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FLANGES: TYPES, CLASSES AND ASSEMBLY

MECHANICAL ENGINEERING

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INTRODUCTION

The previous modules discussed calculation of the required wallthickness for straight pipe and some overall piping system design considerations. However, there is more to the pressure boundary of a piping system than just straight sections of pipe. These straight pipe sections must be connected to each other and to valves and equipment, have changes in direction, and beinterconnected between systems. This is accomplished by using flanges and fittings. Selecting a flange or fitting requires the engineer to:

Know the types of flanges and fittings that can be usedbased on Saudi Aramco and industry standards.

Select a material specification, material group and class,given design pressure, temperature, and pipe material.

This module discusses the different types of flanges and fittingsand how to select the correct type when designing a piping syste

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FLANGE ASSEMBLY

A flange is used to connect a pipe section to a piece of equipment, valve, or another pipe in a way that will permit relatively simple disassembly. Such disassembly may be required for maintenance, inspection or operational reasons. Figure 1 shows a typical flange assembly. Flange assembly is normally used for pipe sizes above 38 mm (1-1/2 in.) NPS.

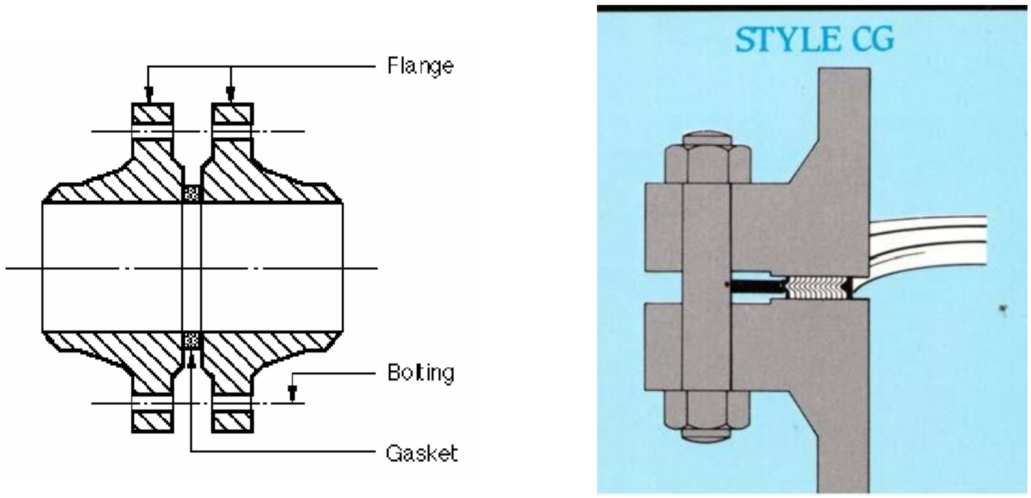


Figure 1. Typical Flange Assembly

A flange assembly consists of:
Two flanges.
A gasket to provide a seal between the flanges.
Bolting to keep the assembly together.
One flange is attached to each of the items being joined. For example, a flanged valve may be installed in a piping system, and the pipe ends on each side of it also will have flanges. A gasket is a resilient material that is inserted between the flangesand seated against the portion of the flanges called the “face” or“facing”. The gasket provides the seal between the fluid in the pipe and the outside, and thus prevents leakage. Bolts compress the gasket to achieve the seal, and hold the flanges together against pressure and other loading. There are several types of flanges, flange attachment methods, flange facings, and gasket types.

FLANGE TYPES

This section describes the various flange types that are used in Saudi Aramco piping systems. We can divide the flanges into two categories. They could be either conventional (standard) orspecialty flanges. There are several standard types of pipe flange. Two items must be specified to completely define a flange type.

Flange Type = Attachment Method + Face Type

A flange type is specified by stating the type of attachment and face. For example, "A weld-neck flat-faced flange." The type ofattachment defines how the flange is connected to a pipe section or piece of equipment (such as a pressure-vessel nozzle). The type of flange face or facing defines the geometry of the flange surface that contacts the gasket.

Flange Attachment Types

From an attachment criteria, the conventional types are eitherone of the flowing:

Threaded Flanges

Blind flange

Socket-welded flange

Threaded Flanges

A threaded flange has pipe threads machined into its bore as shown in Figure 2. The flange is screwed to matching threadson the pipe end. Threaded flanges are used only for small-diameter piping systems, up to 50 mm (2 in.) NPS (nominal pipe size), at locations where pipe disassembly may be required for maintenance, field modifications, or to match specialty fittingsand valves.

For hazardous services, a threaded flange may only be used upto 38 mm (1-1/2 in.) NPS. However, based on Saudi Aramco Engineering Standard SAES-L-009, *Metallic Flanges, Gaskets, and Bolts*, welded slip-on-type flanges are preferred over threaded flanges in screwed piping systems. Threaded flanges,and threaded piping systems in general, are not employed in larger diameters because of the increased difficulty of obtaining sufficient and uniform thread engagement. The preference for slip-on rather than threaded flanges is based on the greater likelihood of having a leak in a threaded-flange attachment joint.

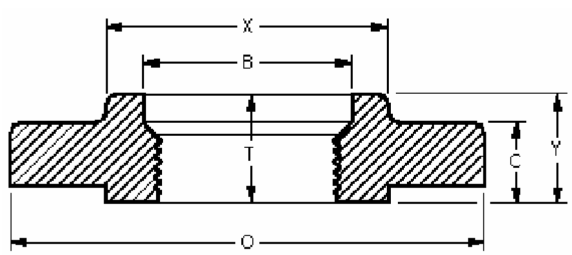
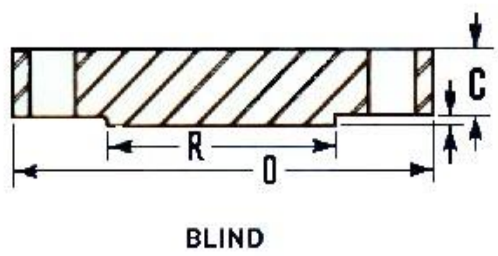


Figure 2. Threaded Flanges

Blind Flanges

A blind flange, as shown in Figure 3, is a flat metal plate that is used to block flow in a piping system. A blind flange is included here for completeness. However, it is not attached to the pipe, but bolted to a mating flange. It is used when a pipe end or equipment nozzle must be blocked from flow, but there still mustbe an easy means of internal access.



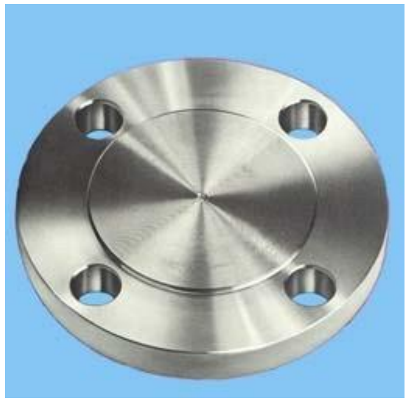


Figure 3. Blind Flange

Socket-Welded
Flanges

A socket-welded flange has an oversized bore that is partially machined into the end opposite the face, as shown in Figure 4.The pipe is inserted into this "socket" and the flange fillet is welded to the pipe OD. The section of this module that discusses socket-welded fittings describes socket-welded attachments in more detail.

Based on Saudi Aramco Engineering Standard SAES-L-010, *Limitations on Piping Joints*, the maximum size of socket- welded joints in hazardous services shall be 38 mm (1-1/2 in.) NPS for new construction. A maximum 50 mm (2 in.) NPS may be used for maintenance, minor field modifications of existing systems, and when needed to match existing equipment connections. However, as with threaded piping systems, SAES-L-009 indicates that welded slip-on-type flanges are preferred over socket-welded flanges in socket-welded piping systems.

Here again, this preference is based on the assumed greaterreliability of a slip-on versus a socket-welded-type flange attachment.

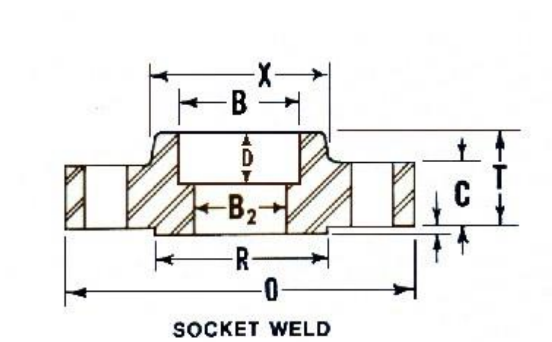


Figure 4. Socket-Welded Flange

Slip-on Flanges

A slip-on flange, as shown in Figure 5, has an oversized bore. Itis slipped over the pipe OD and projects slightly beyond the pipeend. The flange is then fillet welded to the pipe OD, and also between the flange bore and the pipe end.
Slip-on flanges are typically a lower cost alternative to the welding-neck-type flange that will be described below. This is because a slip-on flange is lighter (i.e., uses less material) and requires less welding to attach it to the pipe. However, a slip-onflange is not suitable for high-temperature, cyclic, high-pressureor high external loading situations.

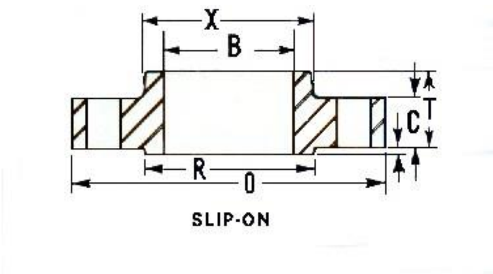
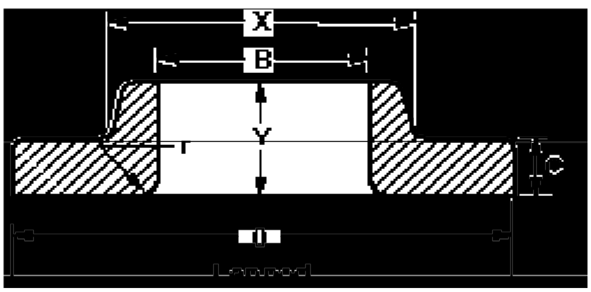


Figure 5. Slip-on Flange

Based on SAES-L-009, Saudi Aramco requires that an ASMECode Section VIII, Division 1 flange analysis be performed if aslip-on flange is used for any of the following cases:
Severe cyclic conditions (i.e., large and frequent temperaturefluctuations, or vibration-prone services).
Design temperature greater than 230°C (450°F).
ASME Class 400 or higher rating.
Pipe size over 600 mm (24 in.).
The flange analysis must consider thermal and other external piping loads, and must demonstrate that the flange will not be over stressed. Because of this extra analysis requirement, it isunlikely that a slip-on-type flange will be used in these servicesbecause its economic attractiveness will be reduced.

Lapped Flange

A lapped flange, as shown in Figure 6, is not physically connected to the pipe. It is slipped over a pipe stub that has a flared end, and the pipe stub is welded to the major pipe section. The flared pipe end has a machined face where the gasket is seated. The bolting holds the flanges and gasket jointtogether.



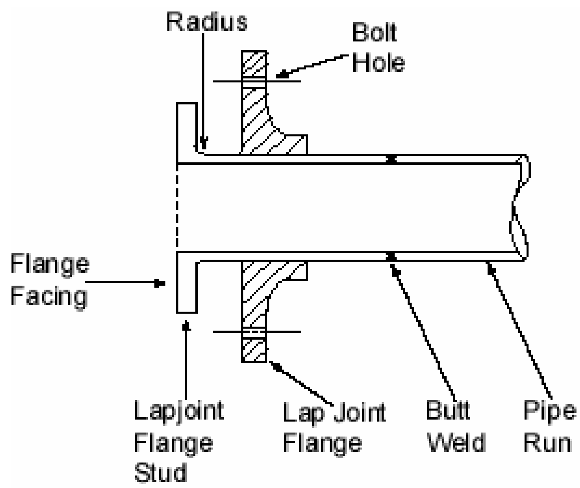


Figure 6. Lapped Flange Assembly and Typical Lap Flanges with theStub Ends.

Their use is also limited to special applications such as:No part of a lapped flange contacts the process fluid.
Therefore, in high-alloy piping systems, a lapped flange maybe made from less costly carbon steel material.
To avoid welding dissimilar materials.
To facilitate lining up the bolt holes in underwater flanged joints.The nature of a lap-joint flange allows it to be easily rotated to facilitate bolt hole alignment because it is not permanentlyattached to the pipe.
A lapped-flange assembly is less able than other attachment types to absorb loads from a piping system because there is no connection between the flange and the pipe. Therefore, the capability to absorb loads must be considered in the overall system design. The use of lap-joint flanges is the exception rather than the rule. The main advantage of a lapped flange is cost, and then only in high-alloy piping systems. Based on SAES-L-009, Saudi Aramco prohibits the use of lap-joint flangesin severe cyclic conditions.

Welding-Neck Flanges

A welding-neck flange, as shown in Figure 7, is the strongest ofthe standard flange attachment types. The end of the flange is butt-welded to the end of the pipe. The flange bore is sized to match the pipe bore.
A welding-neck flange is the most widely used in refinery services because of its greater strength and ability to be used athigh temperature and in cyclic service. However, it is the most expensive of the various flange attachment types because it is the heaviest (i.e., uses the most material) and requires the mostwelding to attach to the pipe end. Based on SAES-L-009, this isthe preferred flange type in metallic piping systems, 50 mm (2 in.) NPS and above.

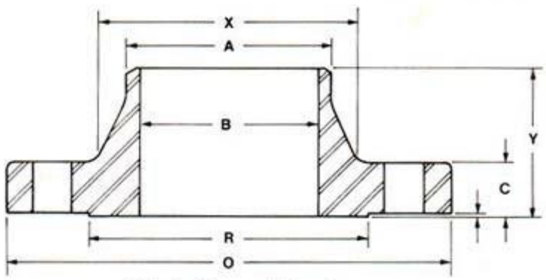


Figure 7. Welding-Neck Flange Facing Types

The area of a flange where the gasket is positioned is called the*face* or *facing*. The three primary flange facings are the flat face, raised face and ring joint. Any of the flange attachment types that were described above, except for the lapped flange, may use any of these facings. The facing for a lapped flange islocated on the flared pipe stub end, not on the flange. The primary three type of flange facing will be discussed.

Flat-Faced Flanges

In the flat-faced flange shown in Figure 8, the area where the gasket is located is at the same elevation as the surrounding flange surface. There is no change in elevation in proceedingfrom the flange inside diameter to its outside diameter. This provides uniform flange contact with the gasket over a large surface, and limits local flange bending that is caused by bolt load.

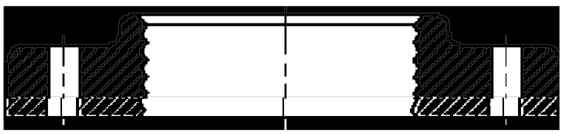


Figure 8. Flat-Faced Flange

A flat face is typically used only for cast or ductile iron flanges, with relatively low-strength material, or when a steel flange mustmate to such a flange. Minimization of flange bending is necessary for cast iron, ductile iron, or other relatively low- strength materials, but not for steel flanges. Therefore, there are few applications for flat-face flanges in refinery or petrochemical services because there are relatively few applications where such low-strength flange materials are acceptable. Sheet-type gaskets that extend from the flange inside diameter to the outside diameter (i.e., full face) typically are used with flat-face flanges.
Based on SAES-L-009, a flat-faced flange with a full-face gasketshall be used when one or both of the mating flanges are cast iron, aluminum, plastic, or any other material that could be overstressed by the bolt load. Also, the are used foe highly corrosive service where contact of fluid with flange facing must be avoided.

Raised-Face Flanges

A raised-face flange is shown in Figure 9. The area where the gasket is located is higher than the surrounding flange surface, typically by 1.5 mm (1/16 in.). This raised-face portion of the flange has a specially machined, serrated finish that is suitable for the typical gasket types used in process plant applications. Any gasket type, other than a ring type, may be used with a raised-face flange. The raised face results in much less contactarea and higher gasket contact stresses as compared to a flat face. The gasket is compressed and sealed only in the area of the raised face. A smooth machine finish, 3.2-6.4 micrometer AARH (arithmetic average roughness height), should be specified for use with spiral-wound gaskets.
A raised-face flange is used for a very broad range of services,and is the most common type.

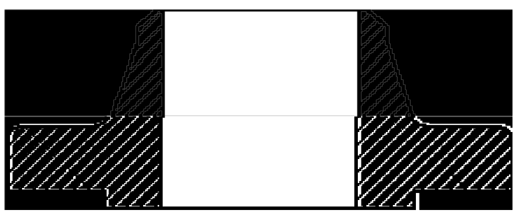


Figure 9. Raised-Faced Flange

………………Ring-Joint Flanges

A ring-joint flange face, as shown in Figure 10, consists of a groove that is machined into the flange end. The sealing surfaces of the groove are smoothly finished to 63 micro inch surface roughness, and are free of any detrimental ridges or toolmarks. The presence of such surface defects will result in a

leaking joint, since a very smooth contact surface is required toachieve a leak- proof, metal-to-metal seal. A solid metal ring- type gasket is inserted in the groove.
The ring-joint flange is used for the most severe service applications where the other possible flange face and gasketcombinations will not provide acceptable performance.
Typically, these are high-pressure and/or high-temperatureservices.
Based on SAES-L-009, a ring-joint flange is required for steel flanges of Class 900 and higher, for design temperatures over480°C (900°F), or for underwater pipelines in Class 300 and higher
.

Figure 10. Ring Joint Flange

FLANGE STANDARDS

Saudi Aramco uses industry standards to define which flanges are used in Saudi Aramco piping systems. Piping is typically sized and purchased to meet standard diameters. Because standard pipe sizes are used, it is practical to have standard flange sizes and dimensions to assist manufacturer to reproduce qualified flanges. Figure 15 illustrates typical processof manufacturing forged flanges.

There are four industry standards, a Saudi Aramco EngineeringStandard, and a Saudi Aramco Material System Specification that cover flanges:

ASME B16.5 flanges.
API-605 flanges.
MSS flanges.
ASME B16.47 flanges.
Saudi Aramco Special Flanges, as specified by standarddrawings listed in SAES-L-009 and 02-SAMSS-011.

Figure 15. Typical Forging and ManufacturingProcess of ASME of Flanges

ASME B16.5 Flanges

ASME B16.5, *Pipe Flanges and Flanged Fittings*, provides flange dimensional details and pressure/temperature ratings forstandard pipe sizes from 13 through 600 mm (1/2 through 24 in.). This Standard covers a wide range of material types, and will typically be the flange standard used for process plant applications.

The pressure/temperature ratings that are contained within ASME B16.5 specify the combinations of pressure and temperature that are acceptable for given flange sizes and dimensions. The term *class* is used to designate groupings of acceptable pressure/temperature combinations contained withinASME B16.5. ASME B16.5 contains seven classes designated as classes 150, 300, 400, 600, 900, 1500, and 2500. As the number of the class increases, the strength of the flanges withinit increases. Therefore, higher flange classes can withstand higher pressure/temperature combinations. Determination of the appropriate flange class will be discussed later in this module.

Saudi Aramco Engineering Standard SAES-L-009, *Metallic Flanges, Gaskets and Bolts*, contains the following requirementsregarding the use of ASME B16.5 flanges:

ASME B16.5 classes 150, 300, 600, 900 and 1500 shall be used for carbon and alloy steel flanges in 13 through 600 mm (1/2 through 24 in.) nominal pipe sizes. It shall be usedfor Class 2500 in nominal sizes 13 through 300 mm (1/2 through 12 in.).

Class 400 carbon steel flanges shall not be used for nominalsizes of less than 750 mm (30 in.).

API 605 Flanges

API 605 encompasses raised-face carbon steel welding-neck flanges in 650-1,500 mm (26-60 in.) nominal pipe sizes with pressure ratings corresponding to classes 75, 150, 300, 400, and 600. It also includes a class 900 for welding-neck flanges in650-1,200 mm (26-48 in.) nominal pipe sizes. Finally, it also specifies flanges that are cast or forged as the integral ends of valves, fittings, or nozzles for classes 75, 150, or 300.
API 605 begins where ASME B16.5 stops in terms of pipe size. However, it does not reach the maximum pressure/temperatureratings of ASME B16.5, nor does it cover material other than carbon steel. Based on SAES-L-009, API-605 flanges may be used for only class 75 in sizes of 650-900 mm (26-36 in.) in 50 mm (2 in.) increments, and sizes 1,050-1,500 mm (42-60 in.) in 150 mm (6 in.) increments.

MSS Flanges

MSS standards are developed and revised by the Manufacturers Standardization Society of the Valve and FittingsIndustry. MSS-SP-44, *Steel Pipe Line Flanges*, originally was developed to establish uniform flange dimensions for use with high-pressure pipelines of 650 through 1,500 mm (26 through 60 in.) size in pressure classes of 300 through 900. It later was revised to include sizes down to 300 mm (12 in.) and Class 150.The flange designs are intended primarily for use with API 5LX line pipe, and they are proportioned accordingly. Their design reflects also the higher design stresses that are permitted in pipeline service.
There is a basic difference between ASME B16.5 and MSS-SP- 44 flanges. ASME B16.5 flanges originally were designed for attachment to relatively thick-walled pipe. However, the larger diameter SP-44 flanges have hubs that specifically are designedfor attachment to relatively thin-walled, high yield-strength pipe.
The "x" grades of the API 5L pipe material specification have relatively high yield strengths. Special attention should be paidto situations where an ASME B16.5 flange is attached to a thin-walled pipe operating near the maximum atmospheric temperature/pressure rating of the flange, or where an SP-44

flange is attached to a relatively thick-walled pipe. The stress atthe flange-hub attachment point should be checked in each of these cases to ensure that it is not excessive.
MSS-SP-44 flanges may be used within the following limitations,in accordance with SAES-L-009:
Classes 150, 300, 400, 600, and 900 for nominal pipe sizesof 300-600 mm (12-24 in.) for welding-neck flanges with single-taper hub only.
Classes 400 and 600 for pipe sizes of 1,250-1,500 mm (50-60 in.), welding-neck and blind flanges, raised face only.
Class 900 for pipe sizes 650 through 1,200 mm (26 through48 in.) welding-neck and blind flanges.

ASME B16.47

ASME B16.47, *Large-Diameter Steel Flanges*, is essentially a combination of the API 605 and MSS SP-44 flanges. ASME B16.47 covers pipe flanges in 650 through 1,500 mm (26 through 60 in.) nominal sizes in ratings corresponding to classes75, 150, 300, 400, 600 and 900. MSS SP-44 flanges are designated as *Series A* flanges, and API 605 flanges are designated *Series B*. The materials that are covered by ASME B16.47 are the same as those in ASME B16.5, except that nickel-base alloys are excluded. Pressure/temperature ratings are consistent with ASME B16.5.
02-SAMSS-011, *Forged Steel Weld-Neck Flanges for Low - andIntermediate-Temperature Service*, permits the use of ASME B16.47 flanges, Series B, Class 75 for sizes that are not covered by Saudi Aramco Standard Drawings.

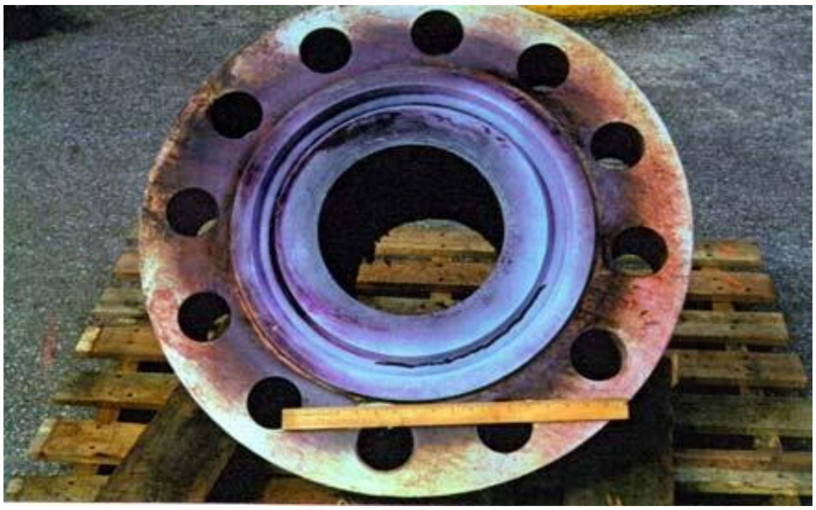


Table 1. Standard Drawings for Flanges

NPS Range	Class	Type	Facing	Standard Drawing
26-60	150	WN	RF	AD-036634
26-60	300	WN	RF	AD-036991
26-48	300	WN	RJ	AC-036484
54-60	300	WN	RJ	AC-036437
30-48	400	WN	RF	AD-036698
26-48	600	WN	RF	AD-036673
26-48	600	WN	RJ	AC-036442
26-48	300	Lap	RJ	AC-036486
54-60	300	Lap	RJ	AE-036438
26-48	600	Lap	RJ	AC-036443
54-60	75	Blind	RF	AD-036696

Where:
WN: Weld neck. Lap: Lapped flange
RF: Raised face. Blind: Blind flangeRJ: Ring joint.

02-SAMSS-011, *Forged Steel Weld-Neck Flanges for Intermediate-Temperature Service*, provides Saudi Aramco purchase requirements for forged steel weld-neck flanges in low- and intermediate-temperature services. Services that havedesign temperatures above 425°C (800°F) or below -60°C (- 75°F), or those that require the use of higher alloy pipe material,

are not covered by this SAMSS and must be handled as specialcases.
02-SAMSS-011 was first issued in February 1994 and supersedes Standard Drawing AB-036028. It expands upon theflange material selection requirements that are specified in SAES-L-009 and the requirements that are specified in the relevant industry standards. These additional Saudi Aramco requirements are meant to ensure higher overall flange materialquality based on past experience, and to minimize the probability of experiencing problems during piping system fabrication and operation.
02-SAMSS-011 adds additional restrictions on material usage,and further requirements in the following areas:
Flange manufacturing details.
Maximum hardness limitations.
Heat treatment.
Material chemistry.
Mechanical strength testing.
Impact testing.
Hardness testing.
Nondestructive examination.
Repairs.
Markings.
Painting and shipping.
Participants are referred to 02-SAMSS-011 for specific details.

DETERMINING THE MATERIAL GROUP FOR ASME FLANGES ANDFLANGED FITTINGS

The next step in specifying a flange or flanged fitting is to selectthe material specification and group number, which are neededto select the class or rating of the flange or flanged fitting. This section discusses the selection of flange materials specificationand material group number. Flange material specifications are listed in Table 1A of ASME B16.5. A portion of this Table is reproduced as Addendum B-1. Material selection for threaded,socket-welded, and butt-welded fittings is not as involved but also will be discussed.

Work Aid 1 summarizes the flange material selection process,the use of SAES-L-009 in selecting flange material specifications, and how to use the Materials Specifications Table.

The Materials Specification Table

The Materials Specification Table is divided into two sections:

Material groups.

Product forms.

Material Groups

Material specifications are grouped within specific *Material Group Numbers* in this table. These groupings have been madeto provide compatible flanged-joint ratings for materials that are likely to be used together. The lowest strength material in each group was used to determine the pressure rating for that group at a given temperature. Therefore, the ratings of some materials within a group are conservative.

Product Forms

This table also indicates three different product forms that are possible for flanges and flanged fittings: forging, castings, and plates. The relevant ASTM specifications are specified for these product forms. Most material groups have representativespecifications in each of the product forms. However, some material chemistries within a material group might not be represented in each product form. For example, carbon steel inGroup 1.1 can be found in all three product forms. However, C-Mn-Si steel in Group 1.1 can be plate only. ASME B16.5 specifies that plate may be used only for blind flanges, and certain sized reducing flanges where a blind flange is used.

Selection Procedure of the Material Group for ASME Flanges andFlanged Fittings

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The following procedure may be used to select the correctflange material and Material Group Number.
Identify the material chemistry (such as carbon steel, 1 1/4Cr - 1/2 Mo) that is being used for the connected piping.
Identify the design temperature.
For pipeline applications, identify the Specified MinimumYield Stress of the pipe material that is being used.
If the piping material is not carbon steel, refer to Table 1A in ASME B16.5 (Addendum-B-1), and continue in this step. If itis carbon steel, go to Step 5.
Select the appropriate material specification that corresponds to the identified material chemistry and

product form. The product form for flanges will almostalways be a forging.
Identify the Material Group Number that corresponds tothe material specification.
If the material is carbon steel (or a low-alloy specification that is identified in SAES-L-009 and 02-SAMSS-011), refer to SAES-L-009 and Table 1 of 02-SAMSS-011 to select the appropriate flange material specification. The most commoncarbon steel flange material specifications for plant piping systems are summarized below.
a) Identify the Material Group Number that corresponds to the material specification, from Table 1A in ASME B16.5(Addendum-B-1). Material Group 1.1 corresponds to theabove specifications.
Refer to SAES-L-009 and 02-SAMSS-011 for additional requirements and conditions that are not included, and forpipeline applications.

Table 2: Flange Material Selection Guide

Flange Material	**Limitations**
ASTM A 105	Restricted to non hydrocarbon service (except flare lines), -18 to 425°C (0 to 800°F).
ASTM A 105 N (normalized)	Can be used for hydrocarbon service , -18 to 425°C (0 to 800°F).
ASTM A 350 Gr. LF 2	-30 to 345°C (-20 to 650°F).
ASTM A 350 Gr. LF 2 LO TEMP	-45 to 345°C (-50 to 650°F). Impact testing required.

FLANGE RATING CLASS

After the Material Group has been determined, the next step in the selection process for flanges and flanged fittings is to select the appropriate class. The class is based on pressure and temperature, and is determined by using pressure/temperature rating tables, the Material Group, design metal temperature, anddesign pressure. Selecting the class sets all the detailed dimensions for flanges and flanged fittings. The objective is to select the lowest class that is appropriate for the design conditions.

This section will discuss the appropriate pressure/temperaturerating classes for flanges and flanged fittings.

The following will deal only with ASME B16.5 because this is themost widely used and broadest flange standard. The classes ofAPI 605, MSS-SP-44, and ASME B16.47 flanges are identical to those that are contained in ASME B16.5 for the same numberdesignations. API 605 is limited to carbon steel material.

Pressure/Temperature Rating Tables

The class accounts for the required flange designtemperature and pressure.

ASME B16.5 contains seven classes designated Classes150, 300, 400, 600, 900, 1500, and 2500. Each class specifies the design pressure and temperaturecombinations that are acceptable for a flange having that designation.

As the number of the class increases, the strength of theflanges increases. Therefore, higher flange classes canwithstand higher pressure/temperature combinations.

As the number of the class increases, the cost of the flangesalso increases because more material is being used to makethe higher class stronger. Therefore, there is an economic incentive to use the lowest class that will meet the design requirements.

Each of the material group has a table in ASME B16.5 thatprovides the ratings for all classes, Addendum B-2 and B-3are extracts for material group 1.1 and 2.1 respectively.

For MSS Sp-44 flanges there is only one table of flange ratingwhich is extracted in Addendum-B-4. ASME B31.3 and B31.4 permit higher pressures than are indicated in the rating table for conditions that exist for shorter duration. These will be discussed in a later section.
A general flange class selection procedure is outlined next.

Guidelines for Determining the Flange Rating Class

Use the following procedure to determine the Class for ASMEB16.5 flanges and flanged fittings. Fill in the blank lines as required.
Given:
Generic pipe material_____ (such as Carbon Steel, C-1/2 M, 3-1/2 Ni)
Design Pressure, kPa (psig)_____
Design Temperature, °C (°F)____
Nominal Pipe Size, mm (in.)_____
Pipe material SMYS
(pipeline applications), MPa (psi)_

Selection Procedure:
Review SAES-L-009 and 02-SAMSS-011 for carbon and lowalloy steel flange requirements.
Saudi Aramco Requirement_____
Determine the required flange product form (forging, casting,and plate). Most pipe flanges are forging.
a) Product Form___

Proceed to Table 1A of ASME B16.5 to select Material Group No., considering the required material and productform. Flange material is to have comparable chemistry topipe material (except possibly lapped flanges), and meet SAES-L-009 and 02-SAMSS-011 requirements.
a) Material Group Number_
Proceed to Table 2, ASME B16.5, for the appropriate material group to determine the flange class. For the specified design temperature, determine the maximum allowable operating pressure (MAOP) proceeding from lowerto higher classes.

Class 150 300 400 600 900 1500 2000

For ASME B31.4 and B31. 8 piping systems, you must note that flanges shall not be derated for temperature. The design pressure for –20 to 100 Deg. F is acceptableup to 250 Deg. F. For temperature higher than 250 Deg.F but not more than 450 Deg. F, the derating factors perMSS SP-44 should be used for carbon steel material ASSHOWN IN Addendum B-4.

Complete this table only until the MAOP for a class exceedsthe design pressure. The required flange class is the lowest one whose MAOP exceeds the design pressure.

a) Required Class _

Flange Dimensions

ASME B16.5, which provides dimensions for all flange classes. The flange geometry is completely specified by the dimensions given in this table. The flange dimensions for a given class are the same for all possible flange materials. Therefore, variations in material strength are accommodated by changes in acceptable temperature/pressure combinations within a given class, rather than changing flange dimensions. A similar table iscontained in ASME B16.5 for each class, but the flange dimensions differ in each class. For the same pipe sizes, flanges become thicker, heavier, and stronger as the class increases.

Sample Problem 2: Flange Material and Class

A new piping system will be installed at an existing Saudi Aramco plant designed and constructed to ASME B31.3. It is necessary to determine the ASME class that is required for theflanges. The following design information is provided:
Pipe Material: carbon steel
Design Temperature: 371°C (700°F).
Design Pressure: 3,448 kPa (500 psig).
All the needed ASME B16.5 tables are contained in the WorkAid section of this module.

Solution

Determine the Material Group Number for the flanges byreferring to ASME B16.5 Table 1A. Find the carbon steel material in the*Nominal Designation Steel* column. The material specification for forged flanges would be A105 or A350 Gr.
LF2, and the corresponding material Group Number is 1.1.
Refer to Table 2 for material group 1.1. Read the allowable design pressure at the intersection of the 371°C (700°F) design temperature. Class 150 gives lower working pressurethan the design.
For class 300, the working pressure is 535 psig which is higherthan the required design 500 psig. Therefore class 300 is acceptable.
The required flange class is 300.

FLANGE MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP)

An engineer may be asked to check the maximum allowable operating pressure (MAOP) for a flange or fitting when there arechanges in the piping design conditions, such as an increase in pressure. This section discusses how to determine the MAOP of the flange/fitting for a given temperature, given a flange/fittingclass.

Previous discussions showed how the required class is determined for flanges and flanged fittings, and threaded andsocket-welded fittings. They also described how the pressure/temperature limitations of wrought steel butt-weldedfittings are determined. In each case, it is a relatively simple matter to work backwards to determine the MAOP for a particular flange or fitting.

Work Aid 3 provides a procedure for determining MAOP.Conditions Beyond Normal Design Conditions

Previous sections described how to determine the maximum allowable long-term operating pressure for flanges and fittings. The ASME B31 Codes permit an allowance for occasional excursions above this long-term design pressure. However, thecodes differ regarding the permissible extent of these excursions.

In ASME B31.3 piping systems, it is permissible to exceed thepressure rating or the allowable stress for pressure design at the temperature of the increased condition by not more than:

33% for no more than 10 hours at any one time and no morethan 100 hours/year, or

20% for no more than 50 hours at any one time and no morethan 500 hours per year.

Referring to the Class 300 flange in Sample Problem 2 at 371°C(700°F), the pressure could rise to 758 psig (1.33 x 570) or 684 psig (1.2 x 570) during a short-time excursion, depending on the duration of the excursion.

The ASME B31.4 and ASME B31.8 transportation piping codesdiffer from B31.3 and from each other with regard to conditionsbeyond normal design conditions. ASME B31.4 will permit a 10% increase over the rated pressure for variations from normaloperation, such as those caused by liquid surges. It does not contain any details covering the maximum duration or number ofthese variations. ASME B31.8 does not contain any permissibleallowance for pressure increases above the normal maximum rated pressure.

SAFETY OF FLANGED JOINTS ASSEMBLY

Though it seems flanged joint assembly is very straightforwardand simple, petrochemical industries have experienced tragic incidents due to failures of flanged joints. The main requirements and factors to achieve reliable flanged joints are the following:
Flange type, material and rating.
Gasket material, type and quality.
Appropriate surface finish of the flange rating
Right bolting procedure is followed
Good workman ship by the people assembling the flanges.
Careful inspection during the above stages as required.
Generally, the flange has very high safety margins in its design.Over the years of experience, it has been found that the humanfactor is the main reason for failures in the flanged joints. Thereare standards and acceptable practices that should be carefullyfollowed to insure safety around the flanged joints. The latest revision of SAES-L-050, 1999, has outlined such procedures in the Appendix-A which has been extracted for importance into this module as Addendum-C. Following are common workmanship mistakes found during assembly of flanges that could lead to leakage:
Improper surface finish of the flange facing.
Gasket is not centered.
Uneven bolting torque.
Torque value are either under minimum required or way overto the point that gasket is completely not functional.
Installing the wrong gasket, type or rating.

Sample Problem 4

An existing piping system currently has a design temperature of149°C (300°F) and a design pressure of 1,482 kPa (215 psig). The flange material is carbon steel, ASTM A350, Grade LF2, and Class 150 flanges are used.
Process engineers have determined that it would be advantageous if the design pressure could be raised to 1,689kPa (245 psig) at the same design temperature. Can this be done using the existing flanges?

Refer to ASME B16.5, Table 1A, in Addendum B-1. Locatethe ASTM A350, Grade LF2 flange material. This corresponds to Material Group 1.1.
Refer to ASME B16.5 Table 2 for Material Group 1.1 in Addendum B-2. At a design temperature of 149°C (300°F)for Material Group 1.1, the maximum allowable operating pressure is 1,586 kPa (230 psig). This exceeds the currentdesign pressure, but is not enough for the proposed designpressure. Therefore, the Class 150 flanges are not acceptable.
Refer to Table 2 for Class 300 in Work Aid 2. Class 300 flanges are acceptable for the new service by a wide margin.Therefore, the flanges and flanged fittings must be changed to Class 300 to be suitable for the proposed increase in design pressure. Note that the existing pipe wall thickness will also need to be checked for the new design condition

SUMMARY

A flange assembly consists of two flanges plus a gasket and bolting. Saudi Aramco requirements specify the flange and gasket types that must be used based on specified service conditions. Industry requirements specify standard flange dimensions and acceptable pressure/temperature combinations,which may be used with these.
Fittings are used to make some change in the geometry of a piping system, and may be attached to the connected pipe bythreading, socket welding, or butt-welding. Acceptable pressure/temperature combinations for fittings are based on comparisons with comparable

References:

References and Addendum

Below are following books and document the above research depended on.

List of Figures

ADDENDUM A

Table A-1. Industry Standards for Flanges and Flanged Fittings

Standard	Title	Scope
ASME B16.1	CAST IRON PIPE FLANGES AND FLANGED FITTINGS, CLASS 25, 125, 250, AND 800.	
ASME B16.5	PIPE FLANGES AND FLANGED FITTINGS.	
ASME B16.47	LARGE-DIAMETER STEEL FLANGES, NPS 26 THROUGH NPS 60.	
API 605	LARGE-DIAMETER CARBON STEEL FLANGES.	
MSS SP-44	STEEL PIPE LINE FLANGES.	
API 6A	WELLHEAD EQUIPMENT.	

ADDENDUM B

Table B-1. List of Material Specifications (Excerpt)

Source Addendum B-1 ASME B16.5

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
1.1	C–Si C–Mn–Si	2-1.1	A 105 A 350 Gr. LF2	A 216 Gr. WCB	A 515 Gr. 70 A 516 Gr. 70 A 537 Cl. 1
1.2	C–Mn–Si 2½Ni 3½Ni	2-1.2	A 350 Gr. LF3	A 216 Gr. WCC A 352 Gr. LCC A 352 Gr. LC2 A 352 Gr. LC3	A 203 Gr. B A 203 Gr. E
1.3	C–Si C–Mn–Si 2½Ni 3½Ni	2-1.3		A 352 Gr. LCB	A 515 Gr. 65 A 516 Gr. 65 A 203 Gr. A A 203 Gr. D
1.4	C–Si C–Mn–Si	2-1.4	A 350 Gr. LF1 Cl. 1		A 515 Gr. 60 A 516 Gr. 60
1.5	C–½Mo	2-1.5	A 182 Gr. F1	A 217 Gr. WC1 A 352 Gr. LC1	A 204 Gr. A A 204 Gr. B
1.7	C–½Mo ½Cr–½Mo Ni–½Cr–½Mo ¾Ni–¾Cr–1Mo	2-1.7	A 182 Gr. F2	A 217 Gr. WC4 A 217 Gr. WC5	A 204 Gr. C
1.9	1Cr–½Mo 1¼Cr–½Mo 1¼Cr–½Mo–Si	2-1.9	A 182 Gr. F12 Cl. 2 A 182 Gr. F11 Cl. 2	A 217 Gr. WC6	A 387 Gr. 11 Cl. 2
1.10	2¼Cr–1Mo	2-1.10	A 182 Gr. F22 Cl. 3	A 217 Gr. WC9	A 387 Gr. 22 Cl. 2
1.13	5Cr–½Mo	2-1.13	A 182 Gr. F5 A 182 Gr. F5a	A 217 Gr. C5	
1.14	9Cr–1Mo	2-1.14	A 182 Gr. F9	A 217 Gr. C12	
2.1	18Cr–8Ni	2-2.1	A 182 Gr. F304 A 182 Gr. F304H	A 351 Gr. CF3 A 351 Gr. CF8	A 240 Gr. 304 A 240 Gr. 304H
2.2	16Cr–12Ni–2Mo 18Cr–13Ni–3Mo 19Cr–10Ni–3Mo	2-2.2	A 182 Gr. F316 A 182 Gr. F316H	A 351 Gr. CF3M A 351 Gr. CF8M A 351 Gr. CG8M	A 240 Gr. 316 A 240 Gr. 316H A 240 Gr. 317
2.3	18Cr–8Ni 16Cr–12Ni–2Mo	2-2.3	A 182 Gr. F304L A 182 Gr. F316L		A 240 Gr. 304L A 240 Gr. 316L
2.4	18Cr–10Ni–Ti	2-2.4	A 182 Gr. F321 A 182 Gr. F321H		A 240 Gr. 321 A 240 Gr. 321H

Table B-1. List of Material Specifications (Excerpt – Continued)

Source Addendum B-1 ASME B16.5

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
2.5	18Cr–10Ni–Cb	2-2.5	A 182 Gr. F347 A 182 Gr. F347H A 182 Gr. F348 A 182 Gr. F348H	A 351 Gr. CF8C	A 240 Gr. 347 A 240 Gr. 347H A 240 Gr. 348 A 240 Gr. 348H
2.6	25Cr–12Ni 23Cr–12Ni	2-2.6		A 351 Gr. CH8 A 351 Gr. CH20	A 240 Gr. 309S A 240 Gr. 309H
2.7	25Cr–20Ni	2-2.7	A 182 Gr. F310	A 351 Gr. CK20	A 240 Gr. 310S A 240 Gr. 310H
2.8	20Cr–18Ni–6Mo 22Cr–5Ni–3Mo–N 25Cr–7Ni–4Mo–N	2-2.8	A 182 Gr. F44 A 182 Gr. F51 A 182 Gr. F53	A 351 Gr. CK3MCuN	A 240 Gr. S31254 A 240 Gr. S31803 A 240 Gr. S32750
3.1	35Ni–35Fe–20Cr–Cb 28Ni–19Cr–Cu–Mo	2-3.1	B 462 Gr. N08020	A 351 Gr. CN7M	B 463 Gr. N08020
3.2	99.0Ni	2-3.2	B 160 Gr. N02200		B 162 Gr. N02200
3.3	99.0Ni–Low C	2-3.3	B 160 Gr. N02201		B 162 Gr. N02201
3.4	67Ni–30Cu 67Ni–30Cu–S	2-3.4	B 564 Gr. N04400 B 164 Gr. N04405		B 127 Gr. N04400
3.5	72Ni–15Cr–8Fe	2-3.5	B 564 Gr. N06600		B 168 Gr. N06600
3.6	33Ni–42Fe–21Cr	2-3.6	B 564 Gr. N08800		B 409 Gr. N08800
3.7	65Ni–28Mo–2Fe	2-3.7	B 335 Gr. N10665		B 333 Gr. N10665
3.8	54Ni–16Mo–15Cr 60Ni–22Cr–9Mo–3.5Cb 62Ni–28Mo–5Fe 70Ni–16Mo–7Cr–5Fe 61Ni–16Mo–16Cr 42Ni–21.5Cr–3Mo–2.3Cu	2-3.8	B 564 Gr. N10276 B 564 Gr. N06625 B 335 Gr. N10001 B 573 Gr. N10003 B 574 Gr. N06455 B 564 Gr. N08825		B 575 Gr. N10276 B 443 Gr. N06625 B 333 Gr. N10001 B 434 Gr. N10003 B 575 Gr. N06455 B 424 Gr. N08825
3.9	47Ni–22Cr–9Mo–18Fe	2-3.9	B 572 Gr. N06002		B 435 Gr. N06002
3.10	25Ni–46Fe–21Cr–5Mo	2-3.10	B 672 Gr. N08700		B 599 Gr. N08700
3.11	44Fe–25Ni–21Cr–Mo	2-3.11	B 649 Gr. N08904		B 625 Gr. N08904
3.12	26Ni–43Fe–22Cr–5Mo 47Ni–22Cr–20Fe–7Mo	2-3.12	B 621 Gr. N08320 B 581 Gr. N06985		B 620 Gr. N08320 B 582 Gr. N06985

(Table 1A continues on next page; Notes follow at end of Table)

Table B-2. Pressure/Temperature Ratings for group 1.1 material (All Classes)

Source Addendum B-1 ASME B16.5

Nominal Designation	Forgings	Castings	Plates
C–Si	A 105 (1)	A 216 Gr. WCB (1)	A 515 Gr. 70 (1)
C–Mn–Si	A 350 Gr. LF2 (1)		A 516 Gr. 70 (1)(2) A 537 Cl. 1 (3)

NOTES:

(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.

(2) Not to be used over 850°F.

(3) Not to be used over 700°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	285	740	990	1480	2220	3705	6170
200	260	675	900	1350	2025	3375	5625
300	230	655	875	1315	1970	3280	5470
400	200	635	845	1270	1900	3170	5280
500	170	600	800	1200	1795	2995	4990
600	140	550	730	1095	1640	2735	4560
650	125	535	715	1075	1610	2685	4475
700	110	535	710	1065	1600	2665	4440
750	95	505	670	1010	1510	2520	4200
800	80	410	550	825	1235	2060	3430
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

Table B-3. Pressure/Temperature Ratings for group 2.1 material (All Classes)

Source Addendum B-1 ASME B16.5

Nominal Designation	Forgings	Castings	Plates
18Cr–8Ni	A 182 Gr. F304 (1)	A 351 Gr. CF3 (2)	A 240 Gr. 304 (1)
	A 182 Gr. F304H	A 351 Gr. CF8 (1)	A 240 Gr. 304H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 800°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	230	600	800	1200	1800	3000	5000
300	205	540	720	1080	1620	2700	4500
400	190	495	660	995	1490	2485	4140
500	170	465	620	930	1395	2330	3880
600	140	435	580	875	1310	2185	3640
650	125	430	575	860	1290	2150	3580
700	110	425	565	850	1275	2125	3540
750	95	415	555	830	1245	2075	3460
800	80	405	540	805	1210	2015	3360
850	65	395	530	790	1190	1980	3300
900	50	390	520	780	1165	1945	3240
950	35	380	510	765	1145	1910	3180
1000	20	320	430	640	965	1605	2675
1050	. . .	310	410	615	925	1545	2570
1100	. . .	255	345	515	770	1285	2145
1150	. . .	200	265	400	595	995	1655
1200	. . .	155	205	310	465	770	1285
1250	. . .	115	150	225	340	565	945
1300	. . .	85	115	170	255	430	715
1350	. . .	60	80	125	185	310	515
1400	. . .	50	65	95	145	240	400
1450	. . .	35	45	70	105	170	285
1500	. . .	25	35	55	80	135	230

Table B-4. MSS SP-44 Steel Pipe Line Flanges (Pressure-Temperature Ratings Maximum Allowable Non-Shock Working Pressures in Pounds Per Square Inch - Gage)

TEMP. F	CLASS 150	CLASS 300	CLASS 400	CLASS 600	CLASS 900
-20 TO 250	285	740	990	1480	2220
300	275	715	955	1430	2145
350	265	690	925	1380	2070
400	255	665	890	1330	2000
450	245	640	860	1285	1925

References

ANSI Flanges: The American Standard
ANSI flange In the United States, ANSI (American National Standards Institute) flanges are widely used. ANSI B16.5 and ANSI B16.47 are two common standards, each with its specifications. The former is suitable for nominal pipe sizes from 1/2" to 24", while the latter covers larger sizes.

DIN Flanges: German Precision
Din flange Germany follows the DIN (Deutsches Institut für Normung) standards for flanges. DIN 2501 and DIN 2633 are notable specifications, offering precision and reliability. DIN 2501 is designed for nominal pressure ratings, while DIN 2633 focuses on welding neck flanges.
ANSI American National Standards Institute.

BS Flanges: British Standards
BS flange British industries follow BS (British Standards) for flanges. BS 10 and BS 4504 are prominent standards, with BS 10 emphasizing on nominal sizes and BS 4504 providing specifications for circular flanges.

ANSI B16.9 ,Factory-Made Wrought Steel Butt-Welding Fittings
. Provides requirements for carbon and alloy steel butt-welding fittings in pipe sizes 13 through 1,200 mm (1/2 through 48 in.).

ANSI B16.11, Forged Steel Fittings, Socket-Welding and Threaded
. Provides requirements for forged steel socket-welded and threaded fittings in sizes 3 through 100 mm (1/8 through 4 in.).

ASME, American Society of Mechanical Engineers.
ASME B16.5 Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24
ASME B16.47 Large Diameter Steel Flanges: NPS 26 Through NPS 60
ASME B16.48 Line blanks
ASME B16.36 Orifice Flanges
MSS SP-6 Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
ASME B16.20 Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed
ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges
ASME B18.2.1 Square and Hex Bolts and Screws, (Inch Series)
ASME B18.2.2 Square And Hex Nuts (inch Series)
ASTM A193 Standard Specification for Alloy-Steel and Stainless Steel Bolting for High

Temperature or High Pressure Service and Other Special Purpose Applications
ASTM A194 Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

ASTM, American Society for Testing and Materials.
AWWA, American Water Works Association.

Flange Class, A numerical designation given to a flange or flanged component that is used to indicate its allowable pressure/temperature rating. These designations are Class 150, 300, 400, 600, 900, 1500, and 2500, in accordance with ASME/ANSI B16.5.

MSS, Manufacturers Standardization Society of the Valve and Fittings Industry.

MSS-SP44, Steel Pipe Line Flanges. Provides flange dimensions for use in high pressure pipeline services in standard pipe sizes 300-1,500 mm (12-60 in.).
Piping & Valves, Flanges & Fittings: Types & Classes Saudi Aramco DeskTop Standards

NPS Standard, Nominal pipe size. For pipe sizes 350 mm (14 in.) and above, the nominal pipe size equals the outside pipe diameter.