot welded to the winding. The thickness of the bar is normally a little less than the winding to reduce the seating force of the gasket. Style 911-T has a better sealability than conventional heat exchanger double-jacketed gaskets. Spiral wound gaskets with pass partition bars are very fragile and must be handled with care.

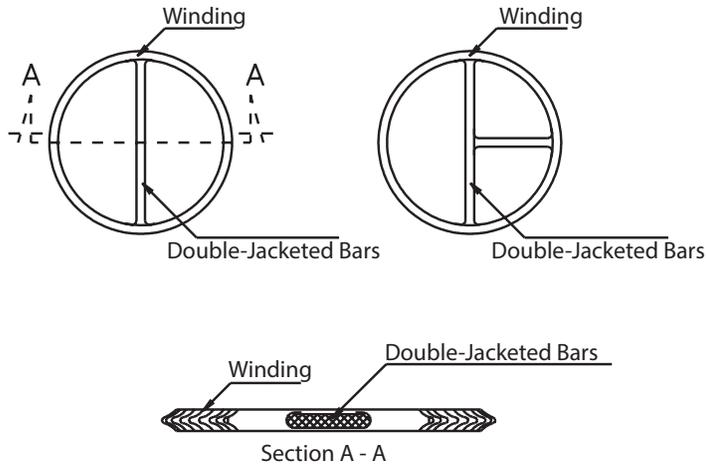


Figure 7.7

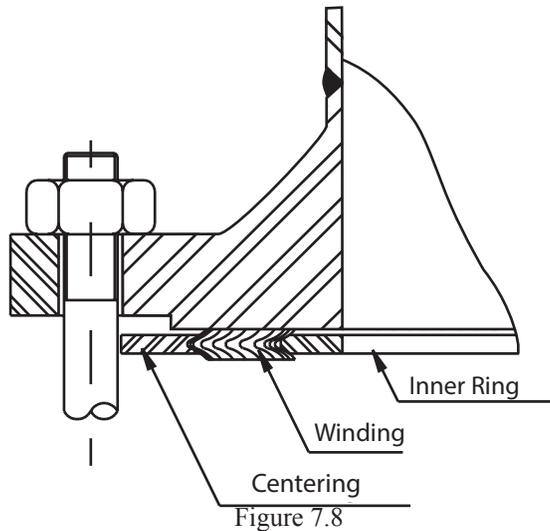
12. STYLE 913M GASKETS PER ASME B16.20

Gaskets per ASME B16.20 [31] have the winding with inner and centering rings as shown in Figure 7.8.

Several countries developed dimensional standards for this style of gasket. The ASME B16.20 [31] standard is one of the most used, worldwide. They were designed for use with ASME B16.5 [46] and ASME B16.47 [47] flanges. Gaskets manufactured following the recommendations of the ASME B16.20 are produced in large quantities. They are low priced compared with other gaskets of equivalent performance. When specifying a metallic gasket they should be the first design option. The use of another type of metal gasket should only be recommended if required by the specific conditions.

12.1. APPLICATION

ASME B16.20 gaskets were designed for use in ASME B16.5 [46] flanges or ASME 16.47 [47]. Therefore, when ordering a spiral wound gasket for these flanges dimensions are not necessary. It is enough to inform materials for the winding metal and filler, which should be compatible with the fluid to be sealed, the nominal diameter and the pressure class of the flange. In Annexes 7.1 to 7.3, at the end of this Chapter, are the dimensions, manufacturing tolerances for ASME B16.20 gaskets.



12.2. MATERIALS

The most common materials are:

- Winding metal: all metals and alloys available in strip form can be used for spiral wound gaskets. Gaskets are commercially available in stainless steels AISI 304L, 316L, 321 and 347, Monel, Inconel and Nickel.
- Filler: fillers commercially available are Flexible Graphite, Mica and PTFE.
- Centering ring: carbon steel AISI 1008/1011 or for very corrosive service in stainless steel or the same material of the winding metal.
- Inner ring: it is normally made with the same material of the winding metal.

12.3. WINDING

The winding has the following construction:

- At least three initial plies of winding metal without filler.
- The initial two plies of winding metal shall be spot-welded circumferentially with a minimum of three welds spaced at a maximum distance of 3 inches (76.2 mm).
- The outer windings shall have a minimum of 3 plies of winding metal without filler, spot-welded circumferentially with a minimum of 3 welds, the last being the terminal weld. The distance of the first weld from the terminal weld shall be no greater than 1.5 in (38.1 mm).
- Up to 4 additional loose preformed metal windings beyond the terminal weld may be used to retain the gasket into the centering ring. These free turns are not included in determining the winding outside diameter.
- The winding thickness is 0.175 in (4.45 mm) plus or minus 0.005 in (0.127 mm) measured across the metal winding not including the filler, which should protrude slightly beyond the metal.

12.4. INNER RING

To avoid the winding inward buckling, ASME B16.20 recommends the use of inner rings. Field accident reports and studies [29, 30] showed that there is no way to ensure no buckling regardless of size or pressure class of the gasket if they do not have an inner ring. Inner rings also reduce turbulence in the flange area. It is normally made of the same material as the gasket winding metal.

Its use is also mandatory in services with abrasive fluids. In high corrosive services, like Hydrofluoric Acid (HF), inner rings are used to reduce the flange sealing surface contact with the fluid.

PTFE filled gaskets can inward buckle due to the low compressibility of the PTFE. This buckling reduces the sealability of the gasket. It is mandatory to use inner rings in PTFE filled gaskets regardless of size and pressure class.

12.5. IDENTIFICATION

The centering ring is permanently marked with lettering at least 1/8 in (3.2 mm) height with the following information:

- Manufacturer's name or trademark.
- Flange size (NPS).
- Pressure class.
- Winding metal abbreviation.
- Filler material abbreviation.
- Centering and inner ring metal abbreviation, except that the abbreviation may be omitted when carbon steel is used for the centering ring and 304 stainless steel is used for the inner ring.
- Standard identification: ASME B16.20.
- Flange identification for ASME B16.47 gaskets. For ASME B16.5, the flange identification is not required.

12.6. COLOR CODING

The outer edge of the centering ring is painted in such a way as to help the identification of the gasket in service. The identification of the metallic strip material should be painted continuously on the outer edge of the centering ring. The filler material is identified with a minimum of four intermittent stripes equally spaced on the outer edge of the centering ring. The color-coding is on Tables 7.8 and 7.9

Table 7.8
Metallic Strip Color Coding

Metallic Strip	Color
AISI 304 / AISI 304L	Yellow
AISI 316 / AISI 316L	Green
AISI 347	Blue
AISI 321	Turquoise
Monel	Orange
Nickel	Red
Inconel	Gold

Table 7.9
Filler Color Coding

Filler	Color
PTFE	White
Flexible Graphite	Gray
High Temperature Flexible Graphite	Black
Mica	Light Blue

13. PERFORMANCE TESTS

At the ASME PVP 2018 Conference the paper PVP2017-65371 Spiral Wound Gaskets Performance Testing study [59] was presented suggesting the adoption of sealability testing to verify that gaskets in accordance with ASME B16.20 meet EPA emission requirements. In this study were analyzed gaskets with different constructions some of which, even meeting the specifications of the standard, did not present the required sealability. At the end of 2017 the ASME B16.20 standard was revised introducing two performance tests for spiral wound gaskets with inner rings. A Methane gas sealability test, similar to that suggested in study PVP2017-65371 and a crush test. The latter is to ensure that the gaskets have a density compatible with the service they are intended for. As explained earlier, density is an extremely important factor for gasket performance.

13.1 SEALABILITY TEST

Introduced in the 2017 revision of ASME B16.20, the sealability test requires that for gaskets with inner and centering rings for all dimensions and corresponding pressure classes be capable of a maximum leakage of 0.0137 mg / s-m. For this calculation the outer perimeter of the spiral shall be calculated according to the table diameter in Annex 7.1.

The test is performed at room temperature with methane gas of at least 97% purity. The test pressure must be 20 bar (290 psi) for pressure class 150 gaskets and 40 bar (580 psi) for other pressure classes. The sealing surface finish shall be in accordance with ASME B16.5 and the tester shall apply uniform seating stress to the entire sealing surface of the gasket.

The gasket seating stress is calculated considering the dimensions of the spiral as per Annex 7.1, shall be as follows:

- Class 150: 35 MPa (5000 psi)
- Classes 300 and 400: 56 MPa (8000 psi)
- Class 600 and higher: 70 MPa (10000 psi)

The test pressure must be maintained for a minimum of 4 hours. After this time, 3 readings are taken 5 minutes apart. The average of these readings is the gasket leak, which should be less than 0.0137 mg/s-m.

13.2 COMPRESSION TEST

Flexible Graphite filled gaskets should be compression tested to ensure they have density compatible with the intended class of service. The minimum thickness after tightening is 3.43 mm when evenly compressed. To calculate the gasket area the inside and outside diameters of the spiral are considered according to Annex 7.1. The gasket stress should be as follows:

- Class 150: 52 MPa (7500 psi)
- Classes 300, 400, and 600: 70 MPa (10000 psi)
- Classes 900 and higher: 140 MPa (20000 psi)

14. OTHER STANDARDS

There are several other standards like BS (United Kingdom) [52], EN (Europe) [32], JIS (Japan), etc.

15. STYLE 913M GASKET DESIGN

Following, are the recommendations that should be followed to design a style 913 gasket.

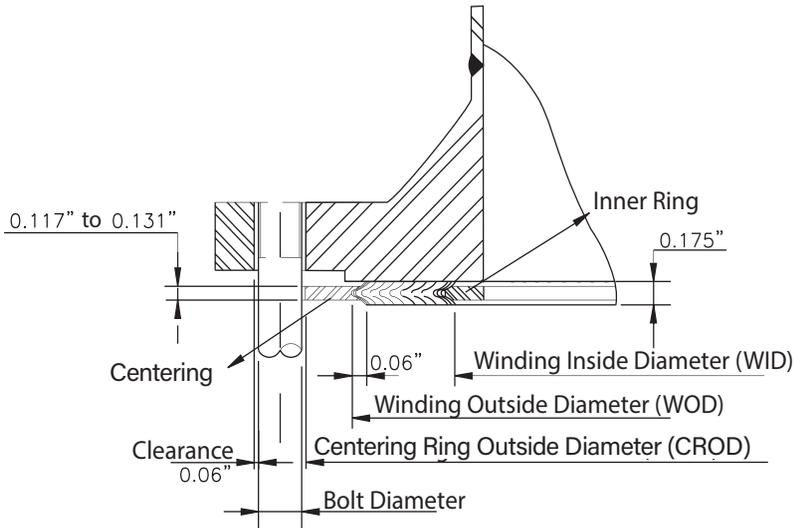


Figure 7.9

15.1. WINDING

- Inside diameter (WID): equal to the inside diameter of flange raised face plus a minimum of 1/4 in (6.4 mm).
- Outside diameter (WOD): designed to meet the recommendations of seating and operating stresses recommendations in Chapter 2. The maximum width should follow the recommendations of Section 6 of this Chapter.
- Winding Thickness: standard manufacturing thickness are 0.175 in (4.45 mm), 3/16 in (4.8 mm) and 1/4 in (6.4 mm). Whenever possible 0.175 in should be used.
- Manufacturing tolerances: are indicated in Section 7 of this Chapter.

15.2. CENTERING RING

- Thickness: 0.117 to 0.131 in
- Inside diameter: equal to the outside diameter of the winding minus 1/8 in (3.2 mm).
- Outside diameter (CROD): equal to the bolt circle diameter minus the diameter of the bolt.
- Manufacturing tolerance: of the outside diameter of the centering ring is plus or minus 1/32 in (0.8 mm).

- Dimensional limitations: as a result of the manufacturing process limitations and the stability of the winding, there are limitations. Minimum widths for centering rings are according to indications on Table 7.10.

Table 7.10
Centering Ring Dimensional Limitations

Centering Ring Inside Diameter in (mm)	Minimum Width in (mm)
Up to 10 (250)	13/64 (5)
10 (250) or greater	25/64 (10)

15.3. INNER RING

As already mentioned, it is used to minimize turbulence in the gasket area, avoid corrosion or erosion of the winding. In gaskets with PTFE filler, it avoids inward buckling of the winding.

- Thickness: 0.117 to 0.131 in
- Inside diameter: equals to the winding inside diameter.
- Outside diameter: equals to the diameter plus 1/8 in.
- Manufacturing tolerance: of the inside diameter of the winding plus 1/8 in (3.2 mm).
- Dimensional limitations: as a result of the manufacturing process limitations and the stability of the winding, there are limitations. Minimum widths for inner rings are according to indications on Table 7.11.

Table 7.11
Inner Ring Dimensional Limitations

Inner Ring Inside Diameter in (mm)	Minimum Width in (mm)
Up to 10 (250)	13/64 (5)
10 (250) or greater	25/64 (10)

15.4. GASKETS WITH DOUBLE JACKETED BARS

Similar to the style 911-T with double-jacketed bars used in shell and tube heat exchangers.

15.5. CENTERING RING WITH BOLT HOLES

To help the fitting on the equipment the centering ring can be manufactured with the same overall diameter and pattern.

16. STYLE ECHELON® HF

The Style Echelon® HF (Figure 7.10) is designed for specific applications where crevice corrosion is a concern. The design of Teadit Echelon® HF is based on an ASME B16.20 spiral wound, but with a camprofiled Monel® inner ring. The inner ring can even be sized to the bore. Typical application is for HF Alkylation Service, however, different metallurgies can be selected for superior corrosion protection in multiple conditions. Flexible Graphite (FG) or Expanded PTFE (ePTFE) may be selected for filler material in the spiral wound portion. For the camprofiled inner ring, to enhance crevice corrosion protection, 1/16" ePTFE is utilized for the facing material.

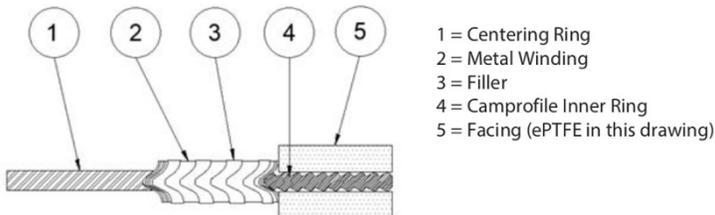


Figure 7.10

17. STYLE 913M-XHR

The Teadit Style 913M-XHR (Figure 7.11) is Teadit's solution for extreme heat resistance. Utilizing a combination of High Temperature Flexible Graphite (APX2®) and high performance Phlogopite Mica (TerMica). This combination provides the oxidation and insulation characteristics of mica, with the sealing performance of high-end Flexible Graphite. Using both APX2® Graphite and TerMica allows for maximum temperature limitations of 1500F (815C), with sealability factors that meet the needs of critical applications. Note: APX2® is a product of SGL Group style of SIGRAFLEX®.

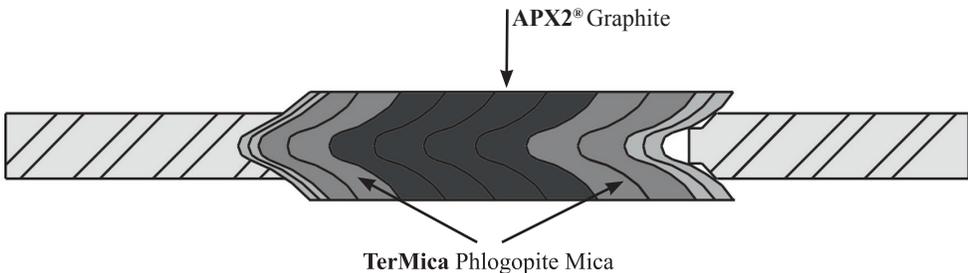


Figure 7.11

18. STYLE 914

Style 914 spiral wound gaskets are windings in non-circular forms like oval, diamond or pear shaped as shown in Figure 7.12.

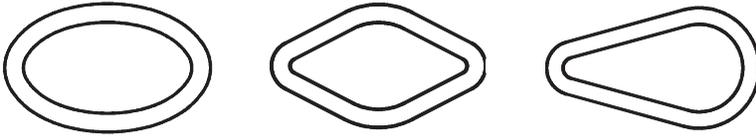


Figure 7.12

18.1. APPLICATION

Style 914 gaskets are used in boiler handholes and manholes, equipment, engine head-gaskets and exhaust systems.

18.2. DESIGN

There is no specific standard for this type of gasket, depending on the design calculations it can be made using the recommendations of the ASME Code.

When ordering 914 gaskets due to its odd shapes, it is always necessary to provide complete specifications, a drawing or a sample.

18.3. THICKNESS

The thickness available for style 914 gaskets are 1/8 in (3.2 mm), 0.175 in (4.45 mm), 3/16 in (4.76 mm) and 1/4 in (6.4 mm).

18.4. GASKETS FOR BOILERS HANDHOLES AND MANHOLES

The majority of boiler manufacturers use the same size of manholes and handholes in their equipment. Therefore even not being standardized some oval gaskets are considered standard in the industry. The dimensions of these gaskets are shown in Annex 7.4.

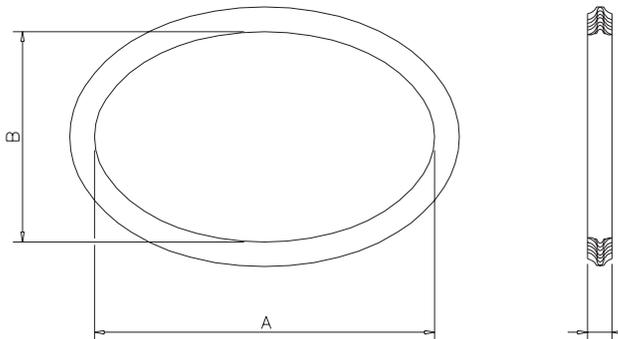
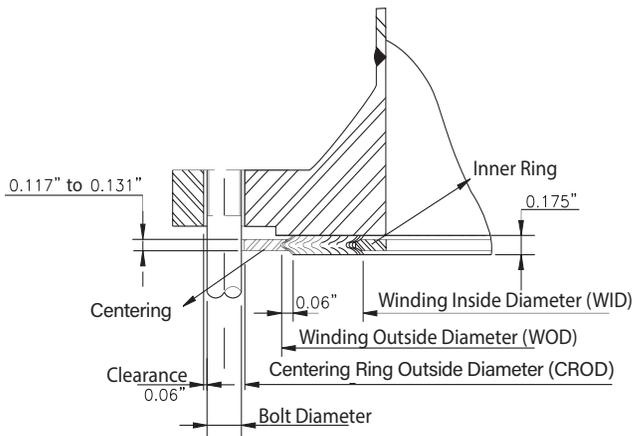


Figure 7.13

Annex 7.1

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.5 Flanges



Nominal Diameter	Gasket Outside Diameter per Pressure Class - inches	
	150, 300, 400, 600	900, 1500, 2500
1/2	1.25	1.25
3/4	1.56	1.56
1	1.88	1.88
1 1/4	2.38	2.38
1 1/2	2.75	2.75
2	3.38	3.38
2 1/2	3.88	3.88
3	4.75	4.75
4	5.88	5.88
5	7.00	7.00
6	8.25	8.25
8	10.38	10.13
10	12.50	12.25
12	14.75	14.50
14	16.00	15.75
16	18.25	18.00
18	20.75	20.50
20	22.75	22.50
24	27.00	26.75

Annex 7.1 (Continued)

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.5 Flanges

Nominal Diameter	Gasket Inside Diameter per Pressure Class - inches						
	150	300	400	600	900	1500	2500
1/2	0.75	0.75	(1)	0.75	(1)	0.75	0.75
3/4	1.00	1.00	(1)	1.00	(1)	1.00	1.00
1	1.25	1.25	(1)	1.25	(1)	1.25	1.25
1 1/4	1.88	1.88	(1)	1.88	(1)	1.56	1.56
1 1/2	2.13	2.13	(1)	2.13	(1)	1.88	1.88
2	2.75	2.75	(1)	2.75	(1)	2.31	2.31
2 1/2	3.25	3.25	(1)	3.25	(1)	2.75	2.75
3	4.00	4.00	(1)	4.00	3.75	3.63	3.63
4	5.00	5.00	4.75	4.75	4.75	4.63	4.63
5	6.13	6.13	5.81	5.81	5.81	5.63	5.63
6	7.19	7.19	6.88	6.88	6.88	6.75	6.75
8	9.19	9.19	8.88	8.88	8.75	8.50	8.50
10	11.31	11.31	10.81	10.81	10.88	10.50	10.63
12	13.38	13.38	12.88	12.88	12.75	12.75	12.50
14	14.63	14.63	14.25	14.25	14.00	14.25	(1)
16	16.63	16.63	16.25	16.25	16.25	16.00	(1)
18	18.69	18.69	18.50	18.50	18.25	18.25	(1)
20	20.69	20.69	20.50	20.50	20.50	20.25	(1)
24	24.75	24.75	24.75	24.75	24.75	24.25	(1)

Tolerance in inches:

Winding thickness: ± 0.005 in – measured across the metallic portion of the gasket not including the filler, which may protrude slightly beyond the metal.

Gasket outside diameter:

from NPS ½ to NPS 8: ± 0.03 in

from NPS 10 to NPS 24: + 0.06 in., – 0.03 in

Gasket inside diameter:

from NPS ½ to NPS 8: ± 0.016 in

from NPS 10 to NPS 24: ± 0.03 in

NOTES:

1. There are no Class 400 gaskets NPS ½ through NPS 3 (use Class 600), Class 900 gaskets NPS ½ through NPS 2 ½ (use Class 1500) and Class 2500 flanges NPS 14 or larger.

Annex 7.1 (Continued)**Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.5 Flanges**

Nominal Diameter	Centering Ring Outside Diameter per Pressure Class - inches						
	150	300	400	600	900	1500	2500
1/2	1.88	2.13	(1)	2.13	(1)	2.50	2.75
3/4	2.25	2.63	(1)	2.63	(1)	2.75	3.00
1	2.63	2.88	(1)	2.88	(1)	3.13	3.38
1 1/4	3.00	3.25	(1)	3.25	(1)	3.50	4.13
1 1/2	3.38	3.75	(1)	3.75	(1)	3.88	4.63
2	4.13	4.38	(1)	4.38	(1)	5.63	5.75
2 1/2	4.88	5.13	(1)	5.13	(1)	6.50	6.63
3	5.38	5.88	(1)	5.88	6.63	6.88	7.75
4	6.88	7.13	7.00	7.63	8.13	8.25	9.25
5	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	8.75	9.88	9.75	10.50	11.38	11.13	12.50
8	11.00	12.13	12.00	12.63	14.13	13.88	15.25
10	13.38	14.25	14.13	15.75	17.13	17.13	18.75
12	16.13	16.63	16.50	18.00	19.63	20.50	21.63
14	17.75	19.13	19.00	19.38	20.50	22.75	(1)
16	20.25	21.25	21.13	22.25	22.63	25.25	(1)
18	21.63	23.50	23.38	24.13	25.13	27.75	(1)
20	23.88	25.75	25.50	26.88	27.50	29.75	(1)
24	28.25	30.50	30.25	31.13	33.00	35.50	(1)

NOTES:

1. There are no Class 400 gaskets NPS ½ through NPS 3 (use Class 600), Class 900 gaskets NPS ½ through NPS 2 ½ (use Class 1500) and Class 2500 flanges NPS 14 or larger.

2. Centering Ring outside diameter tolerance: ± 0.03 in

Annex 7.1 (Continued)

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.5 Flanges

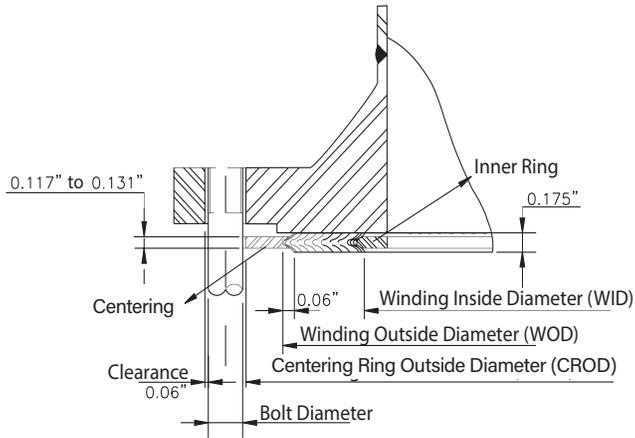
Nominal Diameter	Inner Ring Inside Diameter per Pressure Class - inches						
	150	300	400	600	900	1500	2500
1/2	0.56	0.56	(1)	0.56	(1)	0.56	0.56
3/4	0.81	0.81	(1)	0.81	(1)	0.81	0.81
1	1.06	1.06	(1)	1.06	(1)	1.06	1.06
1 1/4	1.50	1.50	(1)	1.50	(1)	1.31	1.31
1 1/2	1.75	1.75	(1)	1.75	(1)	1.63	1.63
2	2.19	2.19	(1)	2.19	(1)	2.06	2.06
2 1/2	2.62	2.62	(1)	2.62	(1)	2.50	2.50
3	3.19	3.19	(1)	3.19	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	(1)
16	15.75	15.75	15.35	15.35	14.75	14.50	(1)
18	17.69	17.69	17.25	17.25	16.75	16.75	(1)
20	19.69	19.69	19.25	19.25	19.00	18.75	(1)
24	23.75	23.75	23.25	23.25	23.25	22.75	(1)

NOTES:

1. There are no Class 400 gaskets NPS ½ through NPS 3 (use Class 600), Class 900 gaskets NPS ½ through NPS 2 ½ (use Class 1500) and Class 2500 flanges NPS 14 or larger.
2. Inner Ring thickness: 0.117 in to 0.131 in.
3. Inner Ring Inside diameter tolerance: from NPS ½ to NPS 3: ± 0.03 in
NPS 4 and larger: ± 0.06 in

Annex 7.2

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.47 Series A



Nominal Diameter	Gasket Dimensions per Pressure Class - inches								
	150			300			400		
	WID	WOD	GROD	DI	DE	GROD	WID	WOD	GROD
26	26.50	27.75	30.50	27.00	29.00	32.88	27.00	29.00	32.75
28	28.50	29.75	32.75	29.00	31.00	35.38	29.00	31.00	35.13
30	30.50	31.75	34.75	31.25	33.25	37.50	31.25	33.25	37.25
32	32.50	33.88	37.00	33.50	35.50	39.63	33.50	35.50	39.50
34	34.50	35.88	39.00	35.50	37.50	41.63	35.50	37.50	41.50
36	36.50	38.13	41.25	37.63	39.63	44.00	37.63	39.63	44.00
38	38.50	40.13	43.75	38.50	40.00	41.50	38.25	40.25	42.25
40	40.50	42.13	45.75	40.25	42.13	43.88	40.38	42.38	44.38
42	42.50	44.25	48.00	42.25	44.13	45.88	42.38	44.38	46.38
44	44.50	46.38	50.25	44.50	46.50	48.00	44.50	46.50	48.50
46	46.50	48.38	52.25	46.38	48.38	50.13	47.00	49.00	50.75
48	48.50	50.38	54.50	48.63	50.63	52.13	49.00	51.00	53.00
50	50.50	52.50	56.50	51.00	53.00	54.25	51.00	53.00	55.25
52	52.50	54.50	58.75	53.00	55.00	56.25	53.00	55.00	57.25
54	54.50	56.50	61.00	55.25	57.25	58.75	55.25	57.25	59.75
56	56.50	58.50	63.25	57.25	59.25	60.75	57.25	59.25	61.75
58	58.50	60.50	65.50	59.50	61.50	62.75	59.25	61.25	63.75
60	60.50	62.50	67.50	61.50	63.50	64.75	61.75	63.75	66.25

Annex 7.2 (Continued)

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.47 Series A

Nominal Diameter	Gasket Dimensions per Pressure Class - inches					
	600			900		
	WID	WOD	GROD	WID	WOD	GROD
26	27.00	29.00	34.13	27.00	29.00	34.75
28	29.00	31.00	36.00	29.00	31.00	37.25
30	31.25	33.25	38.25	31.25	33.25	39.75
32	33.50	35.50	40.25	33.50	35.50	42.25
34	35.50	37.50	42.25	35.50	37.50	44.75
36	37.63	39.63	44.50	37.75	39.75	47.25
38	39.00	41.00	43.50	40.75	42.75	47.25
40	41.25	43.25	45.50	43.25	45.25	49.25
42	43.50	45.50	48.00	45.25	47.25	51.25
44	45.75	47.75	50.00	47.50	49.50	53.88
46	47.75	49.75	52.25	50.00	52.00	56.50
48	50.00	52.00	54.75	52.00	54.00	58.50
50	52.00	54.00	57.00	There are no Class 900 flanges NPS 50 and larger.		
52	54.00	56.00	59.00			
54	56.25	58.25	61.25			
56	58.25	60.25	63.50			
58	60.50	62.50	65.50			
60	62.75	64.75	68.25			

Tolerance in inches:

Winding thickness: ± 0.005 in – measured across the metallic portion of the gasket not including the filler, which may protrude slightly beyond the metal.

Gasket outside diameter: ± 0.06 in

Gasket inside diameter:

from NPS 26 to NPS 34: ± 0.03 in

NPS 36 and larger: ± 0.05 in

Centering Ring outside diameter: ± 0.03 in

Inner Rings are required for all PTFE filled gaskets and for Class 900, NPS 26 through NPS 48.

Annex 7.2 (Continued)**Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.47 Series A**

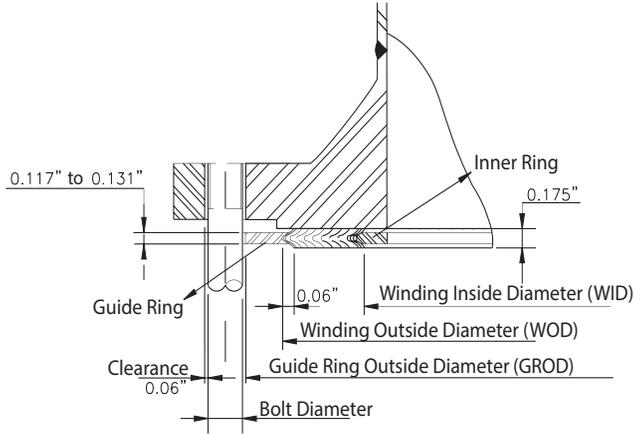
Nominal Diameter	Inner Ring Inside Diameter per Pressure Class - inches				
	150	300	400	600	900
26	25.75	25.75	26.00	25.50	26.00
28	27.75	27.75	28.00	27.50	28.00
30	29.75	29.75	29.75	29.75	30.25
32	31.75	31.75	32.00	32.00	32.00
34	33.75	33.75	34.00	34.00	34.00
36	35.75	35.75	36.13	36.13	36.25
38	37.75	37.50	37.50	37.50	39.75
40	39.75	39.50	39.38	39.75	41.75
42	41.75	41.50	41.38	42.00	43.75
44	43.75	43.50	43.50	43.75	45.50
46	45.75	45.38	46.00	45.75	48.00
48	47.75	47.63	47.50	48.00	50.00
50	49.75	49.00	49.50	50.00	There are no Class 900 flanges NPS 50 and larger.
52	51.75	52.00	51.50	52.00	
54	53.50	53.25	53.25	54.25	
56	55.50	55.25	55.25	56.25	
58	57.50	57.00	57.25	58.00	
60	59.50	60.00	59.75	60.25	

NOTES:

1. Inner Ring thickness: 0.117 in to 0.131 in
2. Inner Ring Inside diameter tolerance: ± 0.12 in.

Annex 7.3

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.47 Series B



Nominal Diameter	Gasket Dimensions per Pressure Class - inches								
	150			300			400		
	WID	WOD	GROD	WID	WOD	GROD	WID	WOD	GROD
26	26.50	27.50	28.56	26.50	28.00	30.38	26.25	27.50	29.38
28	28.50	29.50	30.56	28.50	30.00	32.50	28.13	29.50	31.50
30	30.50	31.50	32.56	30.50	32.00	34.88	30.13	31.75	33.75
32	32.50	33.50	34.69	32.50	34.00	37.00	32.00	33.88	35.88
34	34.50	35.75	36.81	34.50	36.00	39.13	34.13	35.88	37.88
36	36.50	37.75	38.88	36.50	38.00	41.25	36.13	38.00	40.25
38	38.37	39.75	41.13	39.75	41.25	43.25	38.25	40.25	42.25
40	40.25	41.88	43.13	41.75	43.25	45.25	40.38	42.38	44.38
42	42.50	43.88	45.13	43.75	45.25	47.25	42.38	44.38	46.38
44	44.25	45.88	47.13	45.75	47.25	49.25	44.50	46.50	48.50
46	46.50	48.19	49.44	47.88	49.38	51.88	47.00	49.00	50.75
48	48.50	50.00	51.44	49.75	51.63	53.88	49.00	51.00	53.00
50	50.50	52.19	53.44	51.88	53.38	55.88	51.00	53.00	55.25
52	52.50	54.19	55.44	53.88	55.38	57.88	53.00	55.00	57.25
54	54.50	56.00	57.63	55.25	57.25	60.25	55.25	57.25	59.75
56	56.88	58.18	59.63	58.25	60.00	62.75	57.25	59.25	61.75
58	59.07	60.19	62.19	60.44	61.94	65.19	59.25	61.25	63.75
60	61.31	62.44	64.19	62.56	64.19	67.19	61.75	63.75	66.25

Annex 7.3 (Continued)

Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.47 Series B

Nominal Diameter	Gasket Dimensions per Pressure Class - inches					
	600			900		
	WID	WOD	GROD	WID	WOD	GROD
26	26.13	28.13	30.13	27.25	29.50	33.00
28	27.75	29.75	32.25	29.25	31.50	35.50
30	30.63	32.63	34.63	31.75	33.75	37.75
32	32.75	34.75	36.75	34.00	36.00	40.00
34	35.00	37.00	39.25	36.25	38.25	42.25
36	37.00	39.00	41.25	37.25	39.25	44.25
38	39.00	41.00	43.50	40.75	42.75	47.25
40	41.25	43.25	45.50	43.25	45.25	49.25
42	43.50	45.50	48.00	45.25	47.25	51.25
44	45.75	47.75	50.00	47.50	49.50	53.88
46	47.75	49.75	52.25	50.00	52.00	56.50
48	50.00	52.00	54.75	52.00	54.00	58.50
50	52.00	54.00	57.00	There are no Class 900 flanges NPS 50 and larger.		
52	54.00	56.00	59.00			
54	56.25	58.25	61.25			
56	58.25	60.25	63.50			
58	60.50	62.50	65.50			
60	62.75	64.75	68.25			

Tolerance in inches:

Winding thickness: ± 0.005 in – measured across the metallic portion of the gasket not including the filler, which may protrude slightly beyond the metal.

Gasket outside diameter: ± 0.06 in

Gasket inside diameter:

from NPS 26 to NPS 34: ± 0.03 in

NPS 36 and larger: ± 0.05 in

Centering Ring outside diameter: ± 0.03 in

Inner Rings are required for all PTFE filled gaskets and for Class 900, NPS 26 through NPS 48.

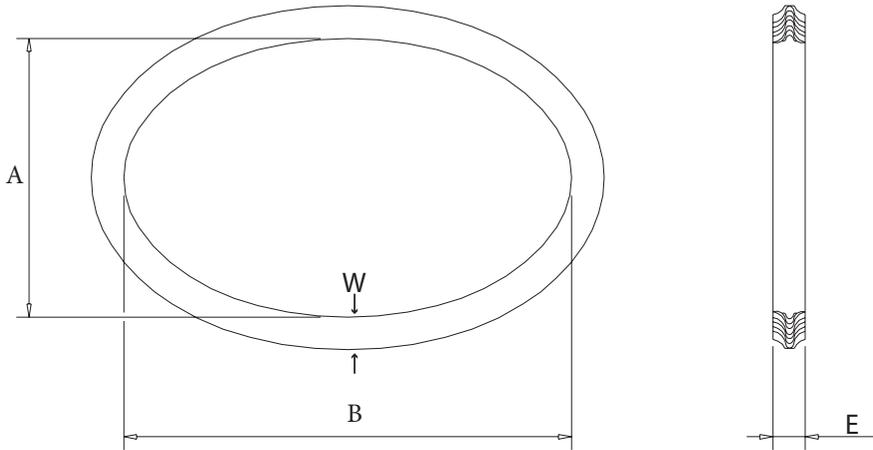
Annex 7.3 (Continued)**Spiral Wound Gasket Dimensions per ASME B16.20 for ASME B16.47 Series B**

Nominal Diameter	Inner Ring Inside Diameter per Pressure Class - inches				
	150	300	400	600	900
26	25.75	25.75	25.75	25.38	26.25
28	27.75	27.75	27.63	27.00	28.25
30	29.75	29.75	29.63	29.63	30.75
32	31.75	31.75	31.50	31.25	33.00
34	33.75	33.75	33.50	33.50	35.25
36	35.75	35.75	35.38	35.50	36.25
38	37.75	38.25	37.50	37.50	39.75
40	39.75	40.25	39.38	39.75	41.75
42	41.75	42.75	41.38	42.00	43.75
44	43.75	44.25	43.50	43.75	45.50
46	45.75	46.38	46.00	45.75	48.00
48	47.75	48.50	47.50	48.00	50.00
50	49.75	49.88	49.50	50.00	There are no Class 900 flanges NPS 50 and larger.
52	51.75	51.88	51.50	52.00	
54	53.75	53.75	53.25	54.25	
56	56.00	56.25	55.25	56.25	
58	58.19	58.44	57.25	58.00	
60	60.44	61.31	59.75	60.25	

NOTES:

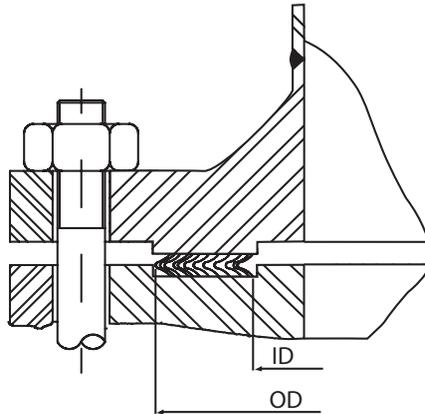
1. Inner Ring thickness: 0.117 in to 0.131 in.
2. Inner Ring Inside diameter tolerance: ± 0.12 in.

Annex 7.4
Style 914 Spiral Wound Gaskets



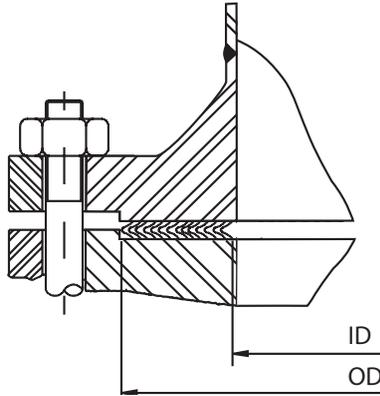
Inside Dimensions - in		Width - W - in	Thickness - E - in
A	B		
14	11	3/4	3/16
14	11	1	3/16
14	11	1 1/4	3/16
15	11	1/2	3/16
15	11	3/4	3/16
15	11	3/4	1/4
15	11	1	3/16
15	11	1 1/4	3/16
15	11	1 1/4	1/4
15 1/2	11 1/4	3/4	3/16
16	12	5/16	3/16
16	12	1/2	3/16
16	12	3/4	3/16
16	12	7/8	3/16
16	12	1	3/16
16	12	1	1/4
16	12	1 1/4	3/16
16	12	1 1/4	1/4

Annex 7.5
Style 911 for Tongue and Groove Flanges



Nominal Diameter	Gasket Dimensions - in			
	Large		Small	
	ID	OD	ID	OD
½	1	1 ⅜	1	1 ⅜
¾	1 ⅝ ₁₆	1 Ⅺ ₁₆	1 ⅝ ₁₆	1 Ⅺ ₁₆
1	1 ½	2	1 ½	1 ⅞
1 ¼	1 ⅞	2 ½	1 ⅞	2 ¼
1 ½	2 ⅛	2 ⅞	2 ⅛	2 ½
2	2 ⅞	3 ⅝	2 ⅞	3 ¼
2 ½	3 ⅜	4 ⅛	3 ⅜	3 ¾
3	4 ¼	5	4 ¼	4 ⅝
3 ½	4 ¾	5 ½	4 ¾	5 ⅛
4	5 ⅜ ₁₆	6 ⅜ ₁₆	5 ⅜ ₁₆	5 Ⅺ ₁₆
5	6 ⅝ ₁₆	7 ⅝ ₁₆	6 ⅝ ₁₆	6 Ⅼ ₁₆
6	7 ½	8 ½	7 ½	8
8	9 ⅜	10 ⅝	9 ⅜	10
10	11 ¼	12 ¾	11 ¼	12
12	13 ½	15	13 ½	14 ¼
14	14 ¾	16 ¼	14 ¾	15 ½
16	17	18 ½	16 ¾	17 ⅝
18	19 ¼	21	19 ¼	20 ⅛
20	21	23	21	22
24	25 ¼	27 ¼	25 ¼	26 ¼

Annex 7.6
Style 911 for Male and Female ASME B16.5 Flanges



Nominal Diameter	Gasket Dimensions - inches			
	Class 150 to 1500 psi		Class 2500 psi	
	ID	OD	ID	OD
1/4	1/2	1	-	-
1/2	1	1 3/8	13/16	1 3/8
3/4	1 5/16	1 11/16	1 1/16	1 11/16
1	1 1/2	2	1 1/4	2
1 1/4	1 7/8	2 1/2	1 5/8	2 1/2
1 1/2	2 1/8	2 7/8	1 7/8	2 7/8
2	2 7/8	3 5/8	2 3/8	3 5/8
2 1/2	3 3/8	4 1/8	3	4 1/8
3	4 1/4	5	3 3/4	5
3 1/2	4 3/4	5 1/2	-	-
4	5 3/16	6 3/16	4 3/4	6 3/16
5	6 5/16	7 5/16	5 3/4	7 5/16
6	7 1/2	8 1/2	6 3/4	8 1/2
8	9 3/8	10 5/8	8 3/4	10 5/8
10	11 1/4	12 3/4	10 3/4	12 3/4
12	13 1/2	15	13	15
14	14 3/4	16 1/4	-	-
16	17	18 1/2	-	-
18	19 1/4	21	-	-
20	21	23	-	-
24	25 1/4	27 1/4	-	-

JACKETED GASKETS

1. DESCRIPTION

A Jacketed Gasket is comprised of a soft pliable core inside a metallic jacket as shown in Figure 8.1. This Chapter covers several styles and applications.

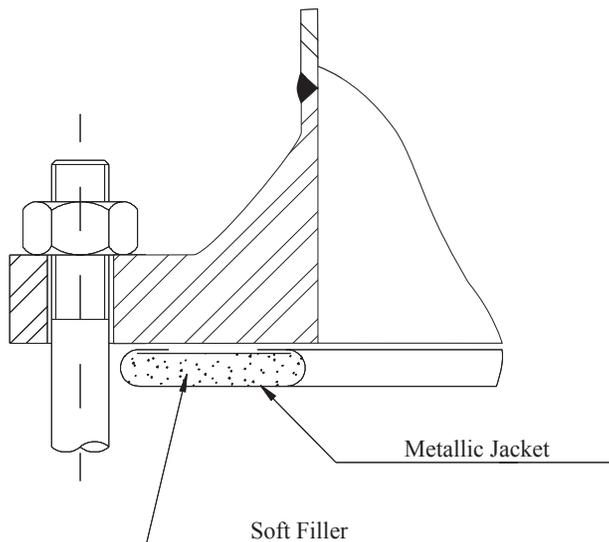


Figure 8.1

2. METALLIC JACKET

Almost any metal or alloy found in sheet form can be used to fabricate the jacket. The choice must take into consideration the fluid to be sealed as explained in Chapter 6 of this book. The metallic jacket is 0.016 in (0.4 mm) to 0.020 in (0.5 mm) thick.

3. SOFT FILLER

The standard filler material is Flexible Graphite. Other fillers like ceramic fiber, mica, PTFE or a softer metal can be used as filler.

4. DESIGN

The following recommendations are based on successful practical applications:

- Gaskets confined by the inside and outside diameters:
 - Gasket inside diameter = groove inside diameter plus 1/16 in (1.6 mm).
 - Gasket outside diameter = groove outside diameter less 1/16 in (1.6 mm).

- Gaskets confined by outside diameter:
 - Gasket inside diameter = flange inside diameter plus a minimum of 1/8 in (3.2 mm).
 - Gasket outside diameter = groove outside diameter less 1/16 in (1.6 mm).

- Non confined gaskets:
 - Gasket inside diameter = flange inside diameter plus 1/8 in (3.2 mm).
 - Gasket outside diameter = bolt circle diameter less the bolt diameter.

- Gasket width: to have adequate seating stress, the design recommendations of Chapter 2 should be followed.

5. STYLES AND APPLICATIONS

5.1. STYLE 920

Style 920 is a round single jacket gasket as shown in Figure 8.2. Used in applications where the seating stress and width are limited. It can be manufactured in circular or oval shape. The maximum gasket width is 1/4 in (6.4 mm) and the standard thickness is 3/32 in (2.4 mm).

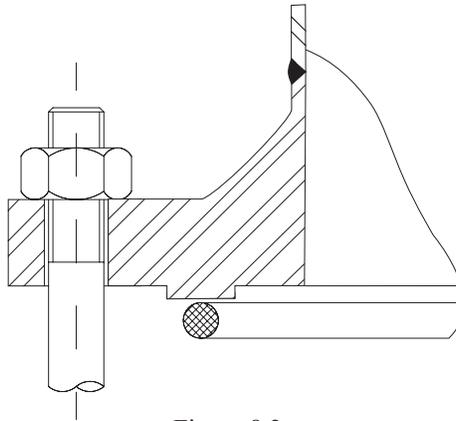


Figure 8.2

5.2. STYLE 923

Style 923 is a flat double jacket gasket as shown in Figure 8.3. The primary application for use is in Heat Exchangers. The standard thickness is 1/8 in (3.2 mm). Section 6 of this Chapter deals with the gaskets for Heat Exchangers.

ASME B16.20 Standard [31] shows the dimensions and tolerances for for double jacket gaskets for ASME B16.5 [46] flanges. Due to its higher cost, it is usually replaced by Spiral Wound Gaskets, already described in Chapter 7 of this book. The paper PVP2018-84907 - ASME B16.20 Jacketed Gaskets Performance Testing [60], presented at the ASME-PVP 2018 Congress, shows that double jacket gaskets are not suitable for gas service, with a high leakage regardless of seating stress. A review of the ASME B16.20 standard was suggested to alert users of this characteristic.

Style 923 gaskets are also used in large size reactors in chemical plants. Another important use is for flanges in the large, low-pressure ducting in Steel Mill Blast Furnaces. To compensate for distortions and irregularities of these flanges, gaskets are 5/32 in (4 mm) to 1/4 in (6 mm) thick.

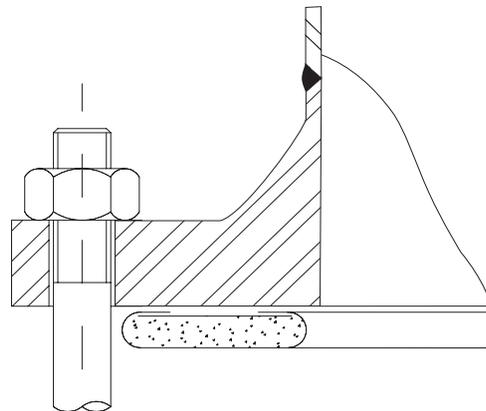


Figure 8.3

5.3. STYLE 926

Similar to style 923 but the metallic jacket is corrugated as shown in Figure 8.4. The corrugations act as a labyrinth increasing the sealability. For ASME B16.5 flanges, the ASME B16.20 Standard provides gasket dimensions. However, Spiral Wound or faced serrated gaskets Camprofile have replaced the use of these gaskets in pipe flanges.

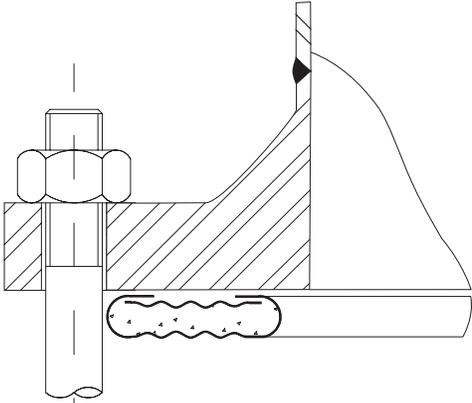


Figure 8.4

5.4. STYLE 929

Similar to style 926 with a corrugated metallic filler (Figure 8.5). Used in applications where it is necessary to have an all metal gasket. Higher temperature applications and greater chemical resistance require this type of gasket.

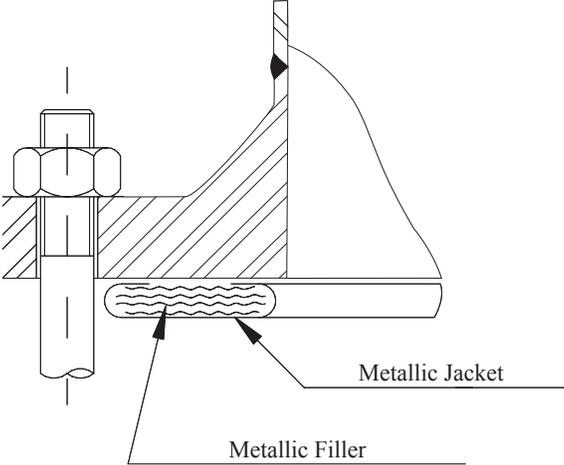


Figure 8.5

6. GASKETS FOR HEAT EXCHANGERS

6.1. HEAT EXCHANGERS

There are several kinds of Heat Exchangers, some of them so much a part of our life style that we hardly notice them, like car radiators or home heating units. All of them transfer heat from one fluid to the other, cooling (radiator) or heating (home heating), according to the process needs.

In industry there are several kinds of Heat Exchangers, some have specific names like radiators, boilers, chillers, etc. However the term Heat Exchanger, in most process industries is referred to as the “Shell and Tube Heat Exchanger”. As the name implies, it is equipment that has a “shell” and a bundle of “tubes”. One of the fluids flows inside the shell outside the tubes and the other fluid flows inside the tubes.

6.2. TEMA STANDARD

The great majority of the Shell and Tube Heat Exchangers are manufactured following the recommendations of the “Standards of the Tubular Exchanger Manufacturers Association – TEMA” [24], which sets the guidelines for design, construction, testing, installation, and maintenance of this equipment.

The TEMA Standard defines three classes of Heat Exchangers:

- **Class R:** are designed for the generally severe requirements of Petroleum and related processing applications. For this service double-jacketed metal (Teadit Style 923, 926 or 927) or solid metal (Teadit Style 940, 941 or 942) gaskets shall be used for internal floating head joints, all joints for pressure of 300 psi and over, and for all joints in contact with hydrocarbons.

- **Class B:** designed for chemical process service. For this service double-jacketed metal (Teadit Style 923, 926 or 927) or solid metal (Teadit Style 940, 941 or 942) gaskets are to be used for internal floating head joints, all joints for pressure of 300 psi and over. For 300 psi and lower, composition gaskets may be used for external joints, unless temperature and/or the corrosive nature of the contained fluid require otherwise.

- **Class C:** are designed for the generally moderate requirements of commercial and general process applications. Gasket selection follows the same requirements of Class B service.

6.3. STYLE 923

Style 923 is the gasket used most in shell and tube heat exchangers. It can be manufactured in a wide range of sizes, shapes and with bars for heat exchangers with several passages. The primary seal is at the inside diameter where there is a higher gasket density after seating. The outside of the gasket is also denser after seating and acts as a secondary seal. Figure 8.6 shows the gasket and how it should be installed in Tongue and Groove flanges.

A nubbin of 1/64 in (0.4mm) height and 1/8 in (3.2 mm) width can be machined on the face of the flange.

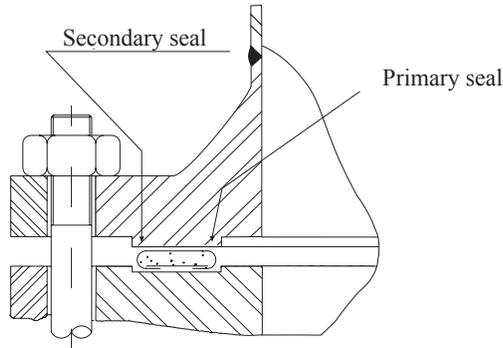


Figure 8.6

This old design is used to increase the gasket sealability. A 1/64" (0.4 m) high by 1/8" (3.2 mm) wide nubbin is machined on the flange surface. This nubbin pressing where the gasket is thinner increases the seating stress in this area. Figure 8.7 shows how a gasket is installed in a flange with a nubbin. Studies [35] have shown that the nubbin reduces the gasket sealability. The ASME PCC-1 [6] recommends the removal of nubbins in existing flanges.

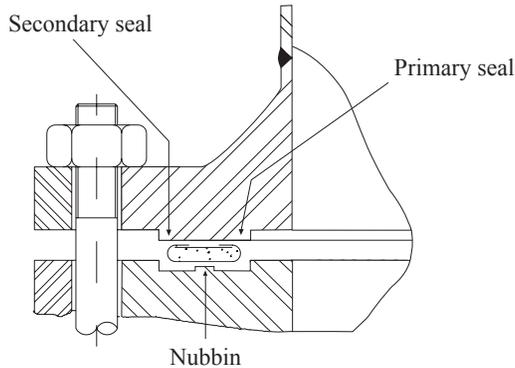


Figure 8.7

6.4. MATERIALS

Gaskets for heat exchangers can be manufactured in almost any metal or alloy available in sheets of 0.016 in (0.4 mm) to 0.020 in (0.5 mm) thick. The choice of jacket material should take into account the operating conditions and the recommendations in

Chapter 6 of this book. The standard filler is Flexible Graphite. Other filler materials like PTFE, mica or ceramic fiber can also be used to meet the specific requirements of the process.

6.5. GASKETS WITH INTEGRAL BARS

Traditionally, double-jacketed gaskets for heat exchangers are manufactured with integral bars as shown in Figure 8.8. There is a radius of concordance between the partition bars and the inside diameter of the gasket.

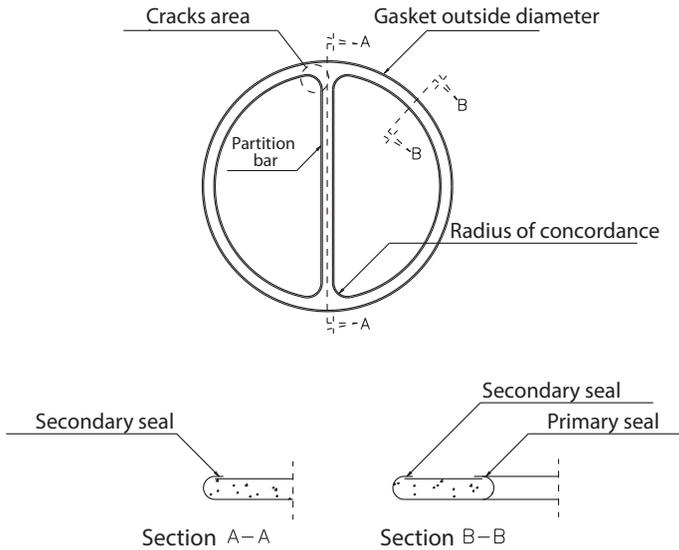


Figure 8.8

The gasket material can crack due to the stresses produced during the forming of the radius (Figure 8.9). The primary seal as explained early in this Chapter is broken. The secondary seal provides all the sealing.

The greater area of the “radius of concordance” region decreases the gasket seating stress and thus reduces the sealability in the radius area.



Figure 8.9

6.6. GASKETS WITH WELDED BARS

Gaskets with welded bars (Figure 8.10) avoid one of the greatest problems of conventional gaskets, which are the cracks in the radius of concordance area as shown before. The primary and secondary seal (Figure 8.11) are 360° around the gasket. The gasket has a greater sealability, reducing leaks to the immediate environment.

Regarding the bar seal between the heat exchanger passes; it is a small leak path at the end of each bar. However due to the low-pressure differential, these leaks do not change the overall performance of the equipment.

The bars are Plasma or TIG welded with spot welds at each end. By doing it this way, the bars are attached without reducing the gasket sealability. These welds should be soft and small to avoid areas of increased resistance to seating.

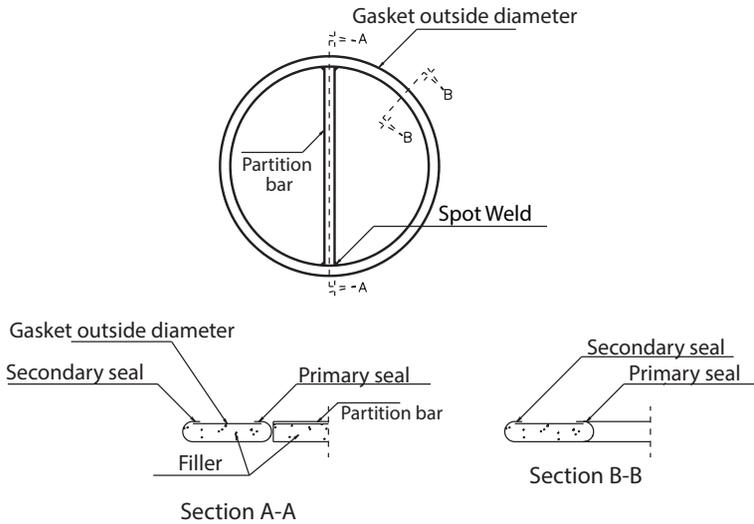


Figure 8.10



Figure 8.11

6.7. DESIGN

Table 8.3 shows the most common shapes of gaskets for heat exchangers.

The normal dimensions for heat exchanger gaskets are:

- Gasket and bar width: 3/8 in (10 mm), 1/2 in (12.7 mm), 5/8 in (15.9 mm), 3/4 in (19 mm) and 1 in (25.4 mm).
- Gasket thickness: 1/8 in (3.2 mm).
- Assembly gap: to allow the seating and assembly of the gasket it is recommended there be a gap of 1/8 in (3.2 mm) between the gasket and its groove.

Table 8.1
Radius of Concordance

Gasket Material	Radius of Concordance minimum - mm
Aluminum	6
Copper	8
Carbon Steel	10
Stainless Steel	12
Nickel	10

6.8. MANUFACTURING TOLERANCES

Gaskets have to follow the recommendation of Tables 8.2 and Figure 8.12.

Table 8.2
Manufacturing Tolerances

Characteristic	Tolerance - in	
Outside Diameter (A)	Gaskets without bars	$\pm 1/16$ (average)
	Gaskets with bars	$\pm 1/16$
Outside Diameter Eccentricity	Gaskets without bars	5/32
	Gaskets with bars	1/16
Width (B)	+0.0, -1/32	
Thickness (E)	+1/32, -0.0	
Overlap (S)	Equal to or larger than 1/8	
Partition Bar Width (C)	+0.0, -1/32	
Partition Bar Location (F)	$\pm 1/32$	

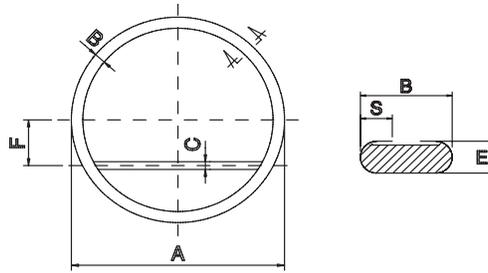


Figure 8.12

6.9. PARTITION BAR WELDING

Partitions are welded in such a way they do not protrude beyond the gasket sealing surface, as shown in figure 8.13.

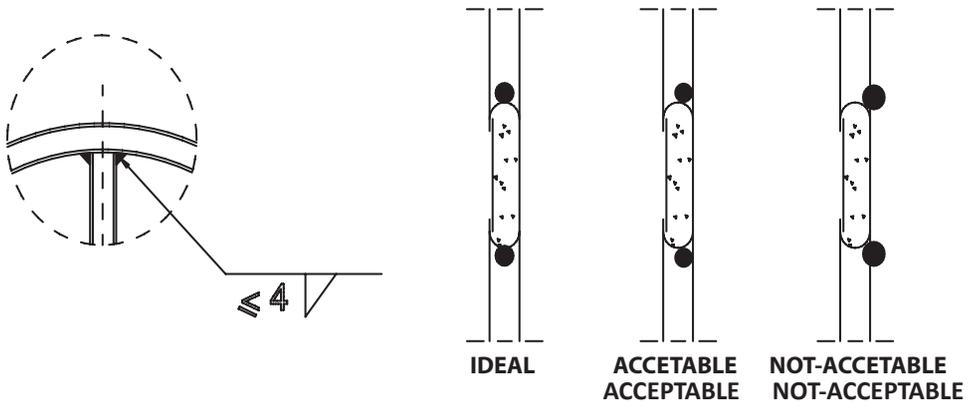


Figure 8.13

7. STYLE 927 GASKETS FOR HEAT EXCHANGERS

Style 927 gaskets are manufactured facing both sides of a Style 923 gasket with Flexible Graphite Corrugated Tape, as shown in Figure 8.14. The gasket construction follows the recommendations of Section 6 of this Chapter.

The Flexible Graphite facing increases the gasket sealability, especially if the flange sealing surfaces have pitting, tool marks or other small irregularities often found in these kinds of equipment.

The Style 927 gaskets combine the welded bar construction advantages with the excellent sealability of the Flexible Graphite, which fills up the small irregularities, providing a high sealability seal. It is recommended to use them if the operational conditions are suitable.

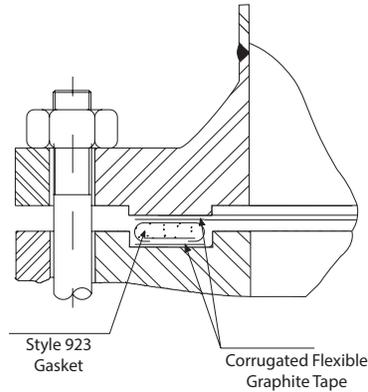


Figure 8.14

8. DIFFERENTIAL THERMAL EXPANSION

Due to the recurrent failures, studies have been conducted to determine the suitability of double jacket gaskets for service in Shell and Tube heat exchangers. The main concern has been differential thermal expansion between flanges, an intrinsic feature of heat exchangers which, by design, are built to transfer heat between fluids in the process industry. The paper PVP2008-61121 Heat Exchanger Gaskets Radial Shear Testing [33] studies the effects of differential expansion on double-jacket joints. Figure 8.15 illustrates the differential expansion, which occurs when the cover flange is in contact with a fluid at a different temperature than the shell side fluid. In a process with frequent thermal cycles this problem gets worse as there is a constant friction between the flanges and the gasket.

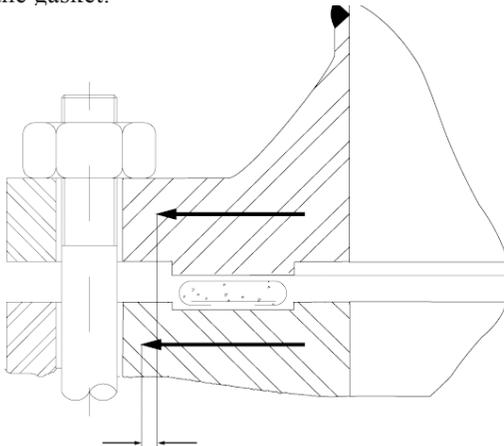


Figure 8.15

In a test simulating a heat exchanger, with a difference of approximately 392F (200C) causing a differential expansion of 1/16 in (1.66 mm) between flanges, after 100 thermal cycles there was a reduction in the bolt load as shown in Figure 8.16. As can be seen from the chart, there was a loss of bolt load of almost 50%, with a downward trend.

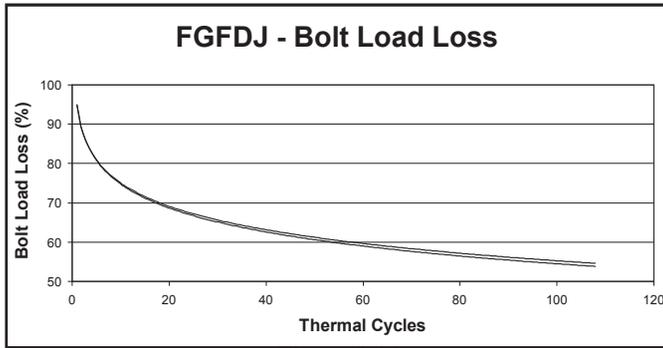


Figure 8.16

Figure 8.17 shows the gasket cross section at the end of 100 cycles. It can be concluded that the friction with the flanges gradually deformed it with the consequent loss of the bolt load.



Figure 8.17

Specifying another type of gasket is recommended whenever the heat exchanger is subjected to frequent thermal cycling. For these applications the process industry standard is the use of a Camprofile type gasket as shown in Chapter 10 of this book.

9. ASME CODE GASKET FACTORS

ASME Code calculation values for double-jacketed gaskets are shown in Table 8.3.

Table 8.3
ASME Gasket Factors

Gasket Metal	m	y
Aluminum	2.75	3700
Copper or Brass	3.00	4500
Carbon Steel	3.25	5500
Monel	3.50	6500
Stainless Steel	3.50	7600

The values for calculations according to the ASME-PCC-1 have not been determined at the editing time of this book.

Table 8.4
List of Standard Heat Exchanger Gaskets

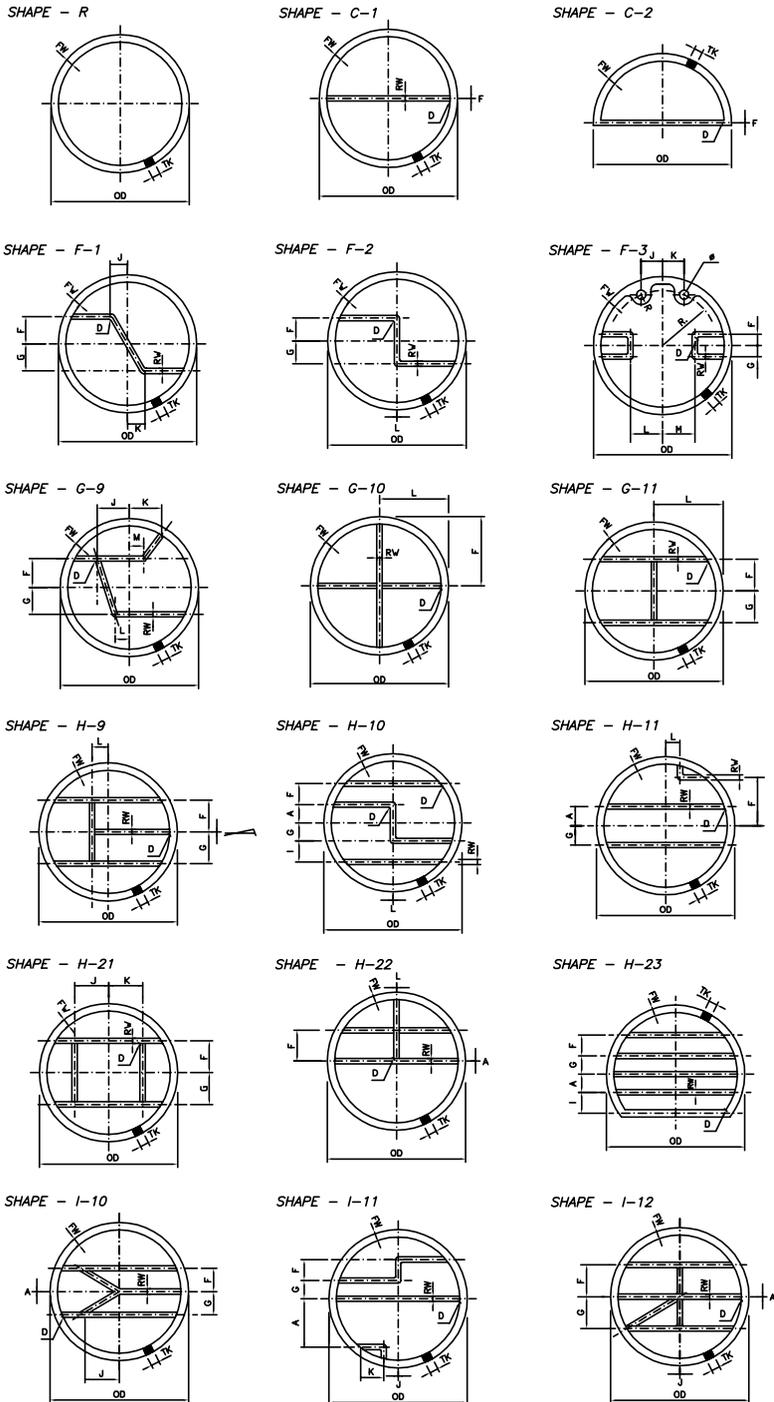


Table 8.4 (Continued)
List of Standard Heat Exchanger Gaskets

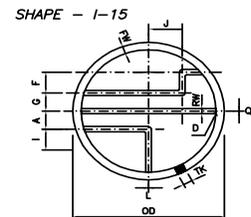
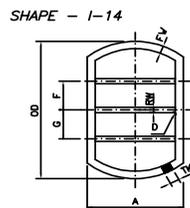
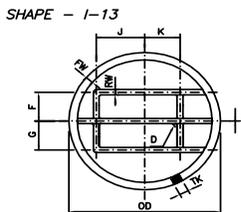
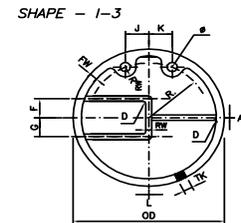
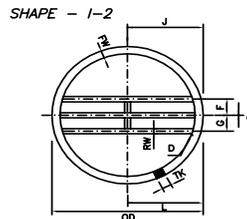
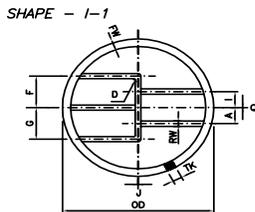
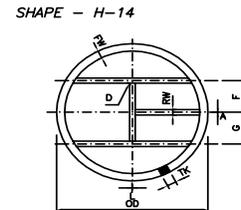
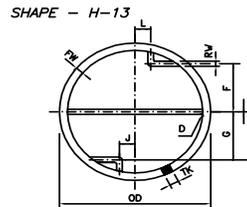
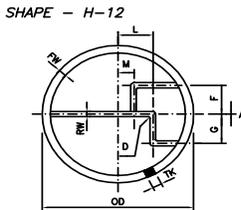
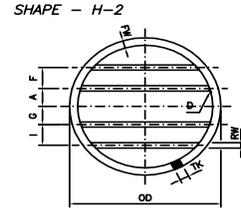
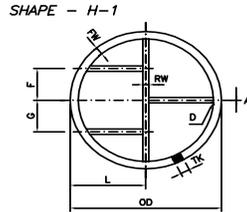
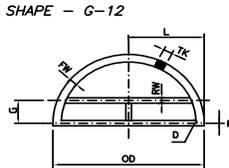
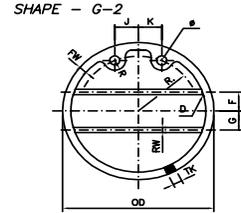
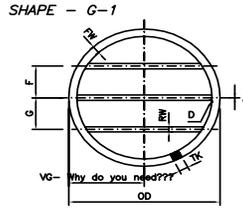
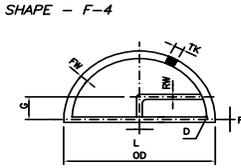
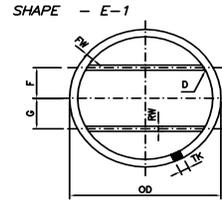
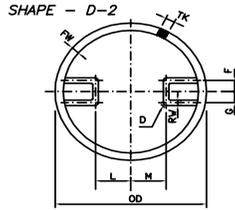
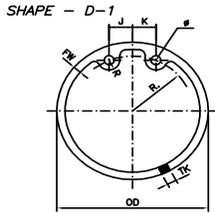
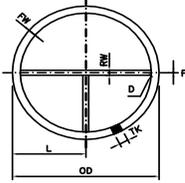
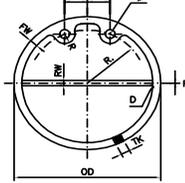


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List of Standard Heat Exchanger Gaskets

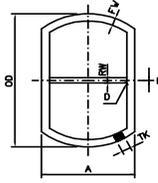
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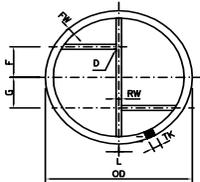
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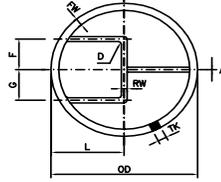
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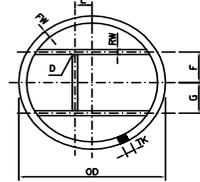
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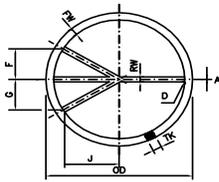
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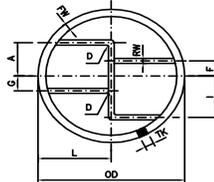
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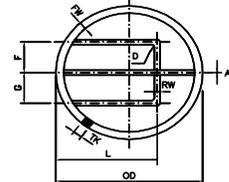
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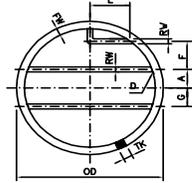
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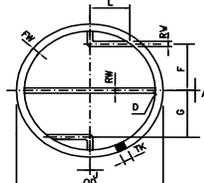
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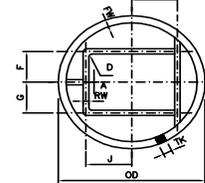
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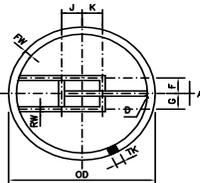
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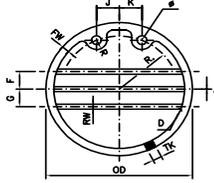
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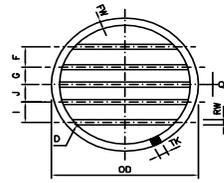
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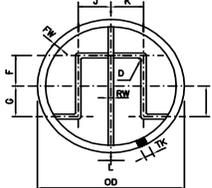
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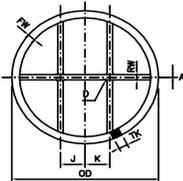
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SHAPE - I-16



SHAPE - I-17



SHAPE - I-18

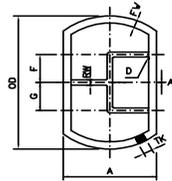
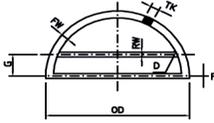
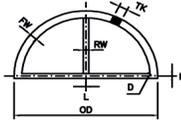


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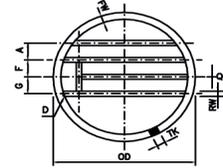
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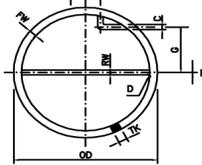


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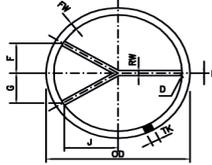


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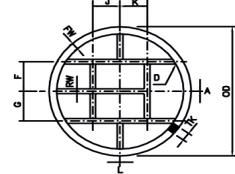
J- You do not need this



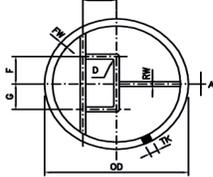
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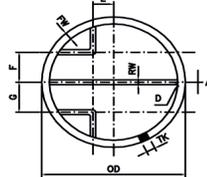
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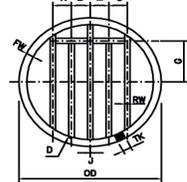
SHAPE - H-6



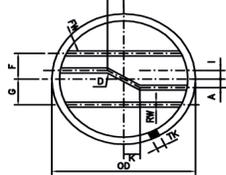
SHAPE - H-7



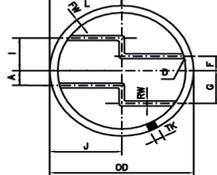
SHAPE - K-7



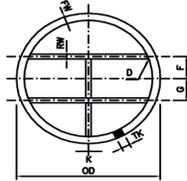
SHAPE - H-18



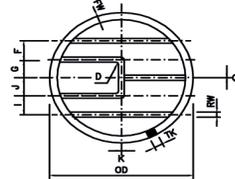
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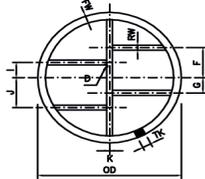
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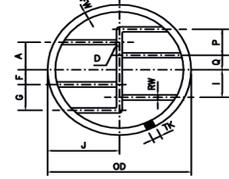
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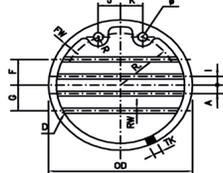
SHAPE - I-8



SHAPE - J-3



SHAPE - J-1



SHAPE - J-2

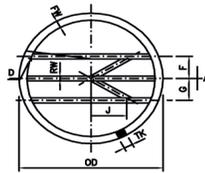


Table 8.4 (Continued)
List of Standard Heat Exchanger Gaskets

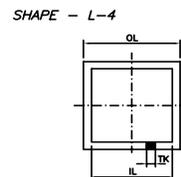
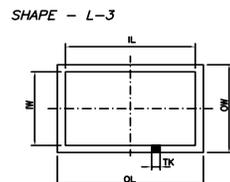
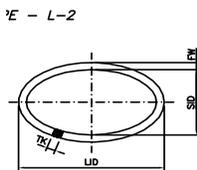
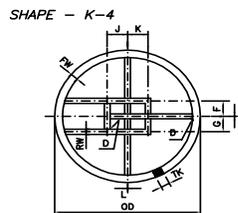
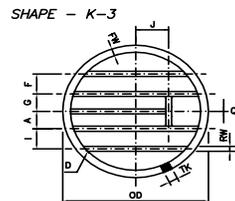
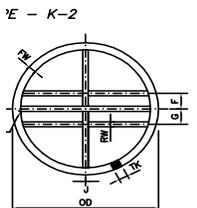
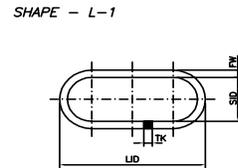
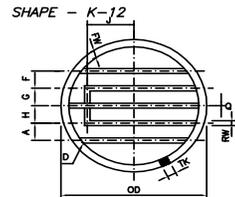
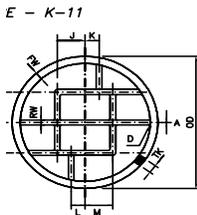
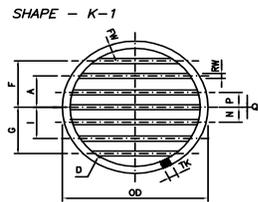
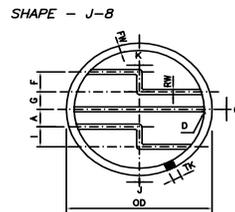
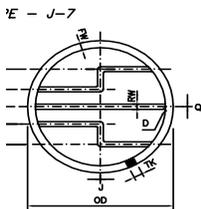
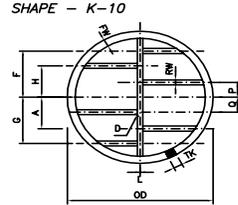
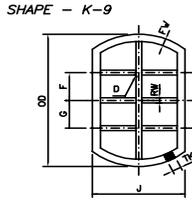
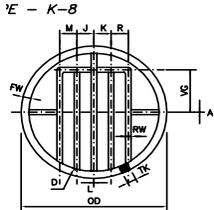
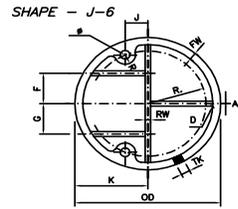
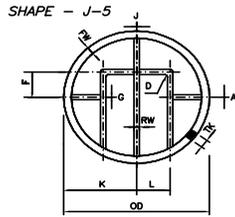
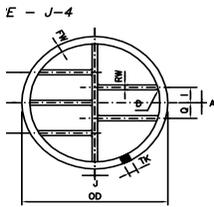
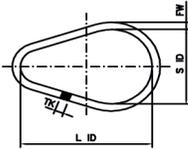
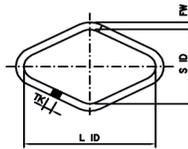


Table 8.4 (Continued)
List of Standard Heat Exchanger Gaskets

SHAPE - L-5



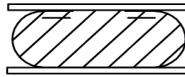
SHAPE - L-6



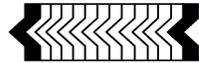
Heat Exchanger Gasket Styles



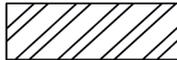
STYLE 830
 CUT GASKET
 IN NON METALLIC
 MATERIAL



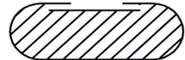
STYLE 927
 DOUBLE JACKETED
 FACED WITH
 NON METALLIC MATERIAL



STYLE 911-T
 SPIRAL WOUND



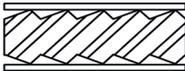
STYLE 940
 FLAT METALLIC GASKET



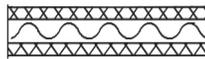
STYLE 923
 DOUBLE JACKETED



STYLE 941
 GROOVED GASKET



STYLE 942
 GROOVED FACED
 WITH NON METALLIC MATERIAL



STYLE 950
 CORRUGATED GASKET

METAL GASKETS

1. METAL GASKETS

Metal gaskets can be divided into two principal categories: Flat gaskets and Ring-Joint gaskets as shown in Figure 9.1. Both are manufactured from a metal or alloy without soft filler.

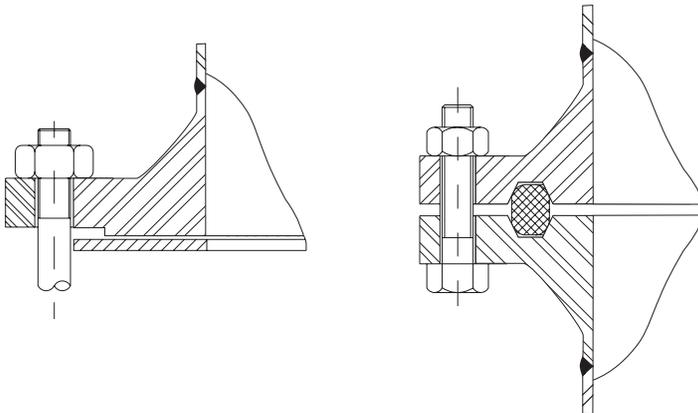


Figure 9.1

2. FLAT METALLIC GASKETS

Defined as gaskets of relatively small thickness compared with its width. They are normally produced from a sheet with or without a machined sealing surface. To have an effective seal, the flange must flow the gasket material; therefore the gasket must always be softer than the flange. The flange surface finish must be smooth and free from radial scratches or tool marks.

3. FLAT METAL GASKET MATERIALS

Any material available in sheet that can be cut, machined, or stamped can be used. The recommendations in Chapter 6 of this book should be followed to specify the material of the gasket.

To manufacture gaskets larger than the maximum sheet size, it is necessary to weld the gasket. This welding must not be harder than the flange material or it will damage the sealing surface.

4. FINISH OF THE FLANGE SEALING SURFACE

For better performance, the use of flanges with a fine finish is recommended. The roughness should be $63 \mu\text{in Ra}$ ($1.6 \mu\text{m Ra}$). Under no circumstances should the finish exceed $125 \mu\text{in Ra}$ ($3.2 \mu\text{m Ra}$). Scratches or radial tool marks are practically impossible to seal with metal gaskets.

5. STYLES OF FLAT METALLIC GASKETS

5.1. STYLE 940

The style 940 (Figure 9.2) is a metallic gasket that has a smooth sealing surface and can be manufactured practically in any shape. Their typical applications are in valves, heat exchangers, hydraulic presses and tongue and groove flanges. The strong points are mechanical and chemical attack resistance and they can be used in elevated temperature and pressure service.

The width of the gasket sealing surface should be at least equal to 1.5 times its thickness.

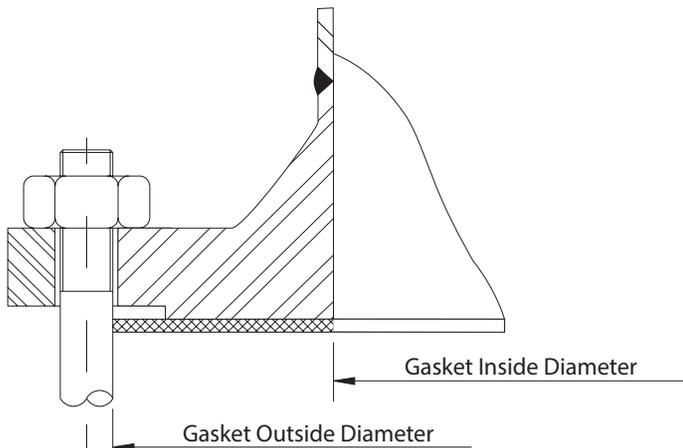


Figure 9.2

These gaskets, depending upon the kind of material have high maximum seating stress. The values for the maximum and minimum seating stress are shown in Table 9.1.

Table 9.1
Seating Stress for Style 940 Gaskets

Material	Seating Stress psi (MPa)	
	Minimum	Maximum
Soft Iron	34 000 (235)	76 000 (525)
AISI 1006/1008	34 000(235)	76 000 (525)
AISI 1010/1020	38 500 (265)	87 000 (600)
AISI 304/316/321	48 600 (335)	108 000 (750)
AISI 309	58 000 (400)	130 000 (900)
Nickel	27 600 (190)	74 000 (510)
Copper	19 600 (135)	43 500 (300)
Aluminum	10 150 (70)	20 300 (140)

5.2. STYLE 941

Style 941 is a flat gasket with concentric grooves as shown in Figure 9.3. They combine the advantage of the style 940 with a reduced area of contact with the flange to increase the seating stress.

Used when a metallic gasket is required but the available seating force is not enough to seal a style 940. Minimum manufacturing thickness: 1/8 in (3.2 mm).

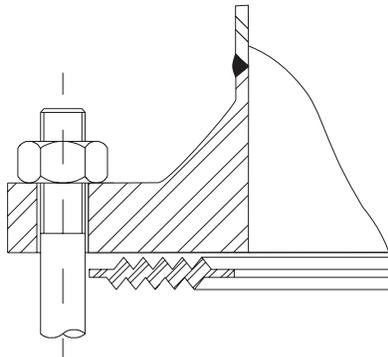


Figure 9.3

5.3. STYLE 943

If the service requires the use of style 941 but the flanges need to be protected to avoid being damaged, the 941 gasket can be jacketed as shown in (Figure 9.4).

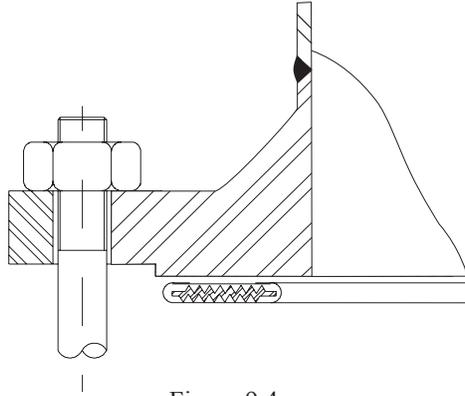


Figure 9.4

5.4. STYLE 900

Style 900 is a corrugated metal gasket as shown in Figure 9.5. They are used in low-pressure applications where there are limitations of weight and space. The thickness of the metal sheet should be 0.010 in (0.25 mm) to 0.04 in (1 mm) depending on the metal and number of corrugations. Due to the thickness of the sheet, the force required to seat the gasket is greatly reduced when compared with gasket styles 940 and 941. A minimum of 3 corrugations is necessary to obtain satisfactory sealing. A small flat area on the inside and outside diameters of the gasket is recommended to increase its mechanical strength. The corrugation pitch can vary between 0.045 in (1.1 mm) to 1/4 in (6.4 mm). The total thickness of the gasket is 40% to 50% of the corrugation pitch. The metal used determines the service temperature limit. Maximum service pressure: 500 psi.

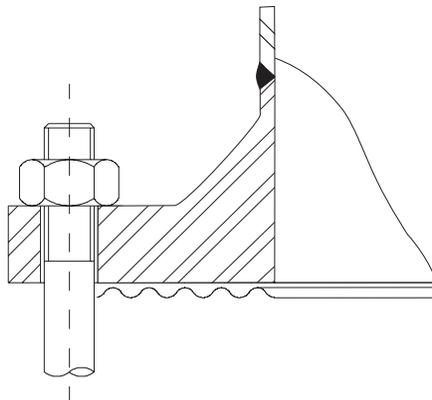


Figure 9.5

5.5. METALBEST STYLE 905

Metalbest Style 905 is a corrugated gasket style 900 metal core with Flexible Graphite or ePTFE facings as shown in Figure 9.6. The main advantage for using a 905 Metalbest is that it provides an extremely effective seal under low bolt loads. This makes the gasket ideal for applications where the available loading is determined to be low and unsuitable for spiral wound or other type of gasket requiring high seating stress. It is designed to maintain a positive seal through thermo-cycling and shock load conditions.

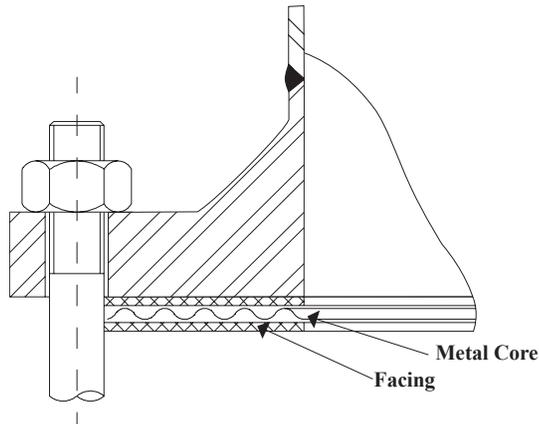


Figure 9.6

Style 905 gaskets can also be manufactured with Ceramic Fiber felt rope facing (Figure 9.7), for use with large size ducts at high temperature and low pressure like in Blast Furnaces and Gas Turbine exhaust. The metal thickness is 0.020 in (0.5 mm) and the corrugation pitch is 5/32 in (4 mm), 3/16 in (4.8 mm) or 1/4 in (6.4 mm) depending on the width of the gasket.

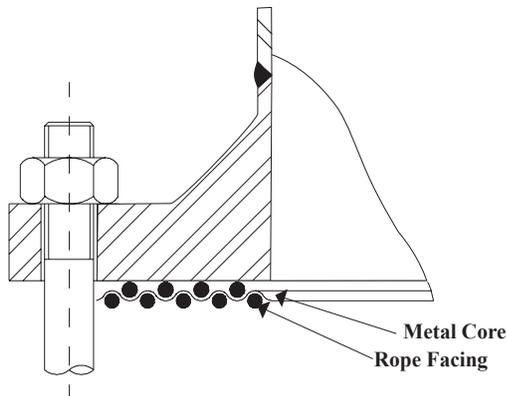


Figure 9.7

Corrugated metal gaskets with Flexible Graphite facings, style 905 Metalbest, have gained popularity in the marketplace in Class 150 and 300 ASME B16.5 flanges due to their ability to seal at low bolt loads. Tedit Style 905 Metalbest gaskets have been fire tested and approved according to the requirements of the PVRC Fire Tightness Test (FITT) procedure and have been sealability tested per ROTT procedure.

One of the most frequent uses of Style 905 Metalbest Gaskets are in shell and tube heat exchangers, due to their ability to avoid mechanical shearing problems associated other gasket types in heavy thermal cycling applications. The standard core material is Austenitic Stainless Steel and the covering layer is Flexible Graphite. Other alloys are available upon request. The gasket thickness before seating is approximately 0.080 in (2 mm), for heat exchanger applications, and the other dimensions and shapes are per application.

6. RING-JOINTS (RTJ)

Metallic Ring-Joints are produced according to the standards established by the American Petroleum Institute, API 6A [38] and API 17D [39] and the American Society of Mechanical Engineers, ASME B16.20 [31], for application at elevated temperatures and/or pressures. A typical application of Ring-Joints is the “Christmas Tree” used in oil fields (Figures 9.8 and 9.9).

The seal is obtained in a line of contact by a wedge action with high seating pressures thus, forcing the gasket material to flow. The small sealing area with high contact pressure results in great reliability. However the contact surfaces of the gasket and the flange should be carefully finished. Some styles of Ring-Joints are pressure activated, that is, the greater the pressure the better the sealability.

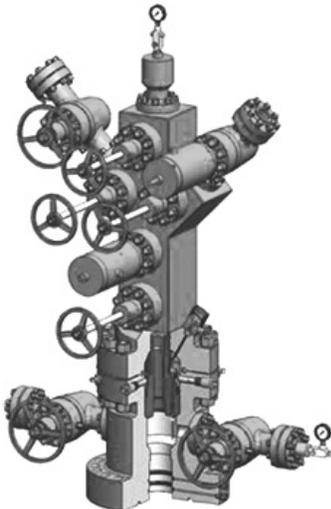


Figure 9.8

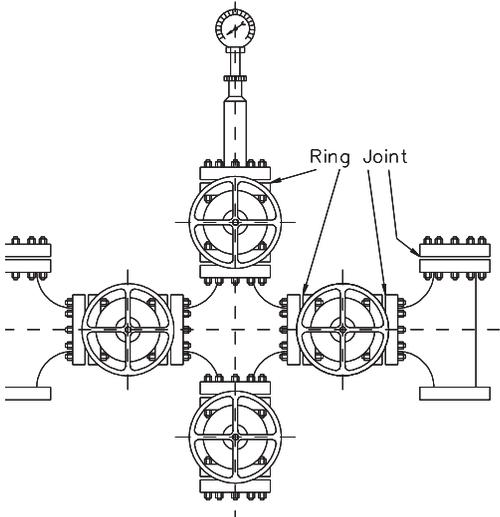


Figure 9.9

6.1. RTJ GASKET MATERIALS

The materials should be produced by centrifugal casting, forged or laminated. Cast materials should not be used. Table 9.2 shows the standard materials recommended by ASME B16.20 for Ring-Joint gaskets.

Table 9.2
Ring-Joints Materials per ASME B16.20

Material	Maximum Hardness Rockwell B	Material Code
Soft Iron	56	D
Carbon Steel	68	S
AISI 502	72	F5
AISI 410	86	S410
AISI 304	83	S304
AISI 316	83	S306
AISI 347	83	S347
Monel	70	M
Inconel 625	68	I
F11	68	F11

6.2. SURFACE FINISH

The gasket sealing surface finish has a maximum roughness of 63 $\mu\text{in Ra}$ (1.6 $\mu\text{m Ra}$) for styles 950, 951 and RX and a maximum of 32 $\mu\text{in Ra}$ (0.8 $\mu\text{m Ra}$) for style BX.

6.3. HARDNESS

The maximum hardness for each gasket material is shown in Table 9.2. It is recommended that the hardness of the gasket be always less than that of the flange so as not to damage it. When the materials of the flange and the gasket are similar, it is recommended to heat-treat the gasket to have the minimum possible hardness.

6.4. DIMENSIONS, TOLERANCES AND ASME CODE GASKET FACTORS

Tables 9.4 to 9.9, at the end of this Chapter, have the dimensions and application data for Ring-Joints per ASME B16.20.

ASME Code calculation values for Ring Joint gaskets are shown in Table 9.3.

Table 9.3
ASME Gasket Factors

Gasket Metal	m	y
Carbon Steel	5.50	18 000
Monel	6.00	21 800
Stainless Steel	6.50	26 000

The values for calculations according to the ASME-PCC-1 have not been determined at the editing time of this book.

6.5. STYLES

6.5.1. STYLE 950

Style 950, which is frequently referred to as the oval ring, was the gasket that was initially standardized (Figure 9.10). Later developments resulted in other styles. If the flange was designed using the older version of the gasket standard, for use with an oval ring, then it should be used only with style 950 gaskets.

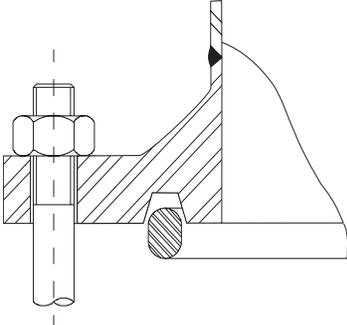


Figure 9.10

6.5.2. STYLE 951

Style 951 has an octagonal section as shown in Figure 9.11. Style 951 has better sealing performance than Style 950 and its use is recommended for new applications. For this style flanges are manufactured according to new issues of ASME and API standards and have grooves with a profile designed to work with both styles 950 and 951.

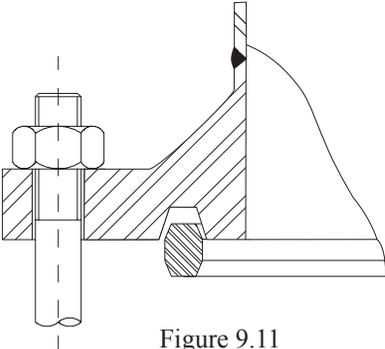


Figure 9.11

6.5.3. STYLE RX

Style RX (Figure 9.12) is a pressure-activated gasket. Its shape is designed to use the fluid pressure to increase the sealability. The outside sealing surface of the gasket makes the initial contact with the flange seating the gasket. As the internal pressure of the piping or equipment is increased the contact pressure between gasket and flange also increases due to the shape of the gasket. High seating pressures are created increasing the sealability. This design characteristic makes this gasket style more resistant to vibrations, pressure surges and shocks that occur during oil well drilling. Style RX is interchangeable with style 950 and 951, using the same flange grooving.

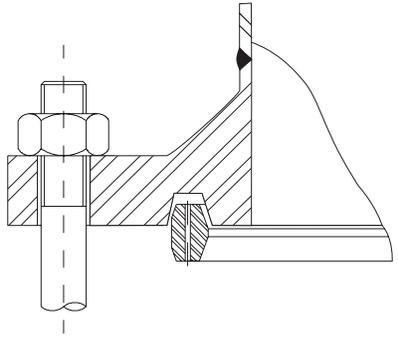


Figure 9.12

6.5.4. STYLE BX

Style BX gasket has a square cross section with bevelled corners as shown in Figure 9.13. Designed for use only in flanges API 6BX. Style BX is recommended for pressures from 5000 psi (34.5 MPa) up to 20 000 psi (138 MPa). The average diameter of the gasket is slightly greater than that of the flange groove. This way when the gasket is seated it stays pre-compressed by the outside diameter creating a high seating stress.

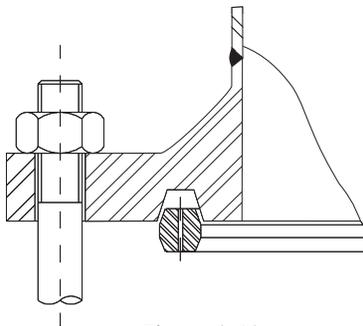


Figure 9.13

6.5.5. STYLE IX

Developed in Norway and standardized by the NORSOK L-005 - Compact Flange Connections [40] and later by ISO 27509 - Petroleum and natural gas industries - Compact flanged connections with IX seal ring [65]. It is used in compact flanges; this type of gasket (Figure 9.14) has increasing applications because of the advantages presented by the small size and weight compared with similar ASME or API flanges. However, its installation is more complex than the traditional types. Annex 9.7 shows the dimensions and application data for IX Rings.

The concept of the compact flange seal is provided by the elastic energy stored by the flange and the gasket at the installation time. The flange faces are in contact and are the primary sealing surface, the IX ring acts as a secondary seal.

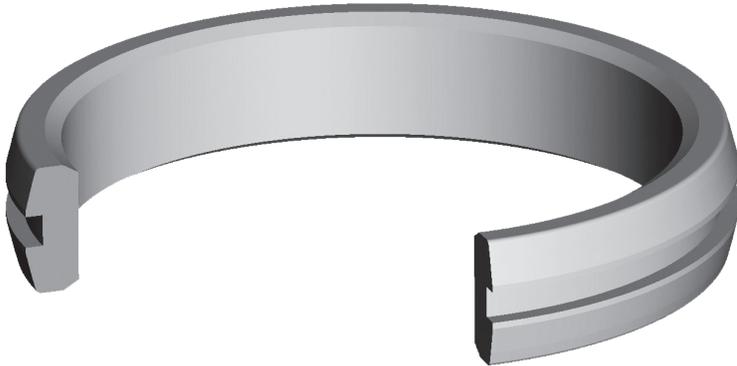
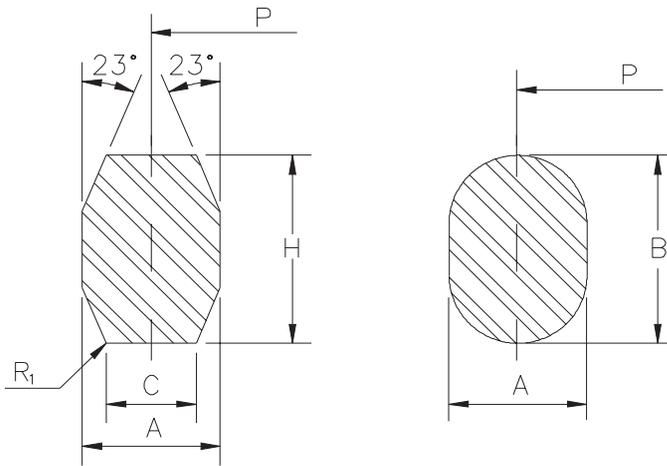


Figure 9.14

6.5.6. OTHER STYLES

There are several other styles of metallic gaskets such as the lens, delta and Bridgeman styles, which are outside of the scope of this book due to their restricted use in specific applications.

Annex 9.1



Octagonal - Style 950

Oval - Style 950

Dimensions for Styles 950 and 951 in inches

Ring Number	Pitch Diameter P	Width of Ring A	Height of Ring		Width Style 951 C	Radius Style 950 R ₁
			Oval	Octagonal		
			B	H		
R-11	1.344	0.250	0.44	0.38	0.170	0.06
R-12	1.563	0.313	0.56	0.50	0.206	0.06
R-13	1.688	0.313	0.56	0.50	0.206	0.06
R-14	1.750	0.313	0.56	0.50	0.206	0.06
R-15	1.875	0.313	0.56	0.50	0.206	0.06
R-16	2.000	0.313	0.56	0.50	0.206	0.06
R-17	2.250	0.313	0.56	0.50	0.206	0.06
R-18	2.375	0.313	0.56	0.50	0.206	0.06
R-19	2.563	0.313	0.56	0.50	0.206	0.06
R-20	2.688	0.313	0.56	0.50	0.206	0.06
R-21	2.844	0.438	0.69	0.63	0.305	0.06
R-22	3.250	0.313	0.56	0.50	0.206	0.06
R-23	3.250	0.438	0.69	0.63	0.305	0.06
R-24	3.750	0.438	0.69	0.63	0.305	0.06
R-25	4.000	0.313	0.56	0.50	0.206	0.06

Annex 9.1 (continued)
Dimensions for Styles 950 and 951 in inches

Ring Number	Pitch Diameter P	Width of Ring A	Height of Ring		Width Style 951 C	Radius Style 950 R ₁
			Oval	Octagonal		
			B	H		
R-26	4.000	0.438	0.69	0.63	0.305	0.06
R-27	4.250	0.438	0.69	0.63	0.305	0.06
R-28	4.375	0.500	0.75	0.69	0.341	0.06
R-29	4.500	0.313	0.56	0.50	0.206	0.06
R-30	4.625	0.438	0.69	0.63	0.305	0.06
R-31	4.875	0.438	0.69	0.63	0.305	0.06
R-32	5.000	0.500	0.75	0.69	0.341	0.06
R-33	5.188	0.313	0.56	0.50	0.206	0.06
R-34	5.188	0.438	0.69	0.63	0.305	0.06
R-36	5.875	0.313	0.56	0.50	0.206	0.06
R-37	5.875	0.438	0.69	0.63	0.305	0.06
R-38	6.188	0.625	0.88	0.81	0.413	0.06
R-39	6.375	0.438	0.69	0.63	0.305	0.06
R-40	6.750	0.313	0.56	0.50	0.206	0.06
R-41	7.125	0.438	0.69	0.63	0.305	0.06
R-42	7.500	0.750	1.00	0.94	0.485	0.06
R-43	7.625	0.313	0.56	0.50	0.206	0.06
R-44	7.625	0.438	0.69	0.63	0.305	0.06
R-45	8.313	0.438	0.69	0.63	0.305	0.06
R-46	8.313	0.500	0.75	0.69	0.341	0.06
R-47	9.000	0.750	1.00	0.94	0.485	0.06
R-48	9.750	0.313	0.56	0.50	0.206	0.06
R-49	10.625	0.438	0.69	0.63	0.305	0.06
R-50	10.625	0.625	0.88	0.81	0.413	0.06
R-51	11.000	0.875	1.13	1.06	0.583	0.06
R-52	12.000	0.313	0.56	0.50	0.206	0.06
R-53	12.750	0.438	0.69	0.63	0.305	0.06
R-54	12.750	0.625	0.88	0.81	0.413	0.06
R-55	13.500	1.125	1.44	1.38	0.780	0.09

Annex 9.1 (continued)
Dimensions for Styles 950 and 951 in inches

Ring Number	Pitch Diameter P	Width of Ring A	Height of Ring		Width Style 951 C	Radius Style 950 R ₁
			Oval	Octagonal		
			B	H		
R-56	15.000	0.313	0.56	0.50	0.206	0.06
R-57	15.000	0.438	0.69	0.63	0.305	0.06
R-58	15.000	0.875	1.13	1.06	0.583	0.06
R-59	15.625	0.313	0.56	0.50	0.206	0.06
R-60	16.000	1.250	1.56	1.50	0.879	0.09
R-61	16.500	0.438	0.69	0.63	0.305	0.06
R-62	16.500	0.625	0.88	0.81	0.413	0.06
R-63	16.500	1.000	1.31	1.25	0.681	0.09
R-64	17.875	0.313	0.56	0.50	0.206	0.06
R-65	18.500	0.438	0.69	0.63	0.305	0.06
R-66	18.500	0.625	0.88	0.81	0.413	0.06
R-67	18.500	1.125	1.44	1.38	0.780	0.09
R-68	20.375	0.313	0.56	0.50	0.206	0.06
R-69	21.000	0.438	0.69	0.63	0.305	0.06
R-70	21.000	0.750	1.00	0.94	0.485	0.06
R-71	21.000	1.125	1.44	1.38	0.780	0.09
R-72	22.000	0.313	0.56	0.50	0.206	0.06
R-73	23.000	0.500	0.75	0.69	0.341	0.06
R-74	23.000	0.750	1.00	0.94	0.485	0.06
R-75	23.000	1.250	1.56	1.50	0.879	0.09
R-76	26.500	0.313	0.56	0.50	0.206	0.06
R-77	27.250	0.625	0.88	0.81	0.413	0.06
R-78	27.250	1.000	1.31	1.25	0.681	0.09
R-79	27.250	1.375	1.75	1.63	0.977	0.09
R-80	24.250	0.313	-	0.50	0.206	0.06
R-81	25.000	0.563	-	0.75	0.377	0.06
R-82	2.250	0.438	-	0.63	0.305	0.06
R-84	2.500	0.438	-	0.63	0.305	0.06

Annex 9.1 (continued)
Dimensions for Styles 950 and 951 in inches

Ring Number	Pitch Diameter P	Width of Ring A	Height of Ring		Width Style 951 C	Radius Style 950 R ₁
			Oval	Octagonal		
			B	H		
R-85	3.125	0.500	-	0.69	0.341	0.06
R-86	3.563	0.625	-	0.81	0.413	0.06
R-87	3.938	0.625	-	0.81	0.413	0.06
R-88	4.875	0.750	-	0.94	0.485	0.06
R-89	4.500	0.750	-	0.94	0.485	0.06
R-90	6.125	0.875	-	1.06	0.583	0.06
R-91	10.250	1.250	-	1.50	0.879	0.09
R-92	9.000	0.438	0.69	0.63	0.305	0.06
R-93	29.500	0.750	-	0.94	0.485	0.06
R-94	31.500	0.750	-	0.94	0.485	0.06
R-95	33.750	0.750	-	0.94	0.485	0.06
R-96	36.000	0.875	-	1.06	0.583	0.06
R-97	38.000	0.875	-	1.06	0.583	0.06
R-98	40.250	0.875	-	1.06	0.583	0.06
R-99	9.250	0.438	-	0.63	0.305	0.06
R-100	29.500	1.125	-	1.38	0.780	0.09
R-101	31.500	1.250	-	1.50	0.879	0.09
R-102	33.750	1.250	-	1.50	0.879	0.09
R-103	36.000	1.250	-	1.50	0.879	0.09
R-104	38.000	1.375	-	1.63	0.977	0.09
R-105	40.250	1.375	-	1.63	0.977	0.09

Tolerances:

- Pitch Diameter P: ± 0.007 in.
- Width of Ring A: ± 0.008 in.
- Height B and H: $+0.05, -0.02$ in. The variation in height along the Ring cannot exceed 0.02 in.
- Width of Flat C: ± 0.008 in.
- Radius R: ± 0.02 in.
- Angle 23° : $\pm 0.5^\circ$.

Annex 9.2
Application Data for Styles 950 and 951

Ring Number R	Pressure Class and Nominal Diameter											
	ASME B16.5					API 6B				ASME B16.47 Series A		
	150	300 600	900	1500	2500	720 960	2000	3000	5000	150	300 600	900
R-11		½										
R-12			½	½								
R-13		¾			½							
R-14			¾	¾								
R-15	1											
R-16		1	1	1	¾	1	1	1	1			
R-17	1 ¼											
R-18		1 ¼	1 ¼	1 ¼	1	1 ¼	1 ¼	1 ¼	1 ¼			
R-19	1 ½											
R-20		1 ½	1 ½	1 ½		1 ½	1 ½	1 ½	1 ½			
R-21					1 ¼							
R-22	2											
R-23		2			1 ½	2	2					
R-24			2	2				2	2			
R-25	2 ½											
R-26		2 ½			2	2 ½	2 ½					
R-27			2 ½	2 ½				2 ½	2 ½			
R-28					2 ½							
R-29	3											
R-30		3										
R-31		3	3			3	3	3				
R-32					3							
R-33	3 ½											
R-34		3 ½										
R-35				3					3			
R-36	4											
R-37		4	4			4	4	4	3 ½			
R-38					4							
R-39				4					4			
R-40	5											
R-41		5	5			5	5	5				
R-42					5							
R-43	6											
R-44				5					5			
R-45		6	6			6	6	6				
R-46				6					6			
R-47					6							
R-48	8											
R-49		8	8			8	8	8				
R-50				8					8			
R-51					8							

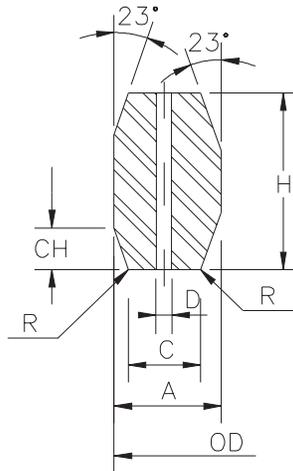
Annex 9.2 (Continued)
Application Data for Styles 950 and 951

Ring Number R	Pressure Class and Nominal Diameter											
	ASME B16.5					API 6B				ASME B16.47 Series A		
	150	300 600	900	1500	2500	720 960	2000	3000	5000	150	300 600	900
R-52	10											
R-53		10	10			10	10	10				
R-54				10					10			
R-55					10							
R-56	12											
R-57		12	12			12	12	12				
R-58				12								
R-59	14											
R-60					12							
R-61		14				14	14	14				
R-62			14									
R-63				14								
R-64	16											
R-65		16				16	16					
R-66			16					16				
R-67				16								
R-68	18											
R-69		18				18	18					
R-70			18					18				
R-71				18								
R-72	20											
R-73		20				20	20					
R-74			20					20				
R-75				20								
R-76	24											
R-77		24										
R-78			24									
R-79				24								
R-80												
R-81												
R-82									1			
R-84									1 ½			
R-85									2			
R-86									2 ½			
R-87									3			
R-88									4			
R-89									3 ½			
R-90									5			
R-91									10			

Annex 9.2 (Continued)
Application Data for Styles 950 and 951

Ring Number R	Pressure Class and Nominal Diameter											
	ASME B16.5					API 6B				ASME B16.47 Series A		
	150	300 600	900	1500	2500	720 960	2000	3000	5000	150	300 600	900
R-92												
R-93											26	
R-94											28	
R-95											30	
R-96											32	
R-97											34	
R-98											36	
R-99							8	8				
R-100												26
R-101												28
R-102												30
R-103												32
R-104												34
R-105												36

Annex 9.3
Dimensions for Style RX in inches



Ring Number	Outside Diameter OD	Width A	Width C	Height CH	Height H	Radius R	Hole D
RX-20	3.000	0.344	0.182	0.125	0.750	0.06	-
RX-23	3.672	0.469	0.254	0.167	1.000	0.06	-
RX-24	4.172	0.469	0.254	0.167	1.000	0.06	-
RX-25	4.313	0.344	0.182	0.125	0.750	0.06	-
RX-26	4.406	0.469	0.254	0.167	1.000	0.06	-
RX-27	4.656	0.469	0.254	0.167	1.000	0.06	-
RX-31	5.297	0.469	0.254	0.167	1.000	0.06	-
RX-35	5.797	0.469	0.254	0.167	1.000	0.06	-
RX-37	6.297	0.469	0.254	0.167	1.000	0.06	-
RX-39	6.797	0.469	0.254	0.167	1.000	0.06	-
RX-41	7.547	0.469	0.254	0.167	1.000	0.06	-
RX-44	8.047	0.469	0.254	0.167	1.000	0.06	-
RX-45	8.734	0.469	0.254	0.167	1.000	0.06	-
RX-46	8.750	0.531	0.263	0.188	1.125	0.06	-
RX-47	9.656	0.781	0.407	0.271	1.625	0.09	-
RX-49	11.047	0.469	0.254	0.167	1.000	0.06	-
RX-50	11.156	0.656	0.335	0.208	1.250	0.06	-
RX-53	13.172	0.469	0.254	0.167	1.000	0.06	-
RX-54	13.281	0.656	0.335	0.208	1.250	0.06	-
RX-57	15.422	0.469	0.254	0.167	1.000	0.06	-
RX-63	17.391	1.063	0.582	0.333	2.000	0.09	-
RX-65	18.922	0.469	0.254	0.167	1.000	0.06	-
RX-66	18.031	0.656	0.335	0.208	1.250	0.06	-

Annex 9.3 (Continued)
Dimensions for Style RX in inches

Ring Number	Outside Diameter OD	Width A	Width C	Height CH	Height H	Radius R	Hole D
RX-69	21.422	0.469	0.254	0.167	1.000	0.06	-
RX-70	21.656	0.781	0.407	0.271	1.625	0.09	-
RX-73	23.469	0.531	0.263	0.208	1.250	0.06	-
RX-74	23.656	0.781	0.407	0.271	1.625	0.09	-
RX-82	2.672	0.469	0.254	0.167	1.000	0.06	0.06
RX-84	2.922	0.469	0.254	0.167	1.000	0.06	0.06
RX-85	3.547	0.531	0.263	0.167	1.000	0.06	0.06
RX-86	4.078	0.594	0.335	0.188	1.125	0.06	0.09
RX-87	4.453	0.594	0.335	0.188	1.125	0.06	0.09
RX-88	5.484	0.688	0.407	0.208	1.250	0.06	0.12
RX-89	5.109	0.719	0.407	0.208	1.250	0.06	0.12
RX-90	6.875	0.781	0.479	0.292	1.750	0.09	0.12
RX-91	11.297	1.188	0.780	0.297	1.781	0.09	0.12
RX-99	9.672	0.469	0.254	0.167	1.000	0.06	-
RX-201	2.026	0.226	0.126	0.057	0.445	0.02 (3)	-
RX-205	2.453	0.219	0.120	0.072 (2)	0.437	0.02 (3)	-
RX-210	3.844	0.375	0.213	0.125 (2)	0.750	0.03 (3)	-
RX-215	5.547	0.469	0.210	0.167 (2)	1.000	0.06 (3)	-

Notes:

1. For Rings RX-82 to RX-91 only one hole is required
2. The Tolerance for these dimensions is +0 in, -0.015 in.
3. The Tolerance for these dimensions is +0.02 in, - 0 in.

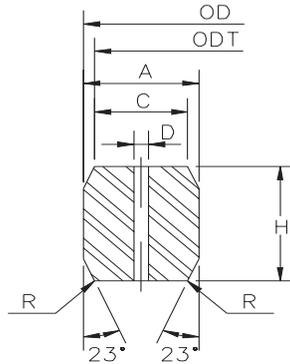
Tolerances:

- Outside Diameter OD: +0.020 in, -0 in.
- Width A: +0.008 in, -0 in. The variation of the width cannot exceed 0.004 in around the ring.
- Width C: +0.006 in, -0 in.
- Height CH: +0 in, -0.030 in.
- Height H: +0.008 in, -0 in. The variation of the height cannot exceed 0.004 in around the ring.
- Radius R: ± 0.02 in.
- 23° Angle: ± 0.5°.
- Hole D: ±0.02 in.

Annex 9.4
Application Data for Style RX

RX Ring Number	Pressure Class and Nominal Diameter - API 6B			
	720 - 960 - 2000	2900	3000	5000
RX-20	1 ½		1 ½	1 ½
RX-23	2			
RX-24			2	2
RX-25				3 ⅛
RX-26	2 ½			
RX-27			2 ½	2 ½
RX-31	3		3	
RX-35				3
RX-37	4		4	
RX-39				4
RX-41	5		5	
RX-44				5
RX-45	6		6	
RX-46				6
RX-47				8
RX-49	8		8	
RX-50				8 ⁽¹⁾
RX-53	10		10	
RX-54				10
RX-57	12		12	
RX-63				14
RX-65	16			
RX-66			16	
RX-69	18			
RX-70			18	
RX-73	20			
RX-74			20	
RX-82		1		
RX-84		1 ½		
RX-85		2		
RX-86		2 ½		
RX-87		3		
RX-88		4		
RX-89		3 ½		
RX-90		5		
RX-91		10		
RX-99	8		8	
RX-201				1 ⅜
RX-205				1 ⅓
RX-210				2 ⅞
RX-215				4 ⅛

Annex 9.5
Dimensions for Style BX in inches



Ring Number BX	Nominal Diameter	Diameter OD	Height H	Width A	Diameter ODT	Width C	Hole D (1)
BX-150	1 ¹¹ / ₁₆	2.842	0.366	0.366	2.790	0.314	0.06
BX-151	1 ¹³ / ₁₆	3.008	0.379	0.379	2.954	0.325	0.06
BX-152	2 ¹ / ₁₆	3.334	0.403	0.403	3.277	0.346	0.06
BX-153	2 ⁹ / ₁₆	3.974	0.448	0.448	3.910	0.385	0.06
BX-154	3 ¹ / ₁₆	4.600	0.488	0.488	4.531	0.419	0.06
BX-155	4 ¹ / ₁₆	5.825	0.560	0.560	5.746	0.481	0.06
BX-156	7 ¹ / ₁₆	9.367	0.733	0.733	9.263	0.629	0.12
BX-157	9	11.593	0.826	0.826	11.476	0.709	0.12
BX-158	11	13.860	0.911	0.911	13.731	0.782	0.12
BX-159	13 ⁵ / ₈	16.800	1.012	1.012	16.657	0.869	0.12
BX-160	13 ⁵ / ₈	15.850	0.938	0.541	15.717	0.408	0.12
BX-161	16 ⁵ / ₈	19.347	1.105	0.638	19.191	0.482	0.12
BX-162	16 ⁵ / ₈	18.720	0.560	0.560	18.641	0.481	0.06
BX-163	18 ³ / ₄	21.896	1.185	0.684	21.728	0.516	0.12
BX-164	18 ³ / ₄	22.463	1.185	0.968	22.295	0.800	0.12
BX-165	21 ¹ / ₄	24.595	1.261	0.728	24.417	0.550	0.12
BX-166	21 ¹ / ₄	25.198	1.261	1.029	25.020	0.851	0.12
BX-167	26 ³ / ₄	29.896	1.412	0.516	29.696	0.316	0.06
BX-168	26 ³ / ₄	30.128	1.412	0.632	29.928	0.432	0.06
BX-169	5 ¹ / ₈	6.831	0.624	0.509	6.743	0.421	0.06
BX-170	6 ⁵ / ₈	8.584	0.560	0.560	8.505	0.481	0.06
BX-171	8 ⁹ / ₁₆	10.529	0.560	0.560	10.450	0.481	0.06
BX-172	11 ⁵ / ₃₂	13.113	0.560	0.560	13.034	0.481	0.06
BX-303	30	33.573	1.494	0.668	33.361	0.457	0.06

Annex 9.5 (Continued)
Dimensions for Style BX in inches

1. For all Rings only one hole is required.

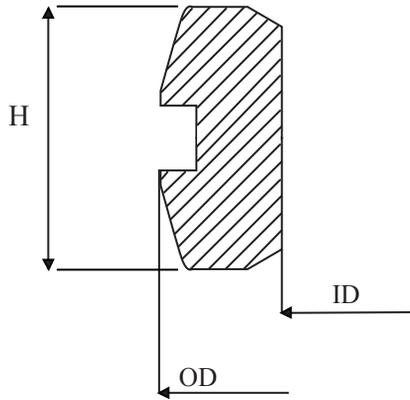
Tolerances:

- Outside Diameter OD: +0 in, -0.005 in.
- Height H: +0.008 in, -0 in. . The variation of the height cannot exceed 0.004 in around the ring.
- Width A: +0.008 in, -0 in. . The variation of the width cannot exceed 0.004 in around the ring.
- Diameter ODT: ± 0.002 in.
- Width C: +0.006 in, -0 in.
- Hole D: ± 0.02 in.
- Radius R: from 8% to 12% of Ring height H.
- 23° Angle: $\pm 0.25^\circ$.

Annex 9.6
Application Data for BX Rings

BX Ring Number	Pressure Class and Nominal Diameter - API 6BX					
	2 000	3 000	5 000	10 000	15 000	20 000
BX-150				1 ¹¹ / ₁₆	1 ¹¹ / ₁₆	
BX-151				1 ¹³ / ₁₆	1 ¹³ / ₁₆	1 ¹³ / ₁₆
BX-152				2 ¹ / ₁₆	2 ¹ / ₁₆	2 ¹ / ₁₆
BX-153				2 ⁹ / ₁₆	2 ⁹ / ₁₆	2 ⁹ / ₁₆
BX-154				3 ¹ / ₁₆	3 ¹ / ₁₆	3 ¹ / ₁₆
BX-155				4 ¹ / ₁₆	4 ¹ / ₁₆	4 ¹ / ₁₆
BX-156				7 ¹ / ₁₆	7 ¹ / ₁₆	7 ¹ / ₁₆
BX-157				9	9	9
BX-158				11	11	11
BX-159				13 ⁵ / ₈	13 ⁵ / ₈	13 ⁵ / ₈
BX-160			13 ⁵ / ₈			
BX-161			16 ³ / ₄			
BX-162			16 ³ / ₄	16 ³ / ₄	16 ³ / ₄	
BX-163			18 ³ / ₄			
BX-164				18 ³ / ₄	18 ³ / ₄	
BX-165			21 ¹ / ₄			
BX-166				21 ¹ / ₄		
BX-167	26 ³ / ₄					
BX-168		26 ³ / ₄				
BX-169				5 ¹ / ₈		
BX-170				6 ⁵ / ₈	6 ⁵ / ₈	
BX-171				8 ⁹ / ₁₆	8 ⁹ / ₁₆	
BX-172				11 ⁵ / ₃₂	11 ⁵ / ₃₂	
BX-303	30	30				

Annex 9.7
Dimensions for Style IX in mm per Norsok Standard L-005



DN	NPS	Ring Number	ID mm	OD mm	H mm
15	½	IX15	22.2	30.19	10.00
20	¾	IX20	27.2	35.20	10.00
25	1	IX25	34.2	42.22	10.00
40	1½	IX40	49.3	58.21	10.56
50	2	IX50	61.3	71.13	11.78
65	2½	IX65	74.4	85.05	12.98
80	3	IX80	89.5	100.96	14.24
100	4	IX100	115.7	128.85	16.19
125	5	IX125	142.0	156.75	17.94
150	6	IX150	170.2	186.66	19.64
200	8	IX200	220.5	238.54	22.36
250	10	IX250	274.9	298.42	25.20
300	12	IX300	325.0	347.36	27.15
350	14	IX350	357.1	380.32	28.46
400	16	IX400	409.3	434.27	30.47
450	18	IX450	459.4	486.23	32.28
500	20	IX500	511.6	539.20	34.06
550	22	IX550	561.7	591.18	35.69
600	24	IX600	611.9	642.16	37.25
650	26	IX650	664.0	695.16	38.81
700	28	IX700	714.1	747.16	40.25
750	30	IX750	766.3	800.16	41.69
800	32	IX800	816.4	851.16	43.03
850	34	IX850	866.6	902.18	44.34
900	36	IX900	918.7	956.19	45.65
950	38	IX950	968.8	1 007.21	46.88
1000	40	IX1000	1021.0	1 060.23	48.12
1050	42	IX1050	1071.1	1 111.26	49.29
1100	44	IX1100	1121.3	1 162.28	50.43
1150	46	IX1150	1173.4	1 215.31	51.59
1200	48	IX1200	1223.6	1 266.35	52.68

CAMPROFILE GASKETS

1. INTRODUCTION

With the continuous advance of the chemical and petrochemical processes, it is necessary to have gaskets for higher pressures and temperatures, especially for Shell and Tube Heat Exchangers. The most used gasket type for this equipment is the Double Jacketed, Teadit Style 923, which is a soft filler with a metallic jacket, as shown in Figure 8.6.

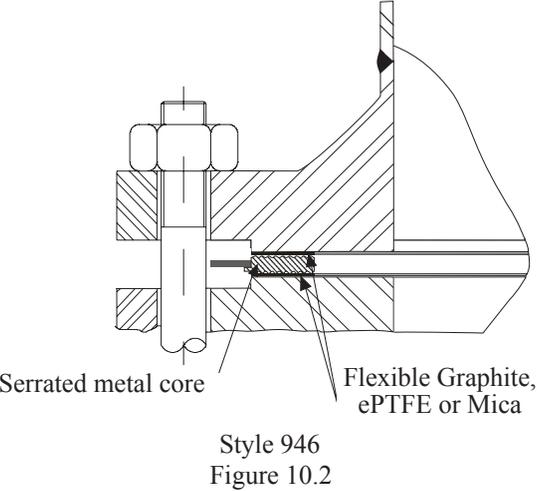
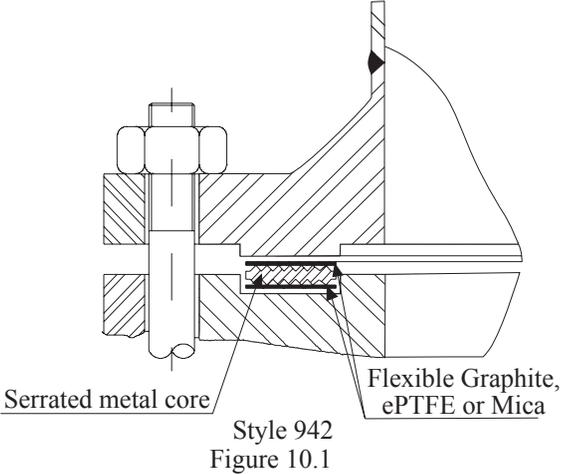
One of the characteristics of gaskets for Heat Exchangers is that they are manufactured according to the dimension of the equipment. There are no dimensional standards or shapes.

In order to be used in a high-pressure application a gasket must be able to resist high seating stress, assuring the sealability. The Double Jacketed Gaskets, due to their design, with a soft core, are capable of filling up the flange irregularities. However, because of the soft core, they are not recommended for applications where the seating stress is higher than 250 MPa (36 000 psi).

For applications that require high seating stresses, flat metal gaskets like the Teadit Style 940 (Figure 9.2) can be used. These gaskets have several manufacturing and installation difficulties. They are very sensitive to any flange irregularity especially scratches, pitting or tool marks. Being made from a solid metal or alloy, it is very difficult to seat and fill up the normal flange irregularities. Due to the large dimensions, some gaskets are larger than the available sheet stock, it becomes necessary to weld, and areas of higher hardness are created during the welding process, making it more difficult to seat the gasket, or even damage the flanges.

To avoid the flat metal gasket problems, the alternative is to use serrated metal gaskets, Teadit Style 941, as shown in Figure 9.3, which have the same high-pressure capabilities. The serrated sealing surface creates a high seating stress and additionally a labyrinth effect. However, the serrated surface, desirable to create a good seal, can damage the flange surface with circumferential marks.

Camprofile Gaskets, Tedit Style 942, combine the pressure resistance of flat metal gaskets with the excellent sealability of a soft facing. The serrated metal core is faced on both sides with a thin tape of Flexible Graphite, Expanded PTFE or Mica paper as shown in Figures 10.1 and 10.2.



In Heat Exchangers excellent field results confirm the results of laboratory experiments where the differential thermal expansion and contraction is simulated. The paper presented at the ASME-PVP 2011 Conference, titled Heat Exchanger Gaskets Radial Shear Testing [33] shows the differences in performance between Camprofile and traditional Double Jacketed gaskets styles 923 and 927. In the research paper Spiral Wound versus Flexible Graphite Metal Faced Serrated Pipe Flange Gaskets Thermal Cycling and Pressure in Comparative Testing [41] it was noticed that that the relaxation and sealability of Spiral Wound and Camprofile gaskets are similar.

Due to these excellent results the standard ASME B16.20 [31] has been revised to include dimensions and tolerances of Camprofile gaskets for ASME pipe flanges.

The Teadit Camprofile gaskets have the following characteristics:

- Operating pressure up to 3,700 psi (250 bar).
- Maximum temperature up to 1830F (1000C).
- Wide range of service.
- Less susceptible to flange imperfections than conventional flat metal gaskets.

The serrated metal core produces a high seating stress with a lower torque. The thin Flexible Graphite or Expanded PTFE facing fills up the flange irregularities and prevents the serrated finish from damaging the flanges. Figure 10.3 shows the metal core and a Flexible Graphite facing after a seating with 43 500 psi (300 MPa). The Flexible Graphite increases its density forming a 0.004 in (0.1 mm) thick film which prevents the metal core from hitting and damaging the flange sealing surface.

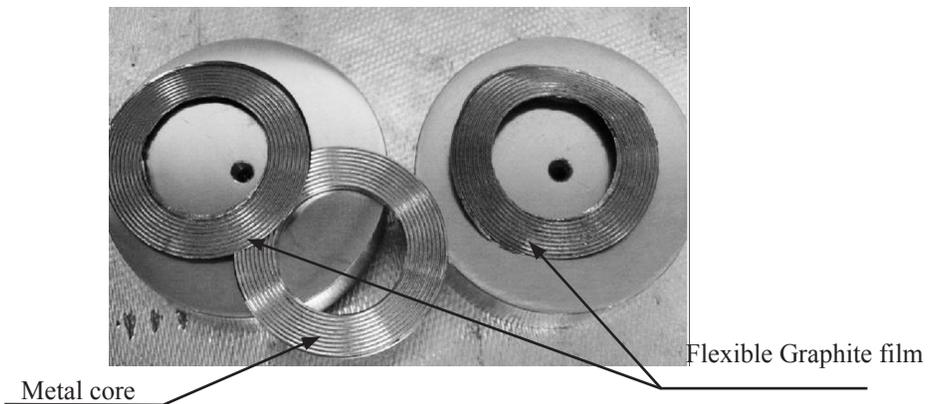


Figure 10.3

In Heat Exchanger flanges, due to the temperature differentials the thermal expansion and contraction of the flanges and the gasket are not the same, the Flexible Graphite, ePTFE or Mica facing being low coefficient of friction materials let the flange slide over the gasket when this thermal movement is present. During the Teadit development of Camprofile gaskets the coefficient of friction between the gasket and the flange was determined to be 0.045 to 0.080.

2. MATERIALS

2.1. METAL CORE

The core material should be chemically and thermally compatible with the fluid to be sealed. If possible, the core metal should be the same as used to manufacture the flanges to avoid corrosion or differential Thermal Expansion. It is recommended that the design should follow the recommendations of Chapters 2 and 6 of this book.

2.2. FACING

The most widely used facing material is Flexible Graphite. For operational conditions where the Flexible Graphite is not recommended, 24BB Expanded PTFE tape for aggressive chemical applications or Mica paper for high temperature is recommended. Table 10.1 shows the Temperature and Pressure limits for the facing materials.

Table 10.1
Facing Materials Temperature and Pressure Limits

Material	Temperature - F (C)		Pressure – psi (bar)
	min.	max.	
Standard Flexible Graphite	-400 (-240)	840 (450)	5000 (345)
High Temperature Flexible Graphite	-400 (-240)	1200 (650)	5000 (345)
Mica Paper	-58 (-50)	1830 (1000)	725 (50)
24BB ePTFE	-400 (-240)	500 (260)	1500 (100)

3. PRESSURE AND TEMPERATURE LIMITS

The Pressure and Temperature range is related to the range of each component, as indicated in Chapter 6 and Table 10.1. The Service Range is the combination of the limit for the metal and facing limits. For example a Teadit Camprofile Style 942 with a Carbon Steel core and Standard Flexible Graphite facing has the following limits:

- Maximum pressure: 5000 psi (345 bar).
- Temperature range: -40 to 840 F (-40 to 450 C)

4. BOLTING CALCULATION

The “m” and “y” values for ASME Code calculation are shown in Table 10.2 and the values for gasket installation calculations per ASME PCC-1 are in Table 10.3.

Table 10.2.
ASME Gasket Factors

Material	m	y-psi
Flexible Graphite	4	4500
PTFE	4	4500
Mica paper	8	5900

Table 10.3
ASME PCC-1 Values

Property	Value (psi)
Minimum Installation Stress ($S_{g_{min-s}}$)	8 000
Minimum Gasket Operating Stress ($S_{g_{min-o}}$)	3 900
Maximum Permissible Gasket Stress ($S_{g_{max}}$)	70 000
Fraction of gasket load remaining after relaxation (ϕ_g)	0.90
Maximum permissible flange rotation ($\theta_{g_{max}}$)	1.1

5. SURFACE FINISH

The recommended Surface Finish for the flange sealing surfaces of equipment flanges (heat exchanger, etc) is 63 to 80 μin (1.6 μm a 2.0 μm) Ra. This finish range is known as “smooth finish”.

6. DESIGN AND MANUFACTURING TOLERANCES

Table 10.4 shows the design recommendations and Table 10.5 shows the manufacturing tolerances for Teadit Style 942 gaskets.

Table 10.4
Gasket Design

Type of Flange	Gasket Diameter	
	Inside	Outside
Tongue and Groove	Groove inside diameter plus 1/16” (1.6mm)	Groove outside diameter less 1/16” (1.6mm)
Gaskets confined by the outside diameter	Flange inside diameter plus 1/8” (3.2 mm)	Flange outside diameter less 1/16” (1.6 mm)
Gaskets confined by the inside diameter	Flange inside diameter plus 1/16” (1.6 mm)	Flange outside diameter less 1/8” (3.2 mm)

Table 10.5
Manufacturing Tolerances

Gasket Inside Diameter - in (mm)	Tolerance - in (mm)	
	Inside	Outside
Up to 20 (500)	+1/32, 0.0 (+0.8 -0.0)	+0.0, -1/32 (+0.0 -0.8)
From 20 (500) to 60 (1500)	+1/16, -0.0 (+1.6 -0.0)	+0.0, -1/16 (+0.0 -1.6)
Larger than 60 (1500)	+3/32, -0.0 (+2.5 -0.0)	+0.0, -3/32 (+0.0 -2.5)

7. SHAPES

The Table 8.4 shows the most used shapes for Heat Exchanger gaskets. The partitions are welded to the gasket inside perimeter.

The standard gasket widths (“FW” dimension) are 3/8”, 1/2”, 5/8” and 3/4” (10, 13, 16 and 20 mm).

The standard thickness (dimension “TK”) is $5/32" \pm 0.008"$ (4 ± 0.2 mm), the metal core is 1/8” (3.2 mm) and 0.020” (0.4mm) for each facing side. Other thicknesses can be manufactured under special order.

8. CAMPROFILE GASKETS FOR ASME B16.5 FLANGES

ASME B16.20 - Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed provides dimensions, tolerances and material identification for pipe flanges according to ASME B16.5 [46]. The most important features of these gaskets are shown below.

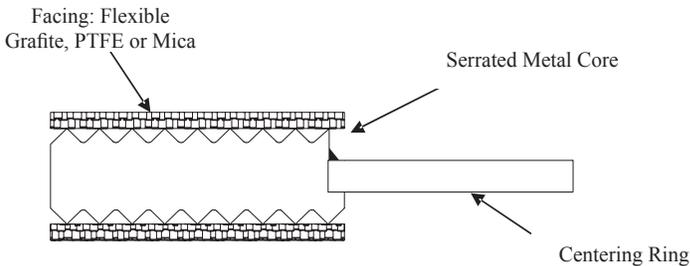


Figure 10.4

8.1 DIMENSIONS AND TOLERANCES

Gasket Dimensions for ASME B16.5 flanges are shown in Tables 10.6.

8.2 IDENTIFICATION

The centering ring is permanently marked with lettering at least 1/8 in (3.2 mm) height with the following information:

- Manufacturer’s name or trademark.
- Flange size (NPS).
- Pressure class.
- Sealing Ring metal abbreviation.
- Cover material abbreviation.
- Centering Ring metal abbreviation.

The material code abbreviations are shown in Table 10.7.

Table 10.6
Camprofile Gasket Dimensions for ASME B16.5 flanges

ND (in)	Sealing Ring		Centering Ring Outside Diameter by Pressure Class (in)						
	Inside Diameter (in)	Outside Diameter (in)	150	300	400	600	900	1500	2500
1/2	0.91	1.31	1.88	2.13	2.13	2.13	2.50	2.50	2.75
3/4	1.13	1.56	2.25	2.63	2.63	2.63	2.75	2.75	3.00
1	1.44	1.87	2.63	2.88	2.88	2.88	3.13	3.13	3.38
1 1/4	1.75	2.37	3.00	3.25	3.25	3.25	3.50	3.50	4.13
1 1/2	2.06	2.75	3.38	3.75	3.75	3.75	3.88	3.88	4.63
2	2.75	3.50	4.13	4.38	4.38	4.38	5.63	5.63	5.75
2 1/2	3.25	4.00	4.88	5.13	5.13	5.13	6.50	6.50	6.63
3	3.87	4.87	5.38	5.88	5.88	5.88	6.63	6.88	7.75
4	4.87	6.06	6.88	7.13	7.00	7.63	8.13	8.25	9.25
5	5.94	7.19	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	7.00	8.37	8.75	9.88	9.75	10.50	11.38	11.13	12.50
8	9.00	10.50	11.00	12.13	12.00	12.63	14.13	13.88	15.25
10	11.13	12.63	13.38	14.25	14.13	15.75	17.13	17.13	18.75
12	13.37	14.87	16.13	16.63	16.50	18.00	19.63	20.50	21.63
14	14.63	16.13	17.75	19.13	19.00	19.38	20.50	22.75	-
16	16.63	18.37	20.25	21.25	21.13	22.25	22.63	25.25	-
18	18.87	20.87	21.63	23.50	23.38	24.13	25.13	27.75	-
20	20.87	22.87	23.88	25.75	25.50	26.88	27.50	29.75	-
24	24.88	26.87	28.25	30.50	30.25	31.13	33.00	35.50	-

Tolerances:

- Sealing Ring Inside Diameter:
 DN 1/2" to DN 8": ± 0.03 in
- Sealing Ring Outside Diameter:
 DN 1/2" a DN 8": ± 0.03 in
- Centering Ring Outside Diameter: ± 0.03 in

Table 10. 7
Gasket Material Identification per ASME B16.20

Material	Abbreviation
Metal Core and Centering Ring	
Carbon Steel	CRS
304 SS	304
304 L SS	304 L
309 SS	309
310 SS	310
316 L SS	316 L
317 L SS	317 L
347 SS	347
321 SS	321
430 SS	430
Monel 400	MON
Nickel 200	NI
Titanium	TI
20Cb-3 alloy	A-20
Hastelloy B	HAST B
Hastelloy C	HAST C
Inconel 600	INC 600
Inconel 625	INC 625
Inconel X-750	INX
Incoloy 800	IN 800
Incoloy 825	IN 825
Facing	
Flexible Graphite	FG
Polytetrafluoroethylene	PTFE
Phlogopite (magnesium mica)	Light Blue

GASKETS FOR ELECTRICAL INSULATION

1. ELECTROCHEMICAL CORROSION

This is the most frequently found type of corrosion. It occurs at room temperature. It is the result of a reaction of two metals in contact in an aqueous solution of salts, acids or alkalis. Figure 11.1 illustrates electrochemical corrosion.

As can be observed, two reactions take place, one at the anode, the other at the cathode.

Anodic reactions are always oxidation and tend to dissolve the metal of the anode or combine with it to form an oxide.

The electrons produced in the anodic reaction participate in the cathodic reaction. These electrons flow across the metal as an electrical current.

The cathodic reactions are always reductions and normally do not affect the metal of the cathode, as the majority of the metals cannot be further reduced.

The basis of electrochemical corrosion is the existence of an anodic reaction where the metal of the anode gives up electrons. The measurement of the tendency of the metal to give up electrons serves as a basic criterion of corrodibility. This measurement, expressed in volts in relation to a gaseous hydrogen cell is found in corrosion manuals.

For Iron the value is 0.44 volts and for Zinc it is 0.76 volts. There is an electrical current from Zinc to Iron, from the higher potential to the lower. Zinc is the anode and is corroded.

If for example in place of Zinc in Figure 11.1 we had Copper, of 0.34 volt potential, we would have corrosion of the iron, which has a greater potential.

This way, the relationship between the electrochemical potentials of metals in contact with each other is what is going to determine which of them will be corroded. The principle is extensively used and the Zinc plating of carbon steel is one of the most common examples of the controlled use of electrochemical corrosion.

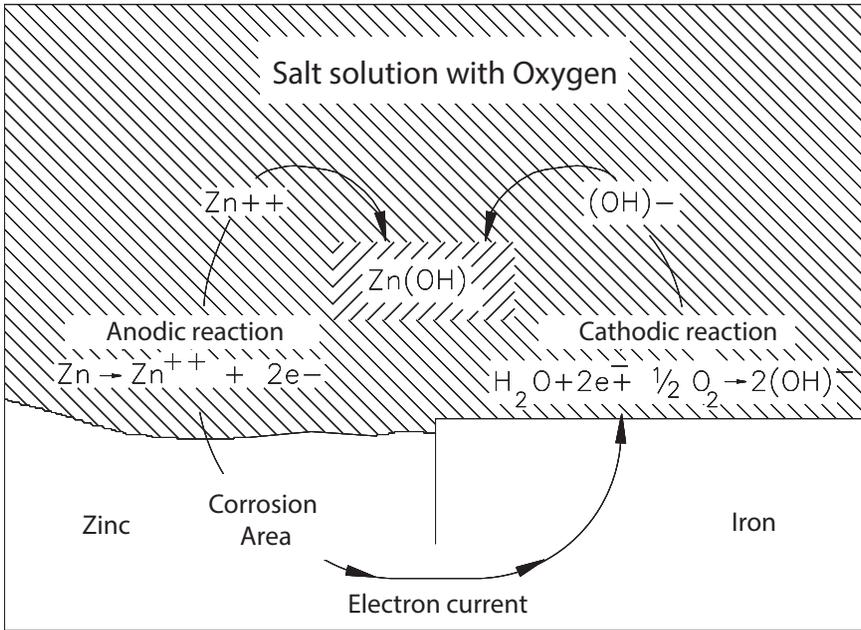


Figure 11.1

Table 11.1
Electrolytic Series in Salt Water

Anode (base)	Magnesium
	Zinc
	Cast Iron
	Carbon Steel
	304 Stainless Steel
	Copper
	316 Stainless Steel
	Inconel
	Titanium
	Monel
Cathode (noble)	Gold
	Platinum

2. CATHODIC PROTECTION

Cathodic protection consists of the controlled use of electrochemical corrosion to protect pipelines, tanks and other submerged equipment. Piping or equipment to be protected should be electrically insulated from the rest of the system to prevent the flow of galvanic current to a non-protected area.

Zinc anodes are installed in sufficient quantities to absorb the galvanic current. These anodes are consumed in the process and should be replaced periodically.

Figure 11.2 illustrates a submerged pipeline protected by Zinc anodes and insulated from the rest of the system.

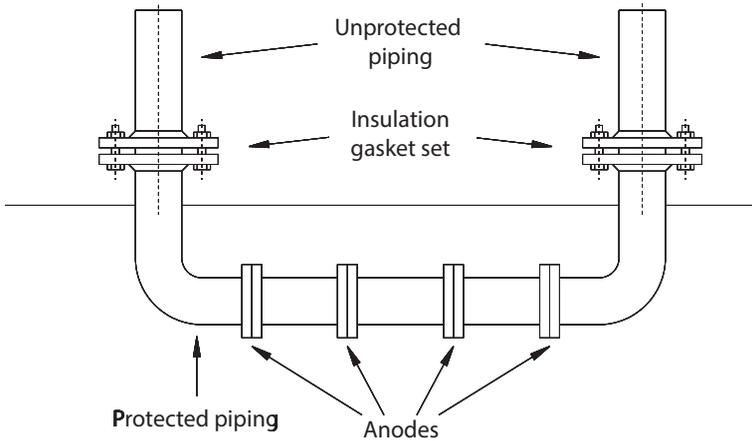


Figure 11.2

3. FLANGE INSULATION KIT

As shown, to avoid electrical current in the process from causing corrosion in other areas, the protected piping section must be electrically isolated from the rest of the system.

Figure 11.3 shows the exploded view of a flange insulation kit.

The insulated side cannot have any metal parts in contact with other side, thus forming a system similar to Figure 11.1.

The components of a flange insulation kit are:

- Insulation gasket.
- Insulation sleeves.
- Insulation washers.
- Metal washers.

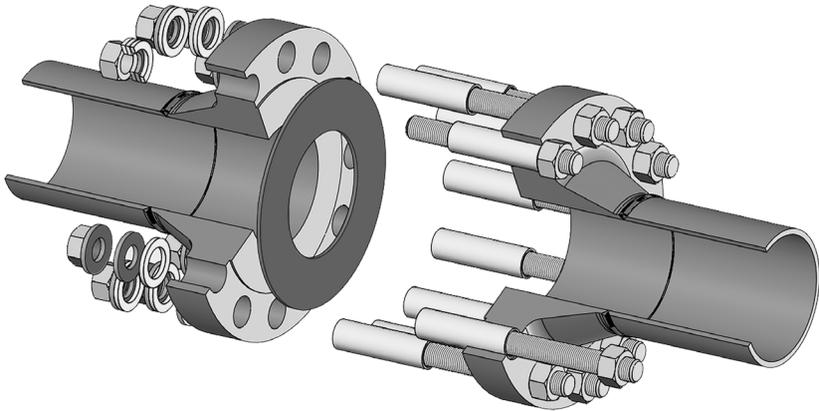


Figure 11.3

Insulation gaskets have traditionally been made from phenolic resin coated with an elastomer or machined as a Ring Joint. Phenolic resin, although having excellent electrical resistance properties, has low mechanical resistance, causing application failures with sometimes-catastrophic leaks.

For class 150 and 300 flange applications gaskets made of Neoprene coated phenolic resin are used. Figure 11.4 shows such a gasket that failed by blow out under test. As can be seen, there was a separation of the elastomer from the phenolic resin core.

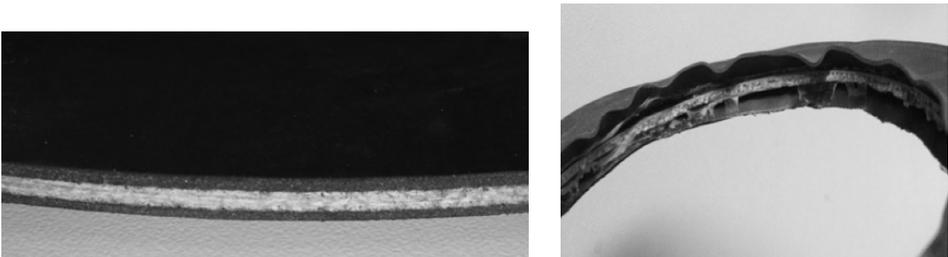


Figure 11.4

For flanges of pressure classes above 300 phenolic resin Ring Joints are often specified. Because they are flanges for high pressure the seating stress is high, often exceeding the maximum for phenolic resin compression stress, resulting in cracks and consequent gasket failure, as shown in Figure 11.5.

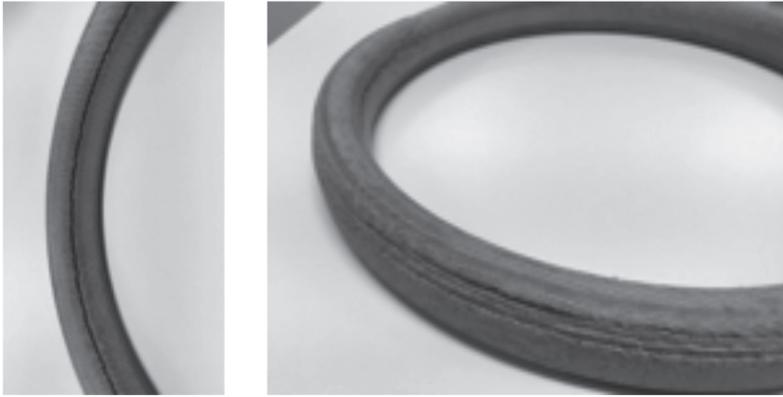


Figure 11.5

To solve the problems of those legacy products Teadit has developed the Electron® gaskets for electrical pipe insulation. As shown below, there are different types that must be selected according to the requirements of the application.

4. INSULATION GASKETS STYLE ELECTRON GS

Electron® GS is an electrical insulating gasket developed from a Compressed Fiber Sheet with a NBR binder, aramid fiber and special filler. The Electron® GS Gasket has been designed to meet sealing and electrical insulation requirements in low-demand applications such as water pipes (sea and waste) and liquid hydrocarbon and non-aggressive chemicals. Electron® GS has superior and more reliable performance than gaskets made from phenolic resin, often used in these applications.

Technical Data	
Flanges Style/Class	FF and RF ASME 150 and 300#
Electrical Resistance	> 100 MΩ (1500 Vcc)
Dielectric Strength	3 kV (60 Hz Vca for 1 minute)
Maximum Seating Stress	140 MPa (20000 psi)
Maximum Temperature	150 °C (302 °F)

Selability	
Standard	DIN 3535-4
Leak rate	1.37E-03 mbar.l/s

Gaskets Constants	
m	3.2
y	3000 psi

The Insulation Kit is supplied with the gasket, fiberglass fabric (G-10) reinforced epoxy resin sleeves and washers and metal washers. In laboratory tests, it was determined that the assembly installation should be as shown in Figure 11.6.

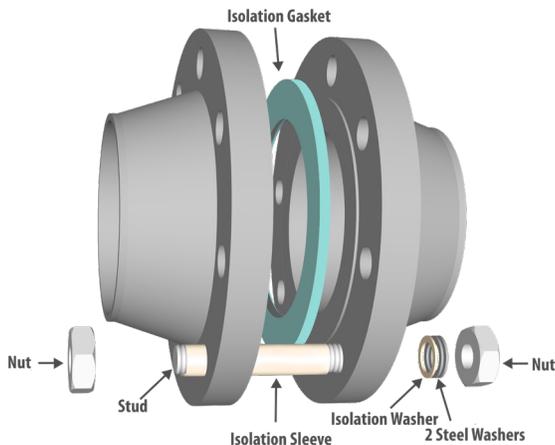


Figure 11.6.

5. INSULATION GASKETS STYLE ELECTRON CS

Electron[®] CS is an electrical insulating gasket developed from Tealon[®] restructured PTFE. The Electron[®] CS gasket has been designed to meet sealing and electrical insulation requirements for chemical aggressive service. The kit is recommended for water pipes (drinking, sea, waste), gases, acids and hydrocarbons in general. Electron[®] CS has superior and more reliable performance than gaskets made from phenolic resin, often recommended in these processes.

Technical Data	
Flanges Style/Class	FF and RF ASME 150 and 300#
Electrical Resistance	> 100 MΩ (1500 Vcc)
Dielectric Strength	4 kV (60 Hz Vca for 1 minute)
Maximum Seating Stress	180 MPa (26000 psi)
Maximum Temperature	180°C (356 °F)

Selability	
Standard	DIN 3535-4
Leak rate	4.11E-05 mbar.l/s

Gasket Constants	
m	2
y	1500 psi

The Insulation Kit is supplied with the gasket, fiberglass fabric (G-10) reinforced epoxy resin sleeves and washers and metal washers. In laboratory tests it was determined that the assembly installation should be as shown in Figure 11.6.

6. INSULATION GASKETS STYLE ELECTRON SCS

Electron® SCS is an electrical insulating and sealing gasket with a 316 stainless steel metal core faced on both sides with restructured Tealon® PTFE (Figure 11.7). The Electron® SCS Gasket is designed to meet the most demanding technical requirements, even when subjected to extreme pressure conditions or exposure to chemically aggressive fluids. It is recommended for water pipes (sea and waste), gases, acids and hydrocarbons in general.

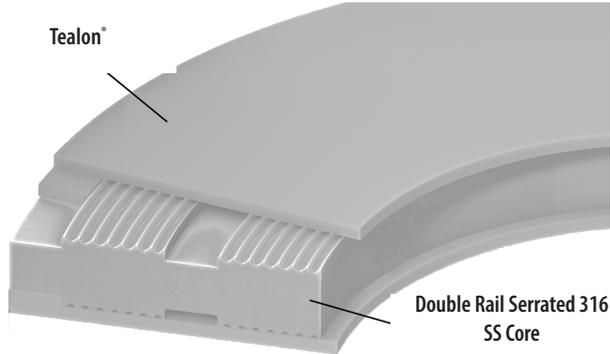


Figure 11.7

Technical Data	
Flanges Style/Class	RF and RTJ ASME 150-2500# and API 6A 2-10K
Electrical Resistance	> 100 MΩ (1500 Vcc)
Dielectric Strength	4 kV (60 Hz Vca for 1 minute)
Water absorption	< 0.1 %
Maximum Seating Stress	350 MPa (50000 psi)
Maximum Temperature	200 °C (392 °F)

Sealability	
Standard	DIN 3535-4
Leak rate	1.83E-08 mbar.l/s

Gasket Constants	
m	2
y	2500 psi

The Insulation Kit is supplied with the gasket, fiberglass fabric (G-10) reinforced epoxy resin sleeves and washers and metal washers. In laboratory tests it was determined that the assembly installation should be as shown in Figure 11.8.

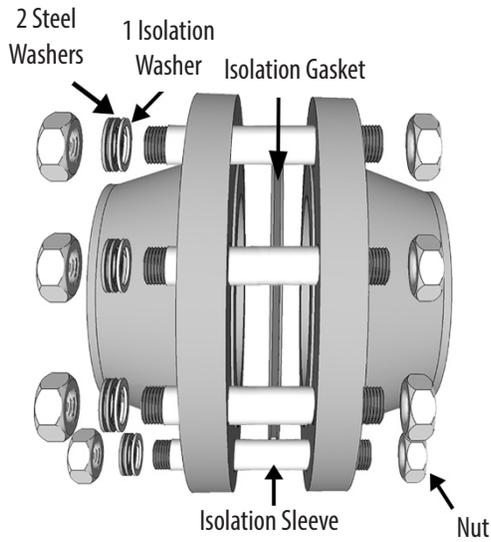


Figure 11.8

7. INSULATION GASKETS STYLE ELECTRON FSS

Electron® FSS is a Fire-Safe proprietary electrical and sealing insulating gasket with a 316 stainless steel metal core faced on both sides with restructured Tealon® PTFE and TerMica mica laminate (Figure 11.9). Its sturdy construction ensures sealing, insulation and fire resistance in process piping, oil production platforms and pipelines. Electron gasket is produced according to the US patent number 9890859 B2 [66].

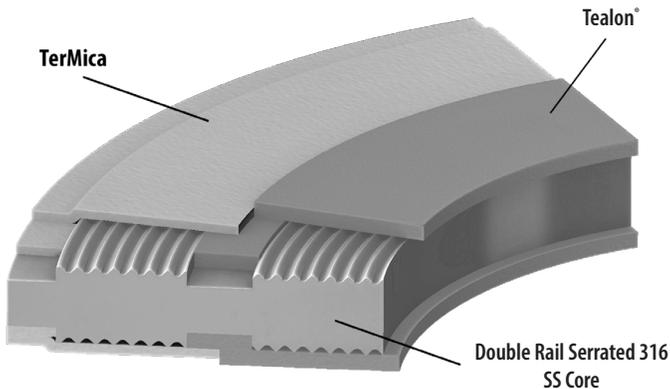


Figure 11.9

The Electron FSS Gasket is designed to meet critical applications even under the most severe pressure and chemical resistance requirements. It is suitable for piping requiring electrical insulation in lines with sea or waste water, chemicals, hydrocarbons and applications requiring fire resistance.

Technical Data	
Flanges Style/Class	RF and RTJ ASME 150-2500# and API 6A 2-10K
Electrical Resistance	> 100 MΩ (1500 Vcc)
Dielectric Strength	5 kV (60 Hz Vca for 1 minute)
Water absorption	< 0.1 %
Maximum Seating Stress	350 MPa (50000 psi)
Maximum Temperature	260 °C (500 °F)

Sealability	
Standard	EN13555
Leak rate	< 1.00E-05 mg/m/s

Gasket Constants	
m	2
y	2500 psi

Fire Safe Certification: The Electron FSS gasket meets the API 6FB specification with no leakage throughout the test procedure.

The Insulation Kit is supplied with the gasket, fiberglass fabric (G-10) reinforced epoxy resin sleeves, TerMica insulation washers and metal washers. In laboratory tests it was determined that the assembly installation should be as shown in Figure 11.10.

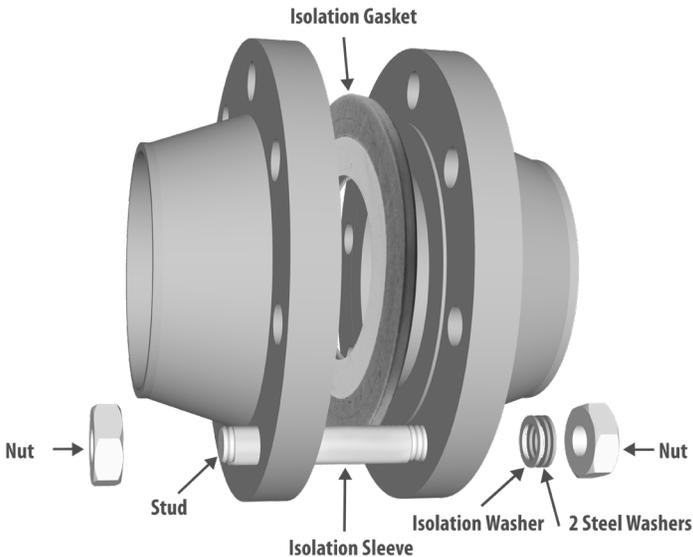


Figure 11.10.

INSTALLATION

1. THE IMPORTANCE OF THE GASKET INSTALLATION

One of the most important points for the proper performance of a gasketed joint is a good installation. Even the best specified gasket might fail if joint assembly procedures are not followed. In practice, it is known that most of the leak problems are due to installation errors. Basics such as lack of bolt and nut lubrication, excessive or insufficient tightening, and gaskets not centered on the flange are major cause of leaks.

The ASME PCC-1 - Guidelines for Pressure Boundary Bolted Flange Joint Assembly [6] was issued with the objective of guiding the installation of gaskets in process piping and pressure vessels. The same document provides guidelines for training and qualification of gasket installation personnel.

2. BOLTS AND STUDS

Bolts and studs used on flanges of process piping and pressure vessels are steel alloy and the material should be selected according to the operating conditions. The selection of these materials is beyond the scope of this book.

In most applications the material of the studs is alloy steel according to ASTM A193-B7 [42] a high yield and tensile strength alloy. Figure 12.1 shows a typical graph of the bolt tightening stress according to the rotation angle of the nut. The usual stress range is between 40% and 75% of the yield strength of the bolt material. In special situations, with very good tightening control, it is possible to use values near the yield strength.

Tightening with values below 40% of the yield strength do not stretch the bolt enough to allow for the gasket relaxation, in this situation there is a risk of losing gasket stress and experiencing high leak rate or even gasket blowout.

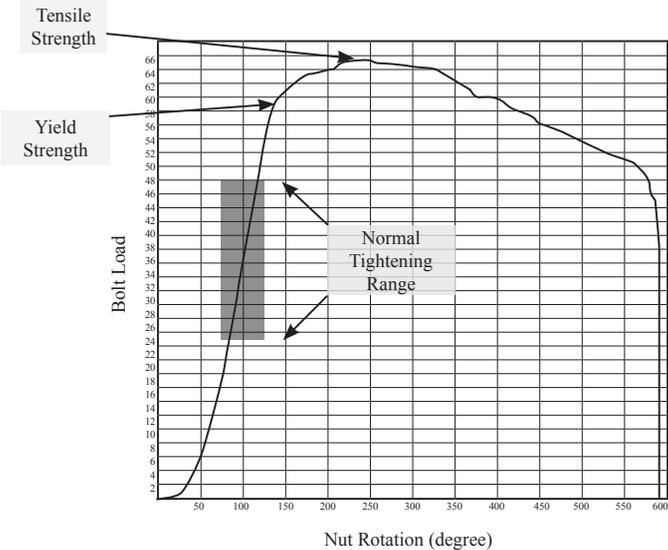


Figure 12.1

The root and stress areas for imperial and metric bolts are shown in Tables 12.1 and 12.2 respectively.

**Table 12.1
Imperial Bolts**

Bolt Size	Threads per inch	Root area (sqin)	Tensile area (sqin)
1/2	13	0.1257	0.1419
5/8	11	0.202	0.226
3/4	10	0.302	0.334
7/8	9	0.419	0.462
1	8	0.551	0.606
1 1/8	8	0.728	0.790
1 1/4	8	0.929	1.000
1 3/8	8	1.155	1.233
1 1/2	8	1.405	1.492
1 5/8	8	1.68	1.78
1 3/4	8	1.98	2.08
1 7/8	8	2.30	2.41
2	8	2.65	2.77
2 1/4	8	3.42	3.56
2 1/2	8	4.29	4.44
2 3/4	8	5.26	5.43
3	8	6.32	6.51
3 1/4	8	7.49	7.69
3 1/2	8	8.75	8.96
3 3/4	8	10.11	10.34
4	8	11.57	11.81

Table 12.2
Metric Bolts

Bolt Size	Root Area (sqmm)	Tensile area (sqmm)
M12 x 1.75	72	84
M14 x 2	100	115
M16 x 2	138	157
M20 x 2.5	217	245
M22 x 2.5	272	303
M24 x 3	313	353
M27 x 3	414	459
M30 x 3.5	503	561
M33 x 3.5	629	694
M36 x 4	738	817
M39 x 4	890	976
M42 x 4.5	1018	1121
M45 x 4.5	1195	1306
M48 x 5	1343	1473
M52 x 5	1615	1 758
M56 x 5.5	1863	2030
M64 x 6	2467	2676
M72 x 6	3 222	3460
M80 x 6	4077	4344
M90 x 6	5287	5591
M100 x 6	6652	6995

3. NUTS

Just like the bolt, the nut material should be appropriate for the operating conditions. The most widely used material for nuts is ASTM A194 2H [43].

4. WASHERS

If the tightening is done with a torque wrench, it is recommended to use hardened washers to reduce friction between the nut and the flange surface. The graph in Figure 12.2 shows the reduction in the tightening force when washers are not used or when they are not made of hardened steel. The ASME PCC-1 Appendix M provides recommendation for washer sizes and materials.

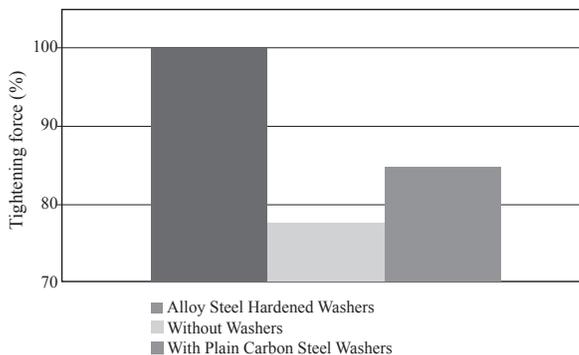


Figure 12.2

5. FRICTION AND LUBRICANTS

5.1. FRICTION FACTOR

The friction force is primarily responsible for maintaining the clamping force of a bolt. Imagining a screw thread “unwound”, we can represent it by an inclined plane. When applying a torque, the effect produced is similar to pushing a body over an inclined plane subject to the forces shown in Figure 12.3.

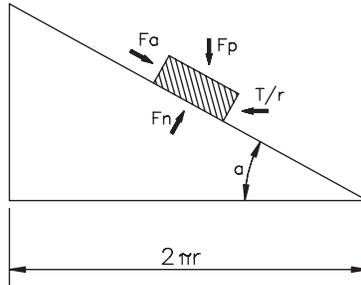


Figure 12.3

Where:

a = the angle of inclination of the thread

d = bolt diameter

r = bolt radius

F_p = bolt clamping force

F_a = friction force

F_n = force perpendicular to the thread

k = friction factor

T = torque applied to the bolt

u = coefficient of friction

The Friction Force F_a is:

$$F_a = uF_n = uF_p \cos a \quad (\text{Equation 12.1})$$

Making the balance of forces acting on the direction parallel to the inclined plane, we have:

$$(T/r) \cos a = F_a + F_p \sin a \quad (\text{Equation 12.2})$$

In the direction perpendicular to the inclined plane, we have:

$$F_n = F_p \cos a + (T / r) \sin a \quad (\text{Equation 12.3})$$

As the angle of the thread is too small, for ease of calculation, we can disregard the $(T/r)\sin a$ in Equation 12.3. Substituting the value of F_a into equation 12.2, we have:

$$(T/r) \cos a = uF_p \cos a + F_p \sin a \quad (\text{Equation 12.4})$$

calculating the value of T , we have:

$$T = F_p r (u + \tan a) \quad (\text{Equation 12.5})$$

Since the coefficient of friction is constant for a given lubrication condition, as is also $\tan a$ constant for each thread angle and substituting r for d , we have:

$$T = k F_p d \quad (\text{Equation 12.6})$$

where k is an experimental factor.

5.2 THE VALUE OF THE NUT FACTOR - k

The nut factor, k , is determined experimentally according the combination of bolt/nut materials and the lubricant to be used for the specific application. Experiments have shown that the k factor is approximately equal to the friction coefficient of the lubricant plus 0.04. For industrial applications with ASTM SA-193 steel bolts k ranges from 0.16 to 0.23.

Since a small variation in the nut factor, k , results in a large change in bolt load. Many studies regarding the use a complete formula as shown in PCC-1 Appendix J or a simplified formula as shown in PCC-1 Appendix K, the precision that can be achieved with torque tools as well as the value of the nut factor have been presented in ASME PVP Conferences [68 through 74]. Due to the large variations in the friction coefficient and torque tool precision it is generally recognized that the use of the complete formula does not improve the accuracy of the actual bolt force. In critical applications it is recommended to determine the most approximate nut factor, k , with tests with the same lubricant, bolts and nuts that will be installed.

6. TIGHTENING TOOLS

The most accurate method of achieving the tension on a bolt, is measuring its elongation. However, in practice, this procedure is costly and difficult. The current trend is to use torque wrenches, tensioning devices or hydraulic tools. Tightening using hand tools without torque control should only be used in mild non-critical service.

The choice of the tool and how it is used depends on several conditions; each tool has advantages and disadvantages that must be analyzed according to the particular circumstances of each case. Among the various alternatives for controlled torque application there are:

- **Manual Torque Wrench with an analog or digital display:** used for small diameter bolts up to 1 in. Due to its ease of use and accuracy, it is a very convenient and fast way to install gaskets.

- **Hydraulic Torque Wrench:** is undoubtedly the most used tool for larger diameter bolts. This type of equipment requires trained operators. The use of hydraulic torque wrenches is slower than manual ones. Figure 12.5 shows a hydraulic torque wrench manufactured by Hytorc Corp.



Figure 12.5

- **Pneumatic Torque Wrenches:** a relatively recent development they are faster than hydraulic torque wrenches with similar accuracy. The pneumatic torque wrenches should not be confused with pneumatic impact wrenches, which lack the precision required for gasket installation. Figure 12.6 shows a pneumatic torque wrench manufactured by Hytorc Corp.



Figure 12.6

• **Hydraulic Tensioner:** equipment that allows gasket installation by stretching the bolt, eliminating the uncertainty caused by the friction. The bolt or stud is hydraulically stretched and the nut turned effortlessly. However, when used in pairs or a bolt at a time, the elastic interaction reduces the accuracy of the applied load. To use hydraulic tensioners the bolts must be previously prepared. The use of tensioners is slower and more complex than torque wrenches. Figure 12.7 shows a hydraulic tensioner.

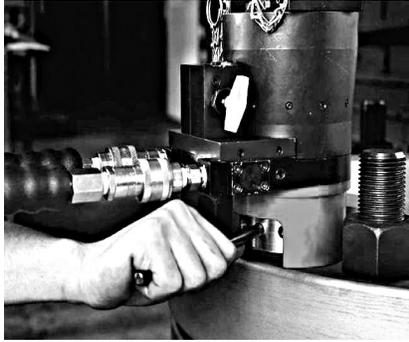


Figure 12.7

Hydraulic torque wrenches or tensioners have to be used when the simultaneous tightening of several or even all bolts is necessary. Various tools are installed with a single hydraulic supply line so that when activated, the hydraulic pump feeds all tools with the same pressure; the same tightening is then applied to all bolts. At least two tools as shown in Figure 12.8 should be used for this kind of installation.



Figure 12.8

Figure 12.9 shows the use of four Hytorc hydraulic tools simultaneously. The numbering of the flange studs shows that only 6 passes are required for each complete turn. When this technique is used there is a large reduction in the installation time. In addition to this advantage, the method also prevents warping and uneven gasket stress.

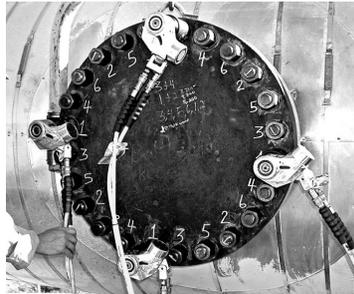


Figure 12.9

7. BOLT LOAD CALCULATION

To calculate the gasket installation torque we must initially determine the values of the bolt forces as shown before. Taking the example of Section 9 of Chapter 2, we have:

- bolt installation stress: $Sb_{sel} = 63,450$ psi
- bolt diameter: $1 \frac{1}{8}$ inches
- Determine the bolt stress area from Table 12.1: $A_b = 0.7276$ sqin
- the bolt force is:

$$F_p = A_b \times Sb_{sel} = 0.7276 \times 63,450$$

$$F_p = 46,166 \text{ lb}$$

- the above F_p value is used to set a hydraulic tensioner force or calculate the torque for a wrench.
- by equation 12.6 we have: $T = k F_p d$

where:

T = torque to be applied
 k = friction factor
 F_p = bolt force
 d = bolt diameter

- considering the Friction Factor $k = 0.20$ we have:

$$T = 0.2 \times 46,166 \times 1.125/12$$

$$T = 856.6 \text{ lb-ft}$$

8. SOFT AND HARD GASKETS

The flatness tolerance of the flange sealing surface depends on the gasket's ability to absorb irregularities. PCC-1 classifies gaskets into two groups:

- **Soft gaskets:** Those with greater capacity to compensate flange sealing surface irregularities. Examples: Spiral Wound gaskets and Non-Metallic gaskets like Compressed Fiber, PTFE or Flexible Graphite greater than 1/16 in thick.

- **Hard Gaskets:** Those with less capacity to compensate flange sealing surface irregularities. Examples: Camprofile, Double Jacketed, Ring-Joints and Non-Metallic gaskets like Compressed Fiber, PTFE or Flexible Graphite less than 1/16 in thick.

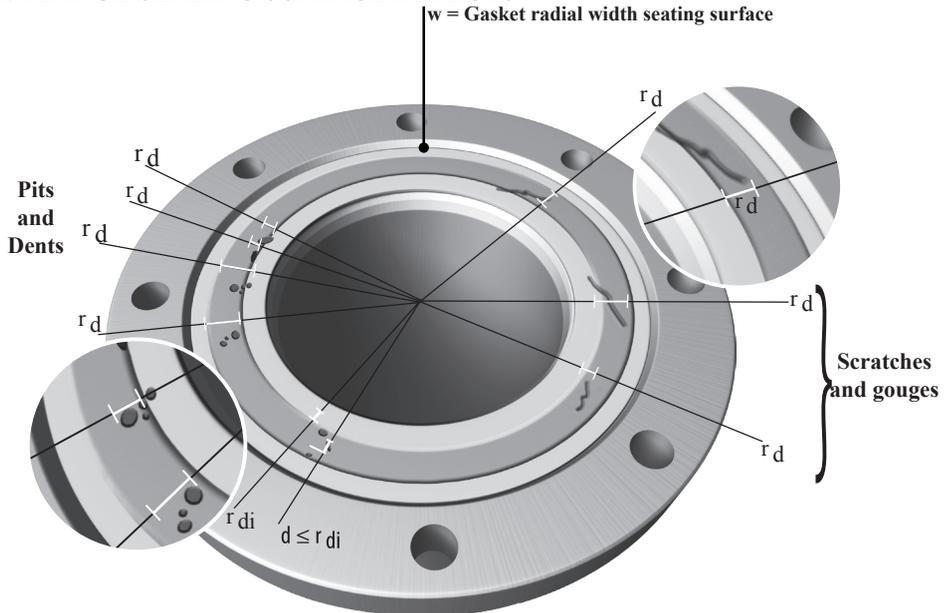
8.1. FLANGE SEALING SURFACE FLATNESS

The flatness tolerance of the flange sealing surface recommended by ASME PCC-1 is shown in Table 12.3.

Table 12.3

Flatness tolerance of the flange sealing surface – T - inches		
Dimensions	Hard Gaskets	Soft Gaskets
Maximum circumferential deviation	$T < 0.006$	$T < 0.01$
Maximum radial deviation	$T < 0.006$	$T < 0.01$

8.2. FLANGE SEALING SURFACE DEFECTS



d = Radial distance between defects

r_d = Projected Radial distance across seating surface

Figure 12.10

Table 12.4

Sealing surface width x maximum allowed defect depth - inches		
Feature	Hard Gasket	Soft Gasket
$rd < w / 4$	< 0.030	< 0.050
$w/4 < rd < w/2$	< 0.010	< 0.030
$w/4 < rd < 3w/4$	Not allowed	< 0.005
$Rd > 3w/4$	Not allowed	Not allowed

8.3. FLANGE ALIGNMENT

Flanges must be aligned as shown in Figure 12.11 to 12.14.

8.3.1. CENTERLINE

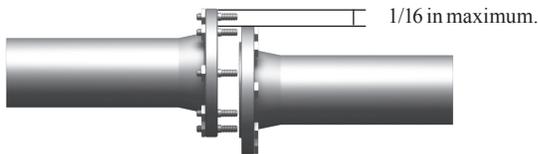


Figure 12.11

8.3.2. PARALLELISM

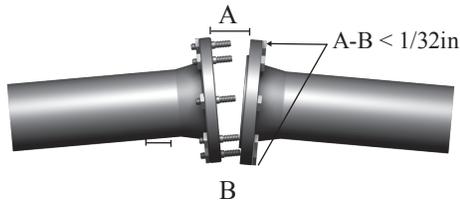


Figure 12.12

8.3.3. FLANGE GAP

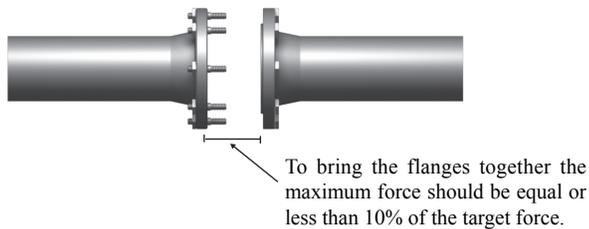


Figure 12.13

8.3.4 BOLT HOLE ALIGNMENT

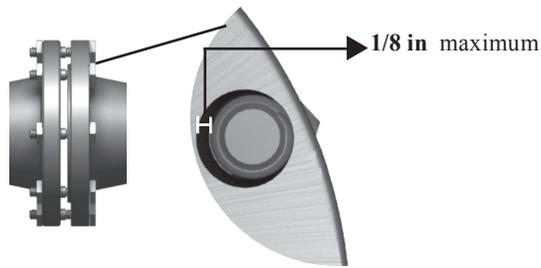


Figure 12.14

9. INSTALLATION PROCEDURE

9.1. GASKET INSTALLATION

To obtain a satisfactory seal, it is necessary that basic procedures be followed during the gasket installation. These procedures are of fundamental importance for a successful operation no matter what style of gasket is used.

a) Inspect the flange-sealing surface. Check for tool marks, dents, scratches or corrosion. Radial tool marks on the sealing surface are difficult to seal regardless of the style of gasket. Be sure that the flange finish is adequate for the style of gasket to be installed.

b) Inspect the gasket. Verify that the gasket material is compatible with the intended service. Check for defects and shipping or storage damage.

c) Inspect and clean bolts, nuts, and washers.

d) Lubricate bolt threads and the nut contact surfaces. Do not install bolts and nuts without lubrication. The lubricant should be compatible with the service temperature. A good lubricant will provide a better application of the torque and, consequently, higher precision of the Bolt Load. There are applications where bolts cannot be lubricated, for these situations the Friction Factor, k , must be previously determined.

e) For Raised Face or Flat Faced flanges installed vertically, start installation with bolts on the lower part. Install the gasket then the other bolts.

f) For Male and Female or Tongue and Groove flanges, the gasket should be installed in the center of the groove.

g) Do not use adhesive or other fixing agents on the gasket or face flanges. If absolutely necessary we recommend using 3M Super 77 spray adhesive. For Non Metallic gaskets such application should be made only on one side of the gasket and using as minimal adhesive as possible.

h) Install the bolts and hand-tighten them. Select the tightening procedure and number the bolts to facilitate the tightening order as shown in Annexes 12.19 to 12.22.

9.2 LUBRICATION

a) Use only a lubricant compatible with the application and a known friction factor (k). This factor should be used in calculating the torque as shown in Section 7 of this Chapter.

b) Apply plenty of lubricant evenly on the surfaces of the nut and on the threads of bolts and nuts.

c) Ensure that the lubricant does not contaminate the gasket or the flange sealing surfaces.

d) There are applications where due to the process it is not possible to use lubricants. For these cases the friction factor must be determined in tests with bolts and nuts of the same material and size of the application.

9.3. BOLT NUMBERING AND INSTALLATION

To help the installation and avoid errors it is recommended to number bolts following the selected tightening sequence method. The Star or Legacy tightening pattern sequence is the best-known and applied method of installing gaskets. Examples can be found in Annex 12.19 of this method for a 24-bolt flange using a single tool, and in Annex

12.20 the same example with simultaneous tightening using two tools.

The Star or Legacy pattern despite offering good results requires great effort and time for large flange sizes. Several studies have been undertaken to improve the efficiency of the gasket installation without reducing its quality.

The most comprehensive study was conducted in Japan, which resulted in the Standard Bolt Tightening Guidelines for Pressure Boundary Flanged Joint Assembly, HPIS Z103 TR [45]. Teadit has successfully used this method, which in the PCC-1 is called Alternative Assembly Pattern 3. For this pattern 4 or 8 bolts are used to make initial tightening reducing considerably installation time without any prejudice to the quality. Annexes 12.21 through 12.22 show examples of this method with one and two tools. PCC-1 also suggests other methods and a methodology for developing sequences more adequate for specific situations.

Installation sequence:

1. Number the studs of flange holes following the sequence of the chosen tightening method.
2. Install each stud with their respective nuts and washers, and hand tighten the nuts in a star pattern sequence. In case it is not possible to obtain parallelism between the flange faces, a hand tool can be used to tighten until the gasket lightly touches the flange face. The stud length should be such that at least two threads protrude beyond the nut. Important: The maximum force for this installation step must not exceed 10% of the final tightening. Washers must be hardened to reduce friction with the nuts during tightening. The hardness of the washers must be between 38 to 45 HRC.
3. Apply the torque or tension according to the sequence of the chosen method.
4. Adjust the tool to obtain the desired torque required at each tightening step.
5. Always tighten the nuts in multiple steps. After each step, measure the dis-

tance between the flange faces at 4 diagonal points to ensure that they are always parallel.

10. START-UP RETORQUE

A retorque as the system is started-up is recommended to avoid leakage in operation for problematic flanged joints especially in heat exchangers that operate with thermal cycling. ASME PCC-1 [6] suggests a procedure to perform the start-up retorque when the temperature of the flanges or studs is between 300F (150C) and 450F (230C) or within 24 hours of unit start-up when the process temperature is below 300F (150C).

The start-up retorque is not the same as live tightening or hot torque which is covered in ASME PCC-2- Repair of Pressure Equipment and Piping [47].

11. BOLT SCATTER

When we tighten a bolt the others that are near loosen up, this is known as bolt scatter. In Figure 12.15 we can see that when tightening the bolt B, forces acting on its neighbors A and C are reduced, making it necessary to retighten them.

To reduce dispersion, it is necessary that the 5th step of the installation procedure

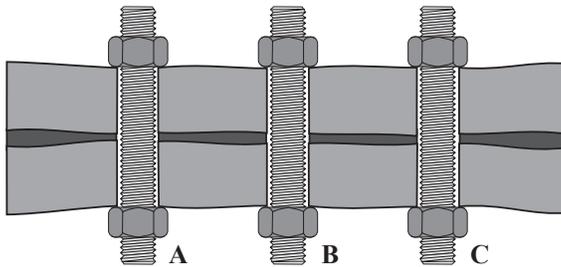


Figure 12.15

is performed. Many gasket installers, in a rush to complete the installation, stop at the 4th step, resulting in various bolts with insufficient load to provide a satisfactory seal.

12. TROUBLESHOOTING

One of the most efficient ways of determining the causes of a leak is a careful analysis of the gasket that was installed. The following are some examples of field application failures and their causes.

12.1. LOW BOLT LOAD

Insufficient load to seat the gasket and maintain the seal is a major cause of leaks or catastrophic failure. Figures 12.16 and 12.17 are typical of insufficient bolt load. The causes may be torque applied without control, lack of bolt lubrication or the use of incor-



Figure 12.16



Figure 12.17

The example in Figure 12.18 illustrates a frequent problem, in the piping or equipment design, not enough space is provided for the tool to tighten the studs properly. In this example, which occurred during a hydrostatic test of an expansion joint, it was not possible to correctly tighten the studs in the hinge region causing the “blow-out” of the Flexible Graphite facing of a Double Jacketed (Style 927) gasket.



Figure 12.18

12.2. EXCESSIVE BOLT LOAD

Excessive tightening can also be a great source of leaks. The small diameter or high-pressure flanges can provide very high seating stress, crushing the gasket when they are installed without bolt load control. Figure 12.19 shows a crushed gasket.



Figure 12.19

12.3. CHEMICAL ATTACK

The gasket material must be chemically compatible with the product to be sealed. Figure 12.20 shows a gasket damaged by chemical attack.



Figure 12.20

12.4. FLEXIBLE GRAPHITE OXIDATION

The oxidation of the Flexible Graphite when in contact with oxygen, including the air, is very common in high temperature process applications. Figure 12.21 shows a Flexible Graphite filled Spiral Wound gasket that was fully oxidized leaving only the stainless steel windings. To avoid this problem it is recommended to use high temperature Flexible Graphite or oxidation resistant filler. Another alternative is to avoid the Oxygen contact with the Flexible Graphite.



Figure 12.21

12.5. GASKET INSTALLED OFF-CENTER

Especially with non-metallic gaskets care is required to install it centered on the flange. Figure 12.22 shows a piece of a gasket that has suffered catastrophic failure due to an off-center installation. It can be clearly seen that the flange serrations are not concentric with the gasket.

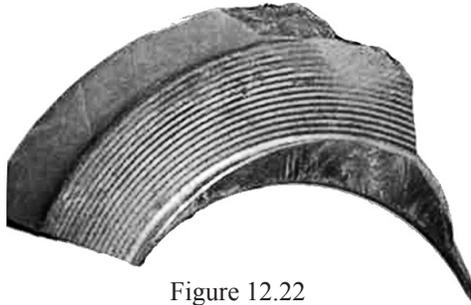


Figure 12.22

12.6. FLANGE SEALING SURFACE FINISH

As shown in Chapter 2, there is an adequate flange finishing for each type of gasket. Figure 12.23 shows a gasket that failed in a steam line. It can be clearly seen that the flange has three lugs with no serrations or roughness as recommended for this type of gasket.



Figure 12.23

Figure 12.24 shows the damage caused to the organic coating of a heat exchanger. In this example, a double jacketed gasket (Style 923) was installed. The minimum seating stress for this gasket style is higher than the coating maximum stress damaging it.



Figure 12.24

12.7. USE OF ADHESIVES

Adhesives should not be used to install gaskets; they can be detrimental to the proper gasket seating. Figure 12.25 shows a laboratory experiment where Compressed Fiber gaskets were installed using several products often used to hold the gasket in place.

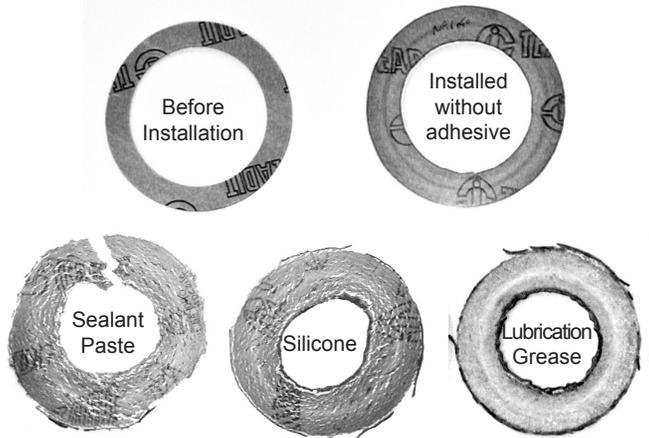


Figure 12.25

Figure 12.26 shows the use of a tape to hold the gasket in place. As can be seen, there is a clear discontinuity on the gasket sealing surface.

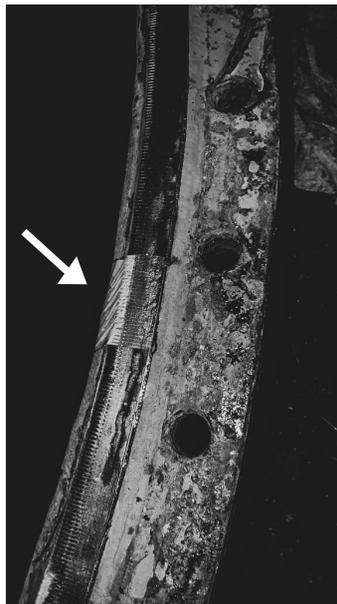


Figure 12.26

12.8 FLANGE DESIGN

Figure 12.27 illustrates the oversizing of the stud diameter, which even with a very low load, was higher than the maximum allowable by the gasket, damaging it. The solution was to change the gasket to Camprofile, which has a higher maximum seating stress.



Figure 12.27

Figure 12.28 shows a failure caused by improper design of one of the flanges causing it to rotate. In the picture on the left it is possible to observe that the lower flange is thinner than the upper one. The picture on the right shows that the region close to the inner diameter shows no gasket seating, which is concentrated on the outer side due to the rotation of the flange.



Figure 12.28

12.9. SPIRAL WOUND GASKETS INWARD BUCKLING

Spiral Wound gaskets without an inner ring can inward buckle with high seating stress, which is common in smaller sizes or high-pressure class flanges. It is recommended the use of inner rings whenever possible. Figure 12.29 shows a typical inward buckled spiral wound gasket.

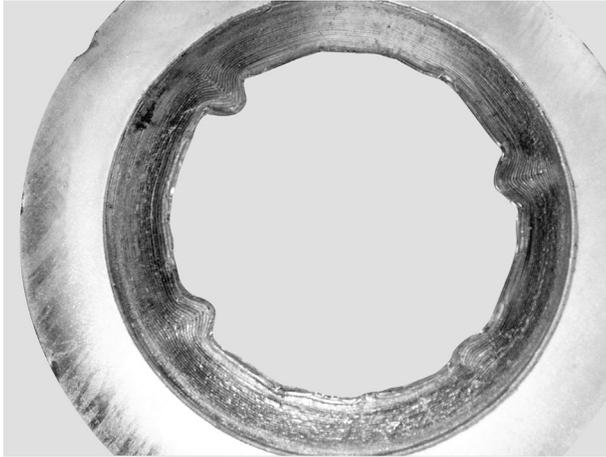


Figure 12.29

12.10. BOLTS MISSING

A very common problem in the field is a gasket installed with bolts missing. Figure 12.30 shows a flange and gasket remains after a blowout accident that caused a fire and sank an oil tanker ship.

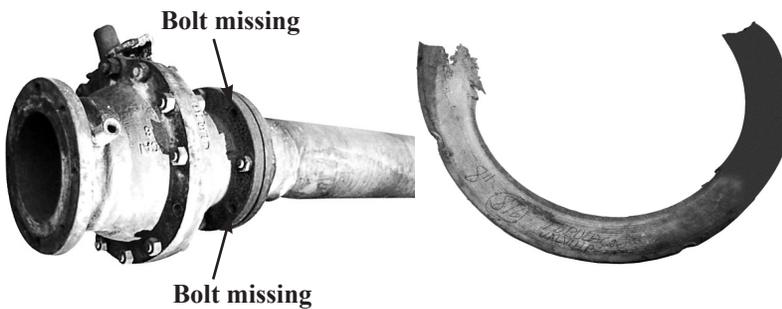


Figure 12.30

12.11. DAMAGED OR SHORT STUDS

Figure 12.31 shows an example of carelessness in the installation, two studs are short and have been cut diagonally.



Figure 12.31

12.12. MULTIPLE CAUSES

The various examples shown before can be combined as shown in Figure 12.32. In this case, a steam line, the gasket is installed out of center, different studs, and one of them too short, and all installed without lubrication.

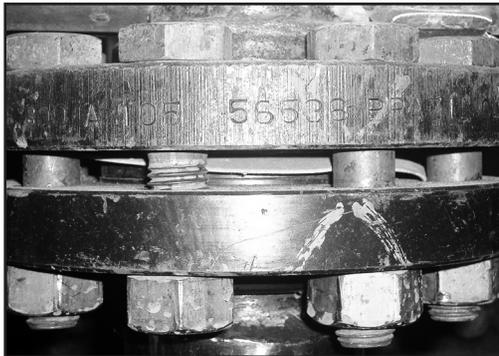


Figure 12.32

13. LIVE LOADING

Just after the gasket seats, the process of Stress Relaxation starts, which is the loss of the bolt load. The Relaxation process is a characteristic of flanged joints and occurs with any kind of gasket.

The relaxation is due to several factors as follows:

- Gasket Relaxation: gaskets are designed to, when seated, fill up the flange irregularities. As this plastic deformation occurs the flanges get closer, reducing the bolt load. The amount of this deformation depends upon the gasket style and the operating temperature.

- **Bolt Thread Relaxation:** when tightened there is a contact between its parts. There are microscopic points where the stress is higher than the Yield Stress for their materials. With time, the material flows at these points, reducing the stress. Studies have shown a reduction of 5% to 10% of the initial stress.

- **Relaxation with temperature:** bolts have the tendency to relax with temperature and time. The amount of the relaxation depends upon the temperature and the time.

- **Vibration:** under vibration bolts tend to relax. The total loss of the tightening can occur at severe vibration condition.

- **Cross Tightening:** normally the tightening follows the cross pattern procedure. When one bolt is tightened the nearest ones lose stress. If simultaneous hydraulic tools are used to install the gasket this problem is reduced.

- **Thermal Expansion:** when the temperature changes from room to operating, there are several thermal expansions. As the flanges and the gaskets are closer to the heat source than the bolts, there are thermal and consequently expansion gradients. The same problem occurs when the system is turned off. These thermal changes relax the flanged joint.

- **Thermal Cycle:** when the system operates with thermal cycling service or is frequently turned off, the relaxation due to the thermal changes is greater.

To compensate for the loss of stress due to the relaxation, the system elasticity has to be increased. This can be achieved with longer bolts and sleeves or with spring washers, as shown in Figure 12.33.

The use of longer bolts and sleeves is not recommended since to be effective it is necessary to have very long bolts, which is not always possible.

The most common system is the use of spring washers, also known as Live Loading.

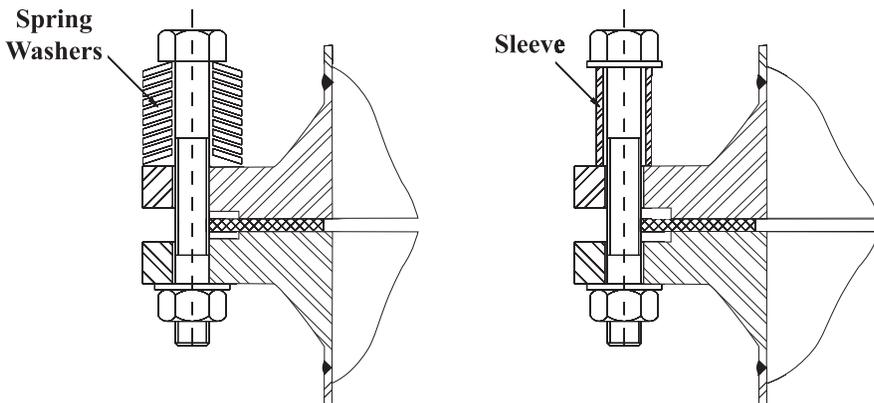


Figure 12.33

To compensate for the relaxation, Teadit has developed the Live Loading System of spring washers specially designed for use in flange applications, as shown in Figure 12.34.

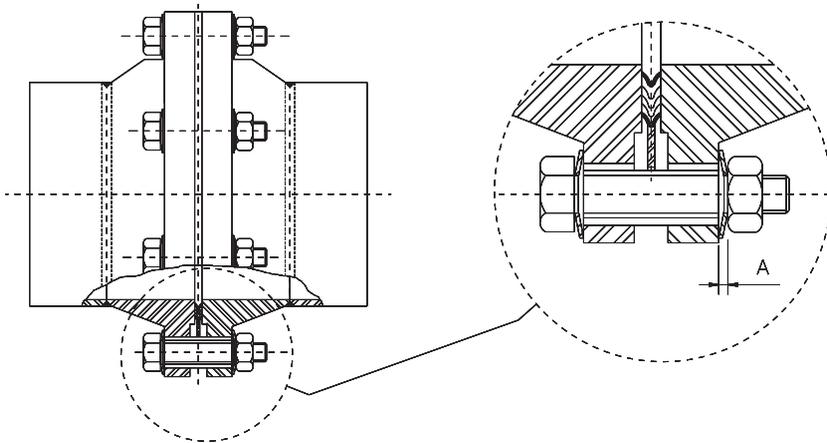


Figure 12.34

Before deciding to use a Live Loading System, it is necessary to study the need for it. It increases installation costs and should be used only when needed.

The Live Loading System does not solve sealing problems, however, as it maintains the Bolt Load, it reduces problems in critical applications.

Live Loading is recommended for the following conditions:

- Products that can cause extensive environmental damage or loss of lives.
- Systems with thermal cycling or operating temperature fluctuations.
- When the ratio of the bolt length to its diameter is less than three.
- Systems with vibrations.
- When the gasket or flange materials have a high tendency to relaxation.
- When there is a history of system leakage.

The Teadit Live Loading System is available for three levels of bolt stress as shown in Table 12.5. When tightened with the torque shown the bolt achieves the stress level of 60 000 psi (414 MPa), 45 000 psi (310 MPa) or 30 000 psi (207 MPa). The Bolt Load at this stress level is also shown.

The Spring Washers are manufactured with alloy steel ASTM A681 type H13, oil finish for use with carbon steel bolts. The recommended temperature is from room to 1100F (590C).

For corrosive applications the Spring Washers can also be manufactured with Stainless Steel ASTM A693 type 17-P7 for temperatures of – 400F (–240C) to 550F (290C). They can also be manufactured with Inconel 718 (ASTM B637) for temperatures – 400F (–240C) to 1100F (590C).

The gaskets are installed as shown in Figure 12.28, with one spring on each side of the flange. When the target torque is achieved the spring will be flat. The spring must have its higher side towards the bolt as indicated; if it is not installed in this way the bolt load can be lower than indicated.

For equipment such as Heat Exchangers that operate in thermal cycling service, more than one spring on each side may be needed. Please consult with Teadit for these applications.

Table 12.5
Teadit Live Loading System

Bolt Nominal Diameter inches	Teadit Part Number	A - mm		Torque N-m	Force N
		Free	Seated		
1/2	ACX00008060	6.7	4.1	80	37830
	ACX00008045	3.9	3.6	60	28390
	ACX00008030	3.4	3.0	40	18960
5/8	ACX00010060	5.4	5.1	160	60360
	ACX00010045	4.7	4.4	120	45300
	ACX00010030	4.0	3.6	80	30230
3/4	ACX00012060	6.5	6.2	270	89160
	ACX00012045	5.7	5.4	200	66900
	ACX00012030	4.8	4.4	140	44630
7/8	ACX00014060	7.6	7.2	430	123300
	ACX00014045	6.7	6.3	330	92500
	ACX00014030	5.7	5.2	220	61700
1	ACX00016060	8.7	8.3	660	161700
	ACX00016045	7.7	7.2	500	121300
	ACX00016030	6.5	5.9	330	80900
1 1/8	ACX00018060	9.9	9.4	960	210760
	ACX00018045	8.7	8.2	720	158100
	ACX00018030	7.4	6.8	480	105430
1 1/4	ACX00020060	11.3	10.7	1360	266760
	ACX00020045	10.2	9.6	1020	200100
	ACX00020030	8.4	7.6	680	133430
1 3/8	ACX00022060	12.4	11.8	1840	328900
	ACX00022045	10.9	10.3	1380	246700
	ACX00022030	9.2	8.4	920	164500
1 1/2	ACX00024060	13.5	13.0	2170	397960
	ACX00024045	11.9	11.3	1630	298500
	ACX00024030	10.1	9.2	1080	199030
1 5/8	ACX00026060	14.9	14.2	2980	474760
	ACX00026045	13.1	12.4	2240	356100
	ACX00026030	11.0	10.2	1490	237430
1 3/4	ACX00028060	16.1	15.4	4070	554760
	ACX00028045	14.1	13.4	3050	416100
	ACX00028060	11.9	11.0	2030	277430
1 7/8	ACX00030060	15.6	14.8	5420	508870
	ACX00030045	15.2	14.4	4070	482100
	ACX00030030	12.8	11.8	2710	321430
2	ACX00032060	16.7	15.8	5970	584870
	ACX00032045	16.3	15.4	4470	554100
	ACX00032030	13.7	12.6	2980	371210
2 1/4	ACX00036060	18.8	17.9	8620	751650
	ACX00036045	18.4	17.4	6470	712100
	ACX00036060	15.5	14.3	4310	474760
2 1/2	ACX00040060	21.0	20.0	11930	937430
	ACX00040045	20.5	19.5	8950	88100
	ACX00040030	17.3	16.0	5970	592100
2 3/4	ACX00044060	18.7	17.5	16060	1146430
	ACX00044045	22.7	21.5	11930	1086100
	ACX00036030	19.1	17.7	8030	724100
3	ACX00048060	25.5	24.2	20940	1374430
	ACX00048045	24.8	23.5	15700	1302100
	ACX00048030	20.9	19.3	10470	868100

ANNEX 12.1**Suggested Torque Values for Use with Teadit Spiral Wound Gaskets style 913M
(with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges****Class 150**

Nominal Pipe Size	Torque FT. LB.
1/2	28
3/4	43
1	50
1 1/4	57
1 1/2	57
2	122
2 1/2	122
3	122
3 1/2	122
4	122
5	202
6	202
8	202
10	325
12	325
14	506
16	506
18	723
20	723
24	1012

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.2

Suggested Torque Values for Use with Teadit Spiral Wound Gaskets style 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

Class 300

Nominal Pipe Size	Torque FT. LB.
1/2	28
3/4	43
1	72
1 1/4	101
1 1/2	151
2	108
2 1/2	144
3	173
3 1/2	202
4	202
5	202
6	202
8	325
10	506
12	723
14	614
16	867
18	1012
20	1012
24	1410

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.3**Suggested Torque Values for Use with Teadit Spiral Wound Gaskets style 913M
(with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges****Class 400**

Nominal Pipe Size	Torque FT. LB.
1/2	No flanges
3/4	No flanges
1	No flanges
1 1/4	No flanges
1 1/2	No flanges
2	No flanges
2 1/2	No flanges
3	No flanges
3 1/2	No flanges
4	325
5	325
6	325
8	506
10	614
12	867
14	867
16	1193
18	1193
20	1410
24	2603

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.4

Suggested Torque Values for Use with Teadit Spiral Wound Gaskets style 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

Class 600

Nominal Pipe Size	Torque FT. LB.
1/2	28
3/4	57
1	86
1 1/4	86
1 1/2	159
2	86
2 1/2	122
3	180
3 1/2	300
4	296
5	448
6	448
8	614
10	867
12	867
14	1193
16	1410
18	1880
20	1880
24	3471

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.5**Suggested Torque Values for Use with Teadit Spiral Wound Gaskets style 913M
(with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges****Class 900**

Nominal Pipe Size	Torque FT. LB.
1/2	No Flanges
3/4	No Flanges
1	No Flanges
1 1/4	No Flanges
1 1/2	No Flanges
2	No Flanges
2 1/2	No Flanges
3	265
4	500
5	840
6	590
8	950
10	950
12	1130
14	1330
16	1830
18	3000
20	3000
24	5000

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.6

Suggested Torque Values for Use with Tedit Spiral Wound Gaskets style 913M (with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges

Class 1500

Nominal Pipe Size	Torque FT. LB.
1/2	80
3/4	100
1	160
1 1/4	200
1 1/2	275
2	200
2 1/2	300
3	400
4	650
5	1000
6	900
8	1400
10	2400
12	2500
14	3200
16	4500
18	6000
20	7730
24	12750

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.7**Suggested Torque Values for Use with Teadit Spiral Wound Gaskets style 913M
(with inner & outer rings)/Standard ASME B16.5 Raised Face Pipe Flanges****Class 2500**

Nominal Pipe Size	Torque FT. LB.
1/2	85
3/4	85
1	125
1 1/4	220
1 1/2	320
2	220
2 1/2	320
3	450
4	750
5	1300
6	2000
8	2000
10	3500
12	5000

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.8
Suggested Torque Values for Use with Teadit 905 Metalbest Gaskets / Standard
ASME B16.5 Raised Face Pipe Flanges

Class 150

Nominal Pipe Size	Torque FT. LB.
1/2	60
3/4	60
1	60
1 1/4	60
1 1/2	80
2	120
2 1/2	120
3	160
3 1/2	120
4	115
5	230
6	260
8	260
10	420
12	420
14	650
16	405
18	650
20	595
24	835

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.9
Suggested Torque Values for Use with Teadit 905 Metalbest Gaskets / Standard
ASME B16.5 Raised Face Pipe Flanges

Class 300

Nominal Pipe Size	Torque FT. LB.
1/2	60
3/4	120
1	120
1 1/4	120
1 1/2	200
2	90
2 1/2	130
3	160
3 1/2	200
4	200
5	260
6	210
8	320
10	500
12	710
14	535
16	835
18	835
20	835
24	1300

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.10
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 150

Nominal Pipe Size	Torque FT. LB.
1/2	40
3/4	60
1	60
1 1/4	60
1 1/2	60
2	120
2 1/2	120
3	125
3 1/2	120
4	115
5	200
6	200
8	225
10	320
12	320
14	500
16	405
18	650
20	595
24	835

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.11
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 300

Nominal Pipe Size	Torque FT. LB.
1/2	40
3/4	65
1	90
1 1/4	105
1 1/2	170
2	90
2 1/2	115
3	160
3 1/2	200
4	200
5	200
6	200
8	320
10	500
12	710
14	535
16	835
18	835
20	835
24	1200

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.12
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 400

Nominal Pipe Size	Torque FT. LB.
1/2	No flanges
3/4	No flanges
1	No flanges
1 1/4	No flanges
1 1/2	No flanges
2	No flanges
2 1/2	No flanges
3	No flanges
3 1/2	No flanges
4	320
5	320
6	320
8	500
10	620
12	875
14	875
16	1200
18	1200
20	1400
24	2600

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.13
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 600

Nominal Pipe Size	Torque FT. LB.
1/2	40
3/4	60
1	85
1 1/4	85
1 1/2	160
2	85
2 1/2	160
3	180
3 1/2	300
4	330
5	470
6	470
8	650
10	875
12	875
14	1020
16	1335
18	1900
20	1900
24	3000

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.14
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 900

Nominal Pipe Size	Torque FT. LB.
1/2	No Flanges
3/4	No Flanges
1	No Flanges
1 1/4	No Flanges
1 1/2	No Flanges
2	No Flanges
2 1/2	No Flanges
3	265
4	500
5	840
6	590
8	950
10	950
12	1130
14	1330
16	1830
18	3000
20	3000
24	5000

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.15
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 1500

Nominal Pipe Size	Torque FT. LB.
1/2	80
3/4	100
1	160
1 1/4	200
1 1/2	275
2	200
2 1/2	300
3	400
4	650
5	1000
6	900
8	1400
10	2400
12	2500
14	3200
16	4500
18	6000
20	7730
24	12750

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.16
Suggested Torque Values for Use with Teadit
Camprofiles 946 (with loose fitting outer rings)/Standard
ASME B16.5 Raised Face Pipe Flanges

Class 2500

Nominal Pipe Size	Torque FT. LB.
1/2	85
3/4	85
1	125
1 1/4	220
1 1/2	320
2	220
2 1/2	320
3	450
4	750
5	1300
6	2000
8	2000
10	3500
12	5000

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.17**Suggested Torque Values for Use with Teadit Compressed Fiber Sheet, Tealon™, Teadit 24SH, or Flexible Graphite grades 2661, 2663 in Standard ASME B16.5 Raised Face Pipe Flanges.****Class 150**

Nominal Pipe Size	Torque FT. LB.
1/2	28
3/4	43
1	50
1 1/4	57
1 1/2	57
2	122
2 1/2	122
3	122
3 1/2	122
4	122
5	202
6	202
8	202
10	325
12	325
14	506
16	506
18	723
20	723
24	1012

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.18

Suggested Torque Values for Use with Teadit Compressed Fiber Sheet, Tealon™, Teadit 24SH, or Flexible Graphite grades 2661, 2663 in Standard ASME B16.5 Raised Face Pipe Flanges.

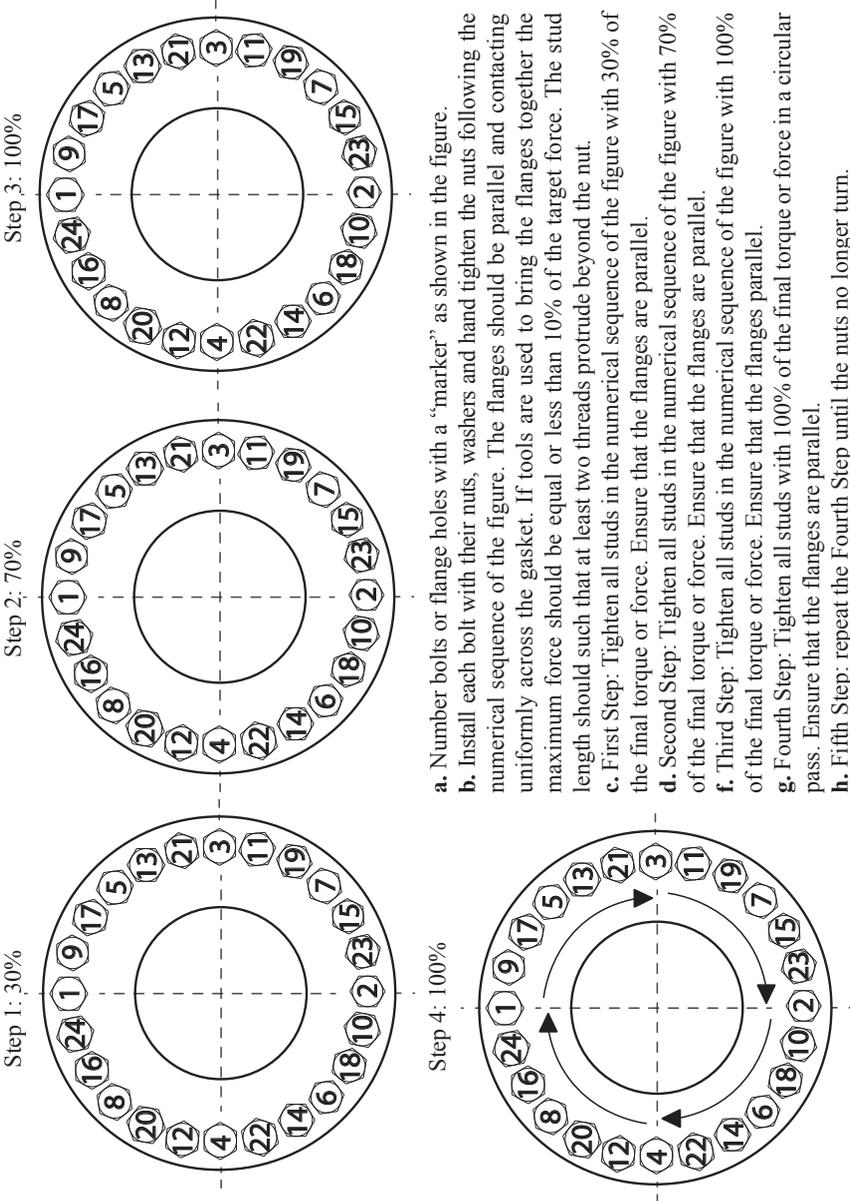
Class 300

Nominal Pipe Size	Torque FT. LB.
1/2	28
3/4	43
1	72
1 1/4	101
1 1/2	151
2	108
2 1/2	144
3	173
3 1/2	202
4	202
5	202
6	202
8	325
10	506
12	723
14	614
16	867
18	1012
20	835
24	1410

Notes:

1. For Use with ASTM A193 B7 Bolting or equal yield strength bolt material and A-105 or stainless steel forged flanges.
2. Charts based on Friction Factor (K) approximately 0.17
3. Use correct size and new bolts, studs, nuts and washers (multiply torques by 0.70 for PTFE coated bolting). Lubricate bolt threads and nut faces with compatible antiseize. Your specific application should not be undertaken without independent study and evaluation for suitability. For specific application recommendations consult TEADIT. Failure to select proper sealing products could result in property damage and/or serious personal injury.

ANNEX 12.19
Example of the Star or Legacy Tightening Pattern for a 24-bolt flange using a single tool

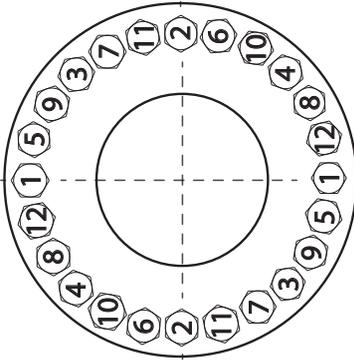


- a. Number bolts or flange holes with a “marker” as shown in the figure.
- b. Install each bolt with their nuts, washers and hand tighten the nuts following the numerical sequence of the figure. The flanges should be parallel and contacting uniformly across the gasket. If tools are used to bring the flanges together the maximum force should be equal or less than 10% of the target force. The stud length should such that at least two threads protrude beyond the nut.
- c. First Step: Tighten all studs in the numerical sequence of the figure with 30% of the final torque or force. Ensure that the flanges are parallel.
- d. Second Step: Tighten all studs in the numerical sequence of the figure with 70% of the final torque or force. Ensure that the flanges are parallel.
- f. Third Step: Tighten all studs in the numerical sequence of the figure with 100% of the final torque or force. Ensure that the flanges parallel.
- g. Fourth Step: Tighten all studs with 100% of the final torque or force in a circular pass. Ensure that the flanges are parallel.
- h. Fifth Step: repeat the Fourth Step until the nuts no longer turn.

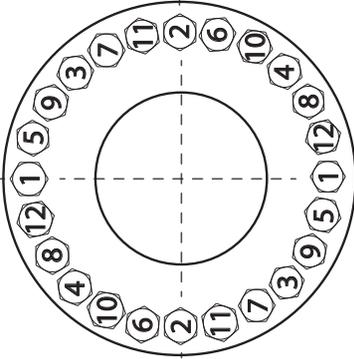
ANNEX 12.20

Example of the Star or Legacy Tightening Pattern for a 24-bolt flange using two simultaneous tools

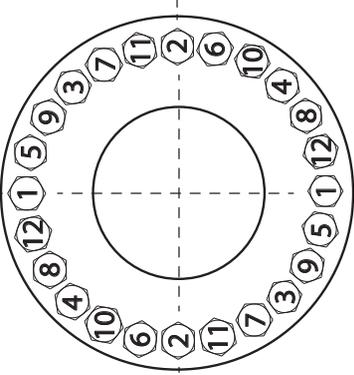
Step 1: 30%



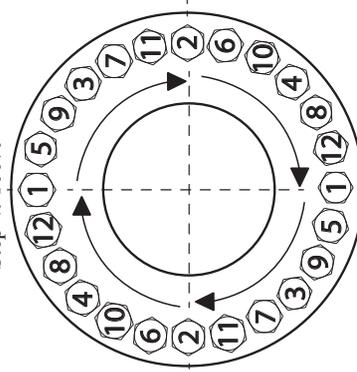
Step 2: 70%



Step 3: 100%

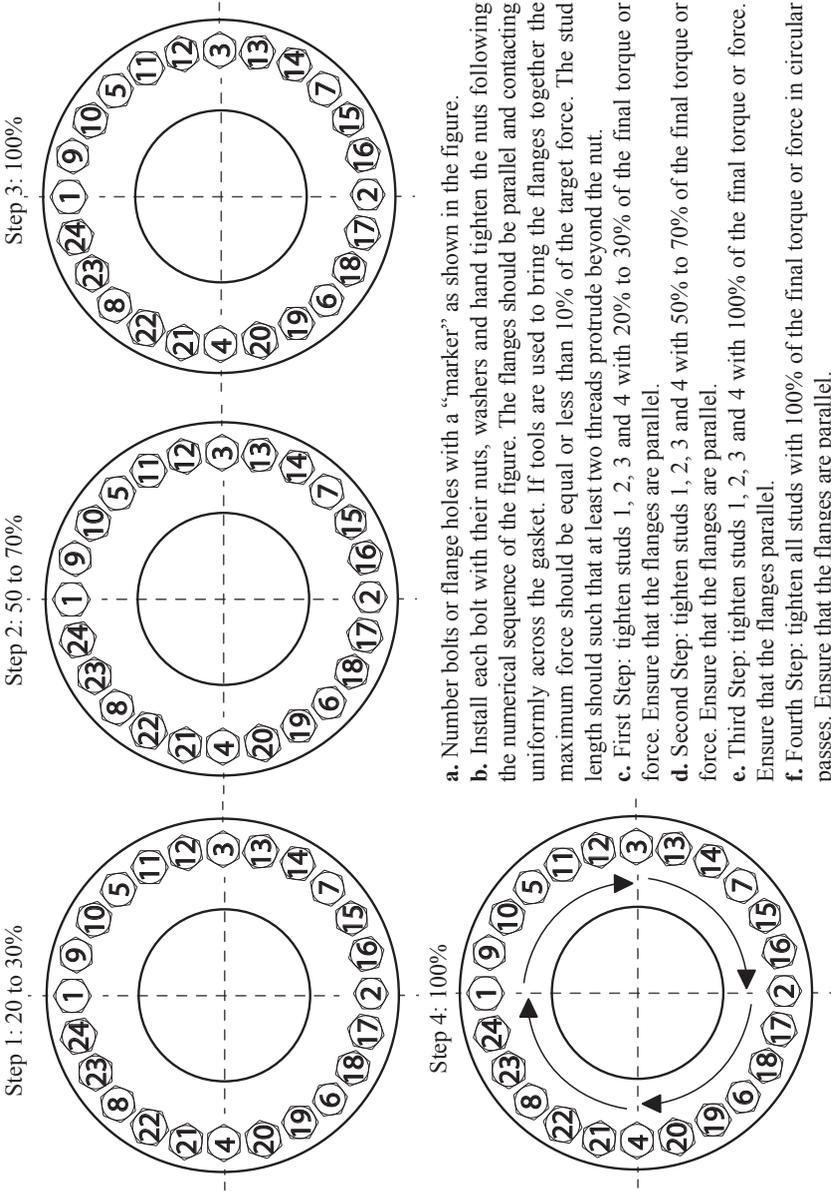


Step 4: 100%



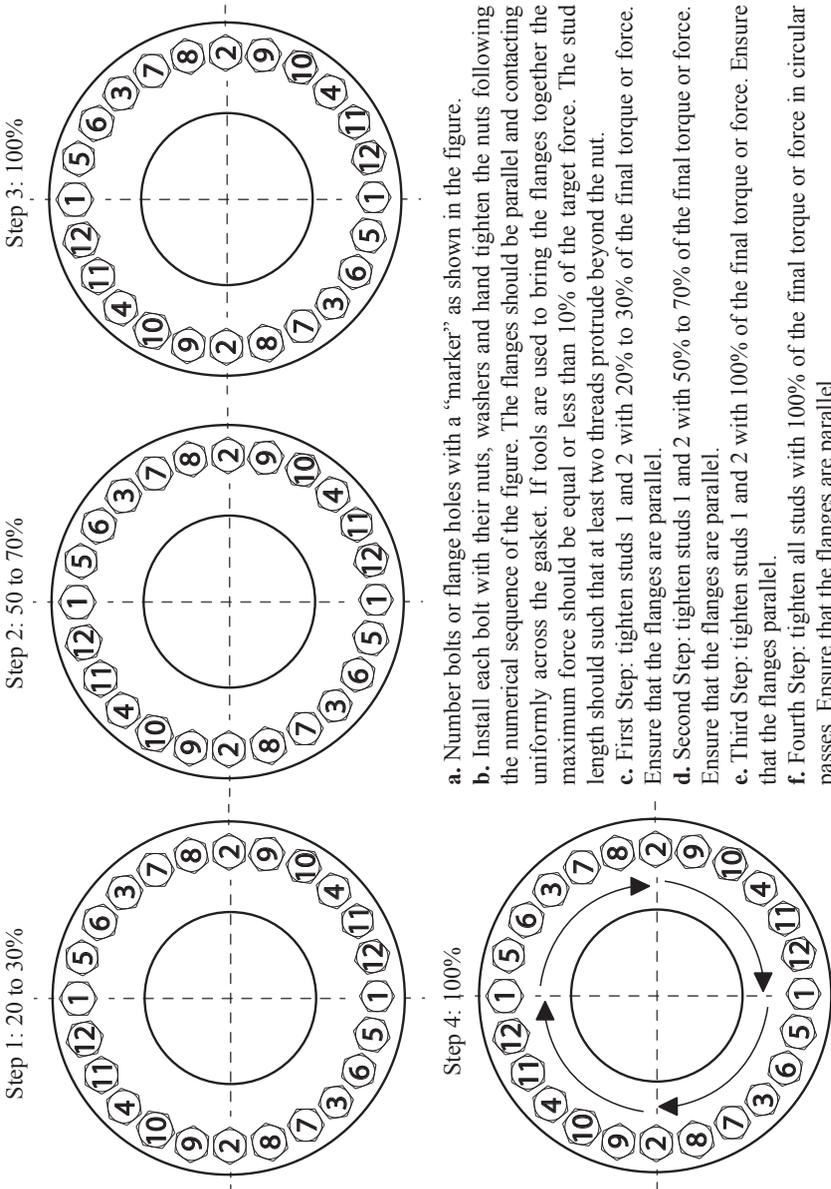
- a. Number bolts or flange holes with a “marker” as shown in the figure.
- b. Install each bolt with their nuts, washers and hand tighten the nuts following the numerical sequence of the figure. The flanges should be parallel and contacting uniformly across the gasket. If tools are used to bring the flanges together the maximum force should be equal or less than 10% of the target force. The stud length should be such that at least two threads protrude beyond the nut.
- c. First Step: tighten all studs in the numerical sequence of the figure with 30% of the final torque or force. Ensure that the flanges are parallel.
- d. Second Step: tighten all studs in the numerical sequence of the figure with 70% of the final torque or force. Ensure that the flanges are parallel.
- e. Third Step: tighten all studs in the numerical sequence of the figure with 100% of the final torque or force. Ensure that the flanges are parallel.
- f. Fourth Step: tighten all studs with 100% of the final torque or force in circular passes. Ensure that the flanges are parallel.
- g. Fifth Step: repeat the Fourth Step until the nuts no longer turn.

ANNEX 12.21
Example of the Alternative Tightening Pattern using a single tool
JSA JIS Standard B2251, 2008



- a. Number bolts or flange holes with a “marker” as shown in the figure.
- b. Install each bolt with their nuts, washers and hand tighten the nuts following the numerical sequence of the figure. The flanges should be parallel and contacting uniformly across the gasket. If tools are used to bring the flanges together the maximum force should be equal or less than 10% of the target force. The stud length should such that at least two threads protrude beyond the nut.
- c. First Step: tighten studs 1, 2, 3 and 4 with 20% to 30% of the final torque or force. Ensure that the flanges are parallel.
- d. Second Step: tighten studs 1, 2, 3 and 4 with 50% to 70% of the final torque or force. Ensure that the flanges are parallel.
- e. Third Step: tighten studs 1, 2, 3 and 4 with 100% of the final torque or force. Ensure that the flanges parallel.
- f. Fourth Step: tighten all studs with 100% of the final torque or force in circular passes. Ensure that the flanges are parallel.
- g. Fifth Step: repeat the Fourth Step until the nuts no longer turn.

ANNEX 12.22
Example of the Alternative Tightening Pattern using two simultaneous tools
JSA JIS Standard B2551, 2008



- a. Number bolts or flange holes with a “marker” as shown in the figure.
- b. Install each bolt with their nuts, washers and hand tighten the nuts following the numerical sequence of the figure. The flanges should be parallel and contacting uniformly across the gasket. If tools are used to bring the flanges together the maximum force should be equal or less than 10% of the target force. The stud length should such that at least two threads protrude beyond the nut.
- c. First Step: tighten studs 1 and 2 with 20% to 30% of the final torque or force. Ensure that the flanges are parallel.
- d. Second Step: tighten studs 1 and 2 with 50% to 70% of the final torque or force. Ensure that the flanges are parallel.
- e. Third Step: tighten studs 1 and 2 with 100% of the final torque or force. Ensure that the flanges parallel.
- f. Fourth Step: tighten all studs with 100% of the final torque or force in circular passes. Ensure that the flanges are parallel.
- g. Fifth Step: repeat the Fourth Step until the nuts no longer turn.

CONVERSION FACTORS

Multiply	By	To obtain
gallon	3.785	liters
degree C	$1.8 C + 32$	degree F
yard	0.9144	meter
kgf / cm ²	14.223	lbf/sqin
kgf-m	9.807	newton-meter (N-m)
kgf-m	7.238	lbf-ft
kg/m ³	6.243×10^{-2}	lb/sqft
pound	0.454	kg
megapascal (MPa)	145	lbf/sqin
megapascal (MPa)	10	bar
mile	1,609	km
newton	0.225	lbf
newton	0.102	kgf
foot	0.305	meter
Square foot	0,09290	square meter
pé cúbico	0.028	sqft
inch	25.4	millimeter
Cubic inch	$1,639 \times 10^{-5}$	cubic meter
Square inch	645.16	square millimeter

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