



CTSA



Training For Saudization Group

INSPECT NEW PIPING

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ASNT –NDT-LEVEL III

ASME AUTHORIZED INSPECTOR

INTRODUCTION

Piping systems are like arteries and veins in the oil industry. Piping systems comprise of pipes, flanges, bolting, gaskets, valves etc. They also include pipe hangers, supporting elements and other items necessary to prevent over pressurization and overstressing of the pressure containing components. Hence, one can say that pipe section when fitted with valves and other mechanical equipment and properly supported by hangers and supports are called piping

The function of piping systems is to safely contain and convey fluids from one location to another. The following are general types of piping systems used for Saudi Aramco projects:

- ***Plant piping***
- ***Cross-country pipelines***

Plant piping is used within the boundaries of a process plant, such as a petroleum refinery or chemical plant. Plant piping transports liquids or gases from one item of plant equipment to another, or between plots within one plant area. Plant equipment consists of items such as compressors, furnaces, heat exchangers, pressure vessels, pumps, and storage tanks.

Cross-country pipelines are used outside the boundaries of process plants. They convey liquid petroleum, petroleum products, liquid-gas mixtures, or natural gas. Depending on the application, these pipelines connect plants or facilities such as wellheads, GOSPs, Pumping or compressing facilities, Oil termination and shipping facilities, Refineries and chemical plants, Temporary storage facilities, Gas treating, Gas metering and regulation, Gas mains, Gas service to end users.

The Piping Inspector shall be knowledgeable on all aspects and components of a piping system including the following:

- *Pipes*
- *Fittings*
- *Joints*
- *Valves*
- *Supports and hangers*
- *Insulation*

Furthermore, the Inspector shall also be required to inspect cross-country pipelines including:

- *Underground pipelines*
- *Aboveground pipelines*

INSPECT PIPES

Pipe is a pressure-tight cylinder used to convey a fluid or to transmit a fluid pressure and conforms to the dimensional requirements of:

- **ASME B36.10M Welded and
Seamless Wrought Steel Pipe**
- **ASME B36.19M Stainless Steel
Pipe**

The Inspector verifies that the pipe conforms to the project specification and design drawings. The following five items should be verified for the pipe:

- Nominal pipe size (NPS)*
- Pipe wall thickness (Schedule number)*
- Method of fabrication*
- Pipe Material*
- Piping Class*

Nominal Pipe Size

Nominal pipe size (NPS) is a dimensionless designator of pipe size. It indicates standard pipe size when followed by the specific size designation number without an inch symbol. For NPS 12 and smaller, the pipe has an outside diameter greater than the size designator. However, for NPS 14 and larger, the pipe diameter will be the same as the size designator in inches.

For example, for a NPS 2, the Inspector should verify that the pipe outside diameter is 2.375 in. For NPS 14 pipe, the Inspector shall measure an outside diameter equals to 14 in. The inside diameter will vary depending on pipe wall thickness (or schedule number).

Pipe Wall Thickness

Pipe wall thickness is expressed by the term schedule. The inspector checks the schedule number, such as 5, 5S, 10, 10S, 20, 20S, 30, 30S, 40, 40S, 60, 80, 80S, 100, 120, 140, 160.

A schedule number indicates the approximate value of the expression $1000 P/S$, where P is the service pressure and S is the allowable stress, both expressed in pounds per square inch (PSI). The higher the schedule number, the thicker the pipe is. The suffix “S” is added to schedule number to differentiate between stainless steel from carbon steel.

Pipe Material

Pipe for plant applications shall be seamless or single-longitudinal seam submerged arc-welded and conform to one of the following:

- *API Spec 5L, Grade B through X60.*
- *ASTM A53, Seamless Grade B, black (not galvanized).*
- *ASTM A106, Grade B.*

Pipe for cross-country pipelines shall conform to one of the following: Electric Resistance Welded (ERW) pipe in accordance with 01-SAMSS-033 or API 5L, Electric Welded Line Pipe or Spiral-welded pipe in accordance with 01- SAMSS-035, API Line Pipe. If 01-SAMSS-035 pipe is not available, API 5L or ASTM A106 pipe may be used, provided it meets the chemical composition and hardness test requirements that are specified in 01- SAMSS-035. For wet, sour service, the pipe must be seamless, or conform to 01-SAMSS-016, Sour, Wet Service Line Pipe, for welded pipe.

Piping Class

A document indicating the dimensional material specifications of pipes, fittings and valve types is called piping class. Each class represents distinct features such as pressure-temperature conditions, corrosion resistance and strength abilities or combination. The Piping Inspector verifies the pipe class, which is designated by 4-alpha-numeric fields containing one or two characters each as follows

INSPECT PIPE FITTINGS

Pipe fittings are used extensively in process plants as well as other piping systems. They serve the overall process in many aspects, such as:

- *Change the flow direction.*
- *Bring two or more pipes together.*
- *Divert a single flow into two branching flows or more.*
- *Alter the pipe diameter.*
- *Tap the process for temperature or pressure readings.*
- *Terminate a pipe.*

There are several ways or techniques for connecting a fitting to a pipe. For the most part, the Inspector should be familiar with the following techniques.

- *Threading.*
- *Socket-welded.*
- *Butt-welded.*

Note: More information on connection techniques will be given later in the Module.

There are many types of pipe fittings. Some are standard types; others could be proprietary controlled by patent regulations. Nonetheless, one of the duties of a Saudi Aramco Inspector is to confirm that the fittings used for the project are sourced from an approved manufacturer per SAES-L-101. The two primary design standards that are used for pipe fittings are:

- *ASME B16.9, Factory-Made Wrought Steel Butt-Welding Fittings.*
- *ASME B16.11, Forged Steel Fittings, Socket-Welding and Threaded.*

ASME B16.11, Forged Steel Fittings, Socket-Welding and Threaded, contains a basis for pressure/temperature ratings for these piping components. Threaded fittings are designated as Pressure Class 2000, 3000 and 6000. Socket-welded fittings are designated as Pressure Class 3000, 6000, or 9000.

The following table summarizes the pipe schedule that corresponds to each fitting pressure class for rating purposes:

RATING OF THREADED AND SOCKET WELD FITTINGS

Type of Fitting	Pressure Class of Fitting	Pipe Used for Schedule No.	Rating Basis Wall Designation
Threaded	2000	80	XS
	3000	160	XS
	6000	160	XXS
Socket-Welded	3000	80	XS
	6000	160	XS
	9000	160	XXS

The Inspector shall also be able to differentiate between the standard types of fittings, such as (See also Figure 1):

- *Elbows*
- *Tees*
- *Laterals*
- *Couplings*
- *Caps & Plugs*
- *Stub-ends*

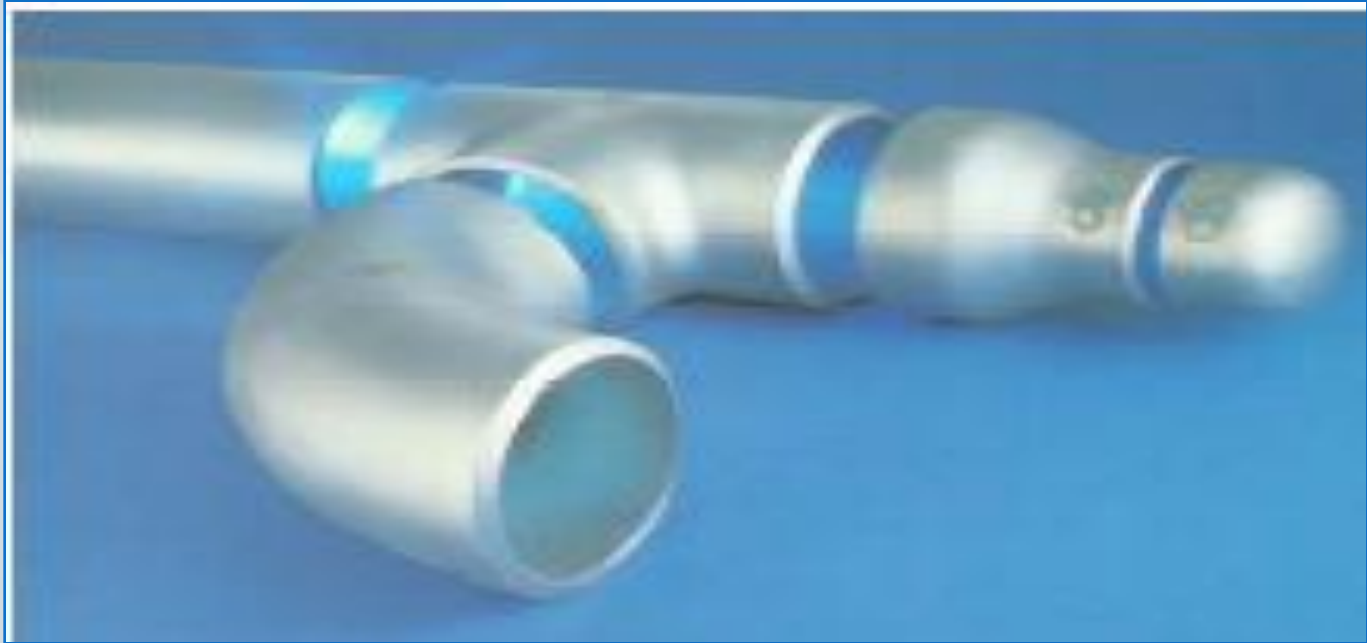


FIGURE 1. MOST COMMON TYPES OF FITTINGS

Elbows

Elbows are used to change the direction of a pipe run. Standard elbows change the direction by either 45° or 90°. Long-radius elbows have a bend radius of 1-1/2 times the nominal pipe size, and short-radius elbows have a bend radius equal to the nominal pipe size. The long-radius elbow is more commonly used. Short-radius elbows are normally only used if there is a space restriction for the piping system layout.

For butt-welded elbows, the Inspector should verify the wall thickness, which should be identical to that of the adjacent pipe sections, since it is normally made from comparable material. However, the thickness at the crotch, inner section, shall be thicker than the nominal wall thickness and at least 10% for grade B as required by 02-SAMS-005. Small-bore elbows, 2 inches and smaller, are usually forged and very thick.

The Inspector verifies that street elbows, one end with female threads and the other end with male threads (Figure 2X), will not be used as per the requirements of SAES-L-105. Additionally, reducing elbows are not permitted. The Inspector checks to verify that no drain, vent, or other branch connection to elbows is present.

Figure 2. Types of Elbows



Butt Welded End 90 ° Elbow



Threaded 90 ° Elbow



Street Threaded 90 ° Elbow

TEES AND CROSSES

As shown in Figure 3, tees provide for the intersection of three sections of pipe. A straight tee has equal diameters for both the run and branch pipe connections. A reducing-outlet tee has a branch diameter, which is smaller in size than the run diameter.

A cross is a special type of tee, which permits the intersection of four sections of pipe. A cross is rarely seen in process plant applications. As shown in Figure 3, crosses are a special type of fittings that combines flow from three directions into one or visa versa.

Tees and crosses are mostly used in plant utility piping, such as instrument air or Nitrogen lines. Tees are designed with extra thickness in the area where the branch connects with the run. The extra thickness provides reinforcement to compensate for the strength reduction that is caused by the hole cut in the run. The Inspector should verify that no street tees (with male threads) are used per SAES-L-105.

FIGURE 3. VARIOUS TYPES OF TEES AND CROSSES



Full Size Welded tee



SOCKET WELDED TEE



THREADED FULL SIZE TEE



Threaded Cross



Seamless Reducing Tee



Socket Weld Cross

Reducers

Reducers change the diameter in a straight section of pipe, and are either of the concentric or eccentric type (See Figure 4). The centerlines of the large and small diameter ends coincide in a concentric reducer, whereas they are offset in an eccentric type. Eccentric reducers simplify the support point structural design of horizontal pipe runs by keeping both pipe diameters at the same bottom-of-pipe elevation. The wall thickness of a reducer will typically be identical to that of the adjacent pipe sections, since they are made of comparable material.

FIGURE 4.

SOCKET SET REDUCERS



Laterals

Laterals are special types of tees as shown in Figure 5. In this case, the branch connection enters the header at an angle, normally 45° . A lateral is used in situations where it is necessary for the two flow streams to combine in a less abrupt transition than provided by a standard 90° tee.

FIGURE 5.

THREADED COUPLINGS



Seamless Y-Lateral



BUTT WELDED
LATERAL



SOCKET WELD
LATERAL

Couplings or Half-Couplings

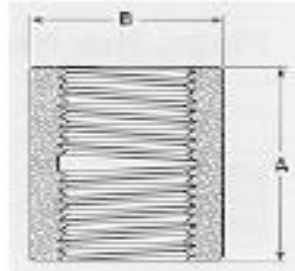
Figure 6 shows various types of couplings, full or half, which are primarily used to make an attachment between a 38-mm (1-1/2 in.) or smaller diameter pipe and a larger diameter header. A coupling is also sometimes used to connect two small diameter pipe sections, rather than butt welding them together.

FIGURE 6.

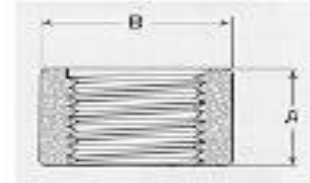
THREADED AND SOCKET- WELDED COUPLINGS



Threaded full coupling



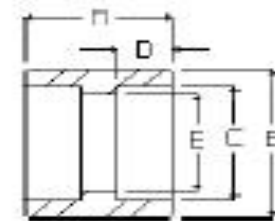
Threaded full coupling



Threaded half coupling



Socket weld full coupling



Socket weld full coupling

Pipe Caps and Plugs

As shown in Figure 7, pipe caps are used to close off the end of a pipe section. This is analogous to the head on a pressure vessel. A pipe cap rather than a blind flange is used in situations where it is known that the pipe end will not have to be opened.

The wall thickness of a butt-welded pipe cap will typically be identical to that of the adjacent pipe section. For 2 inch-diameter piping and smaller, a threaded or socket weld cap may be used. Also, a pipe plug serves the same purpose in a threaded or socket-welded piping system, where the plug will close the coupling or the welding boss.

The Inspector verifies that caps and plugs are properly tightened to preclude any leakage. Additionally, the Inspector must check that the plug is of the round-headed type as opposed to a hexagonal or square type per the requirements of SAES-L-105.

FIGURE 7.

CAPS AND PLUGS



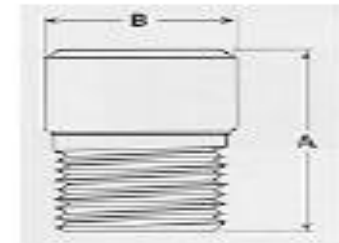
Threaded cap



Butt welded cap



Threaded pipe plug



Threaded pipe plug

Integrally Reinforced Branch Connections

A welding outlet fitting, or integrally reinforced branch connection, shown in Figure 8, is another method of fabricating an intersection between two sections of pipe. This type of forged fitting is designed such that all the reinforcement required to strengthen the opening is contained within the forged fitting itself.

The hole is cut in the header pipe and the fitting is then welded to it. A welding outlet fitting is often a less expensive alternative to a butt-welding tee, and is often used as a substitute. It also may be the preferred option when designing branch connections into large-diameter headers for high pressure or high-temperature conditions, rather than using welded-on reinforcement pads.

Using Figure 9 of SAES-L-110, the Inspector should be able to check the selection of branch fittings for new construction based on header and branch sizes. The type of branch fittings are classified as follows:

Region 1: Equal tee

Region 2: Reducing tee

Region 3: Reducing tee or branch weld with reinforcing pad or full encirclement sleeve

Region 4: Weldolet or branch weld with reinforcing pad

Region 5: Weldolet, sockolet, threadolet, or welding boss per SASD AE-036175 and AE-036643 (See Addendum B).

For example, the Inspector notes that a 2" branch is connected to a 4" header. From Figure 9 (or Chart 1 in SAES-L-110), he finds out that the branch connection should be a reducing tee.

The Inspector must also check that the following items related to branch connections:

- A maximum tolerance of ± 3 mm from design drawings for the location of connections shall not be exceeded per SAES-L-350***
- The lateral transition of branches and connections from the centerline of the run shall not exceed ± 1.5 mm per SAES-L-350***
- Branch connections, 4 inch and smaller, including drain and vent valves and drip legs of all sizes, shall be located at a minimum horizontal distance of 610 mm (24 inches) from any fixed obstruction per SAES-L-310***

FIGURE 8.

INTEGRALLY REINFORCED BRANCH CONNECTIONS



Weldolet



Flanged Pipet



Nozzelet



Nipple Pipet

INSPECT PIPE JOINTS

As discussed earlier for pipe fitting connections, the Inspector should be knowledgeable on the main pipe jointing methods:

- *Threaded Joints*
- *Welded Joints*
- *Flanged Joints*

Threaded Joints

A threaded fitting has pipe threads machined into its bore. The fitting is screwed into matching threads on the pipe end. Threaded fittings are easy to install and useful in areas where frequent maintenance mandate assembling and disassembling process frequently.

It has been the general industry practice to avoid threaded connections as much as possible in flammable and toxic services. As per SAES-L-110, threaded joints should be avoided in any service where crevice corrosion, severe erosion, or cyclic loading may occur.

For threaded joints, the following items needs to be confirmed by the Inspector:

- *Maximum joint size*
- *Seal welding*
- *Thread engagement*

Maximum Joint Size



In hazardous services, the Inspector should confirm that the maximum size of threaded connections is no more than 1½ inches for standard fittings and valves. 2-inch joint connections may be used when required for maintenance, minor field modifications of existing piping systems, and to match threaded specialty devices such as scraper signals and access fittings for corrosion monitoring.

In non-hazardous services, the Inspector should confirm the maximum size of threaded connections is no more than 3 inches for standard fittings and valves, and 4 inches maximum on special items such as fire hydrants unless a larger size is approved by the assigned Chairman, Piping Standards Committee for the specific application:

Seal welding

ASME B31.3 defines seal welding as a weld intended primarily to provide joint tightness against leakage in metallic piping. In Saudi Aramco, seal welding is required for threaded joints in flammable and toxic services per SAES-L-110.

Where seal welding is required, the seal weld shall be a fillet weld going from the outer diameter of the female part, and it should be smooth with slight concavity as allowed by ASME B31, to the male part covering all exposed threads without undercut. The Inspector should check that no PTFE (Teflon) tape or joint compounds are used in threaded connections requiring seal welding. The limitations on seal welding are given as below:

Seal welding of all threaded joints up to the first block valve is required in the following services and applications:

- *All hydrocarbons.*
- *Boiler feed water, condensate, and steam systems utilizing ASME Class 300 and higher flange ratings.*
- *Toxic materials such as chlorine, phenol, hydrogen sulphide, etc.*

- *Corrosive materials such as acid, caustic, etc.*
- *Oilfield chemicals (e.g., corrosion inhibitors, emulsifiers, electrolytes, etc.)*
- *Piping which is subject to vibration, whether continuous or intermittent*

Seal welding is not required for the following services and applications:

- *Thermowells*
- *Bar stock plugs downstream of a seal-welded block valve.*
- *Special devices such as access fittings and scraper signals.*
- *Joints which require frequent disassembly and are located downstream of a seal welded block valve, e.g., sample connections*

- *Instrument piping downstream of the primary instrument isolation valve.*
- *Pipe union ring threads and joints with elastomeric o-rings.*
- *Threaded joints, downstream of a seal welded root valve, which discharge directly to an open drainage system or to the atmosphere.*
- *Extended body valves with integrally reinforced welding end per API STD 602.*

Thread Engagement

A minimum thread engagement must be maintained to insure integrity of the threaded connection and to preclude possibility of leakage. The minimum length of the engaged threads pipe shall meet the requirements of ASME B1.20.1 for taper pipe thread. The minimum number of engaged pipe threads shall meet the requirements of the following table.

Thread Engagement Requirements for Taper Pipe Threads

<i>Nom. Pipe Size</i>	<i>Number of Threads Engaged</i>
<i>1/2" & 3/4"</i>	<i>6</i>
<i>1" through 1- 1/2"</i>	<i>7</i>
<i>2" through 3"</i>	<i>8</i>
<i>4"</i>	<i>10</i>

Welded Joints

Welding is one of the primary ways of joining pipe. Welded joints represent the ultimate in safety and reliability.

As discussed in PEW-402 (Welding Inspection I), welding should be carried out using a qualified procedure and welders. Included in the standard procedure are base-metal specifications, electrode, joint preparation, weld position, welding process, techniques, electrical details, preheat and interpass temperatures, and post-weld heat treatment requirements.

The Inspector should follow the same sequence for pre-welding and welding inspection as detailed in PEW-402 and PEW-403, respectively. Specific information related to pre-welding and welding inspection for piping joints will be briefly discussed in this module, such as:

- *Preparation for welding*
- *Cleaning*

- *Joint preparation*
- *Positive Material Identification*
- *Pre-heating*
- *Post weld heat treatment*

In addition, this module will briefly discuss the standard requirements, including ASME B31, for the three types of welding joints i.e. butt-welded, socket, and fillet joints.

Preparation for Welding



Before any welding is done, the specific details of how it will be carried out, i.e. the welding procedure must be specified and demonstrated to achieve acceptable results. Each of the ASME/ANSI B31 Codes, plus modifications contained in SAES-W-011 or SAES-W-012 as applicable, specify welding procedure qualification requirements.

Welding procedure qualification demonstrates that the approach specified for doing the weld will achieve acceptable results when properly applied. The next step is to qualify the particular welders and welding equipment to carry out the specific welding procedure. Here again, the relevant ASME/ANSI B31 Code plus Saudi Aramco requirements must be met. SAEP-324 specifies how to register certified welder and provide JCC. The result of these two steps is that both the welding procedure, and the individuals and equipment executing it, have been confirmed to produce acceptable results.

Cleaning

Internal and external surface to be thermally cut or welded shall be clean and free from paint, oil, rust, scale, or other material that would be detrimental to either the weld or base metal when heat is applied. If such items are not cleaned, they could mix with the weld metal at elevated temperatures and result in poor quality welds.

END PREPARATION

The ends of the components to be welded must be set to the correct geometric shape suitable for the materials, wall thickness, and welding process involved. Joint design shall comply with the following:

➤ When wall thickness ratio of joined pipes is less than or equal to 1.5, joint design details shall comply with the respective ASME B31 design code.

- *When wall thickness ratio of joined pipes is greater than 1.5, end preparations and geometry shall comply with ASME B16.25 "Butt Welding Ends". Refer to Figure 13 for graphic details of joint design per ASME B31.4*
- *When the wall thickness of the fitting or pipe at the welding end exceeds the wall thickness of the matching pipe resulting in an unequal external and/or internal diameters, the welded joint design shall comply with Fig. 434.8.6(a)-(2) of ASME B31.4 (See Figure 13).*

End preparation is acceptable only if the surface is reasonably smooth and true, and slag from oxygen or arc cutting is cleaned from thermally cut surfaces. Discoloration that remains on a thermally cut surface is not considered to be detrimental oxidation.

POSITIVE MATERIAL IDENTIFICATION

An alloy is used (including welding filler materials), such as chromium, nickel, or molybdenum, to enhance mechanical or physical properties and/or corrosion resistance of the material (pipes, fittings, valves, etc).

In order to verify conformance for the use of alloys and their respective constituents, SAES-A-206 requires positive material identification (PMI) be conducted on the alloying elements. PMI is a physical evaluation or test of a material to confirm that the material that has been or will be placed into service is consistent with the selected or specified alloy material.

Typically, the alloys required to be verified are listed in the following table.

Basic Alloy	Elements to be Verified
Carbon-Molybdenum, Manganese-Molybdenum, and Chromium-Molybdenum steels	Chromium and Molybdenum
Nickel steels	Nickel
Regular carbon grade stainless steels	Chromium, Nickel, and Molybdenum
Low-carbon stainless steels	Chromium, Nickel, Molybdenum, and Carbon
Stabilized stainless steels	Chromium, Nickel, Molybdenum, Titanium and Niobium
Nickel-based alloys	Nickel, Iron, Copper, Chromium, and Molybdenum
Copper-based alloys	Copper, Zinc, and other elements specified in purchase order or SAMS catalog description

PREHEATING

This is used, along with heat treatment, to minimize the detrimental effects of high temperature and severe thermal gradients that are inherent in welding. The necessity for preheating and the temperature to be used shall be specified in the engineering design and stated by procedure qualification. The following identifies specific benefits of preheating:

- *Dries the metal and removes surface moisture, which, if present, would result in porosity of the weld metal.*
- *Reduces the temperature difference between the base metal and the weld to reduce the cooling rate of the weldment, lowers the weld hardness to reduce residual stresses, and reduces cooling/shrinkage stresses.*

- *Helps maintain the weld pool molten for a longer time to permit maximum fluxing and separation of impurities.*
- *Helps drive off absorbed gases (such as hydrogen) which could contribute to weld porosity.*

The Inspector should review specific preheat temperature requirements as specified in ASME/ANSI B31 Codes based on the base metal (P or S numbers), weld metal (A number) and wall thickness that are being joined (See Figure 11). As per SAES-W-011, The preheat temperature shall be established over a minimum distance of 75 mm on each side of the weld.

Note: For more information on pre-heating, refer to Welding Inspection Course PEW-402.

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-No. [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Min. Temperature			
			mm	in.	MPa	ksi	Required		Recommended	
							°C	°F	°C	°F
1	1	Carbon steel	< 25	< 1	≤ 490	≤ 71	...	...	10	50
			≥ 25	≥ 1	All	All	...	...	79	175
			All	All	> 490	> 71	...	...	79	175
3	2, 11	Alloy steels, Cr ≤ 1/2%	< 13	< 1/2	≤ 490	≤ 71	...	...	10	50
			≥ 13	≥ 1/2	All	All	...	...	79	175
			All	All	> 490	> 71	...	...	79	175
4	3	Alloy steels, 1/2% < Cr ≤ 2%	All	All	All	All	149	300	...	...
5A, 5B, 5C	4, 5	Alloy steels, 2 3/4% ≤ Cr ≤ 10%	All	All	All	All	177	350	...	...
6	6	High alloy steels martensitic	All	All	All	All	...	...	149 ³	300 ³
7	7	High alloy steels ferritic	All	All	All	All	...	...	10	50
8	8, 9	High alloy steels austenitic	All	All	All	All	...	...	10	50
9A, 9B	10	Nickel alloy steels	All	All	All	All	...	...	93	200
10	...	Cr-Cu steel	All	All	All	All	149-204	300-400	...	...
10I	...	27Cr steel	All	All	All	All	149 ⁴	300 ⁴	...	...
11A SG 1	...	8Ni, 9Ni steel	All	All	All	All	...	...	10	50
11A SG 2	...	5Ni steel	All	All	All	All	10	50	...	...
21-52	...	...	All	All	All	All	...	...	10	50

NOTES:

- (1) P-Number or S-Number from BPV Code, Section IX, QW/QB-422.
- (2) A-Number from Section IX, QW-442.
- (3) Maximum interpass temperature 316°C (600°F).
- (4) Maintain interpass temperature between 177°-232°C (350°F-450°F).

POST WELD-HEAT TREATMENT

Post weld heat treatment (PWHT) is used to avert or relieve the detrimental effects of high temperature and severe temperature gradients that are inherent in welding, and to relieve residual stresses that are created by bending and forming.

The following summarizes the principal reasons for PWHT:

➤ *Stress relief is the most common reason for specifying PWHT, and is the only consideration for the requirements that are specified in the ASME/ANSI B31 Codes. Residual stresses will remain in the pipe and result from shrinkage as the weld and adjacent pipe metal cool down from elevated welding temperatures. Residual stresses will also remain after bending or forming processes.*

- *After welding the normal grades of stainless steels (i.e., those that are not stabilized with alloy additions), it is necessary to heat-treat the material to restore maximum corrosion resistance.*
- *PWHT is required to prevent caustic embrittlement of welded carbon steel pipe that handles alkaline solutions. Caustic embrittlement is a form of stress corrosion where the residual stresses due to welding are sufficient to cause failure.*

➤ *PWHT is sometimes necessary to reduce weld hardness in certain materials. Minimizing weld hardness reduces the tendency to crack, especially in certain process environments such as caustic or wet H₂S.*

Specific heat treatment temperature and procedure requirements are specified in the appropriate ASME/ANSI B31 codes based on the pipe material and wall thickness being joined (See Figure 12). In case of welded components of varying thicknesses, the Inspector should use the higher thickness value for PWHT determination.

Note: For more information on PWHT, refer to Metal Technology Course PEW-401.

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-Number [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Metal Temperature Range		Holding Time		Min. Time, hr	Brinell Hardness, [Note (4)] Max.
			mm	in.	MPa	ksi	°C	°F	Nominal Wall [Note (3)]			
1	1	Carbon steel	≤ 19 > 19	≤ ¾ > ¾	All All	All All	None 593-649	None 1100-1200	... 2.4	... 1	... 1	
3	2, 11	Alloy steels, Cr ≤ 1½%	≤ 19 > 19	≤ ¾ > ¾	≤ 490 All	≤ 71 All	None 593-718	None 1100-1325	... 2.4	... 1	... 1	... 225
4 ¹⁰	3	Alloy steels, ½% < Cr ≤ 2%	≤ 13 > 13	≤ ½ > ½	≤ 490 All	≤ 71 All	None 704-746	None 1300-1375	... 2.4	... 1	... 2	... 225
5A, 10, 5B, 10, 5C ¹⁰	4, 5	Alloy steels, (2¾% ≤ Cr ≤ 10%) ≤ 3% Cr and ≤ 0.15% C ≤ 3% Cr and ≤ 0.15% C > 3% Cr or > 0.15% C	≤ 13 > 13 All	≤ ½ > ½ All	All All All	All All All	None 704-760 704-760	None 1300-1400 1300-1400	... 2.4 2.4	... 1 1	... 2 2	... 241 241
6	6	High alloy steels martensitic A 240 Gr. 429	All All	All All	All All	All All	732-788 621-663	1350-1450 1150-1225	2.4 2.4	1 1	2 2	241 241
7	7	High alloy steels ferritic	All	All	All	All	None	None	...	...	...	...
8	8, 9	High alloy steels austenitic	All	All	All	All	None	None	...	...	...	...
9A, 9B	10 ...	Nickel alloy steels	≤ 19 > 19	≤ ¾ > ¾	All All	All All	None 593-635	None 1100-1175	... 1.2	... ½	... 1	
10	...	Cr-Cu steel	All	All	All	All	760-816 [Note (5)]	1400-1500 [Note (5)]	1.2	½	½	...

Figure 12. Requirements for Post weld heat treatment (ASME B31.3)

BUTT-WELDS

Butt-welds are made between two components whose edges are in close proximity. Butt-welded joints in piping systems are primarily of the single-V configuration and are welded from the pipe outside surface. Larger diameter pipes, which can be accessed from the inside will often be welded from both sides using a double-V type of joint preparation.

The joint preparation and the procedure that is used ensure that there is complete fusion between the edges of the components being joined. Joint designs per ASME B31.3 or B31.4 shown in Figure 13 or applicable combinations of these joint design details are typically used for ends of equal thickness.

The transition between ends of unequal thickness may be accomplished by taper-grinding the thicker pipe to match the thinner, or by using weld metal to provide a smooth transition per ASME B31.3 or B31.4 as shown in Figure 14. A prefabricated thickness transition section of not less than one-half pipe diameter in length is another means to make the change between pipe thicknesses. Component ends may also be trimmed to allow for fitting a backing ring (See Figures 15 a, b). A backing ring is a material in the form of a ring whose primary function is to support molten weld metal. Where component ends are trimmed, the Inspector should verify that the remaining net thickness of the finished ends is not less than the minimum required wall thickness for the service conditions.

An alternative to a backing ring is the consumable insert. A consumable insert is a pre-placed filler metal that is completely fused into the root of the joint and becomes part of the weld.

Figure 328.3.2 of ASME B31.3 shows typical backing rings and consumable inserts (See Figure 15). ASME B 31.3 requires that backing rings be removed where the resultant crevice associated with backing rings is subject to corrosion, vibration or severe cyclic condition (para. 311.2.3).

In case of orifice flanges, SAES-J-100 requires that flanges be weld-neck (as opposed to threaded or flanged) with an internal bore to match the pipe ID. If backing rings are used, then the Inspector has to verify their removal and confirm that the butt weld is ground flush at the root inside the pipe per SAES-J-100. When it is impractical to remove the backing ring, consideration shall be given to welding without backing rings or through the use of consumable inserts.

It is permissible to size pipe ends to be of the same nominal size to improve alignment if wall thickness requirements are maintained.

Where necessary, weld metal may be deposited inside or outside the component to permit alignment or provide for machining to ensure satisfactory seating of rings or inserts.

Butt-welds will always be used to weld pipe ends together, to weld butt-weld-type flanges or fittings to pipe ends, or to weld the edges of formed plate together when plate is used to manufacture pipe.

Figure 13. Acceptable Butt-Welded Joint Design for Equal Wall Thickness (ASME B31.4)

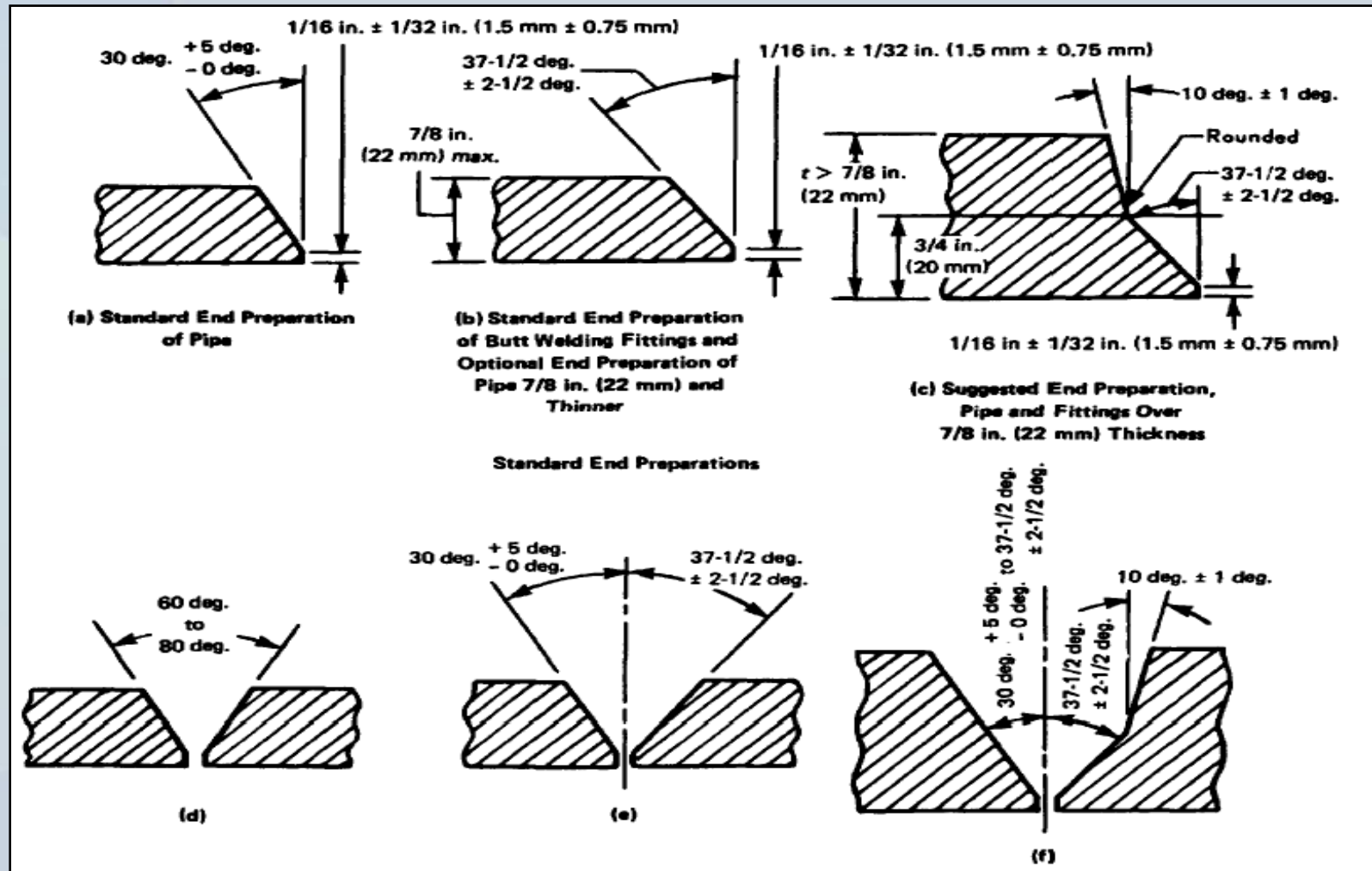


Figure 14. Acceptable Butt-Welded Joint Design for Unequal Wall Thickness (ASME B31.4)

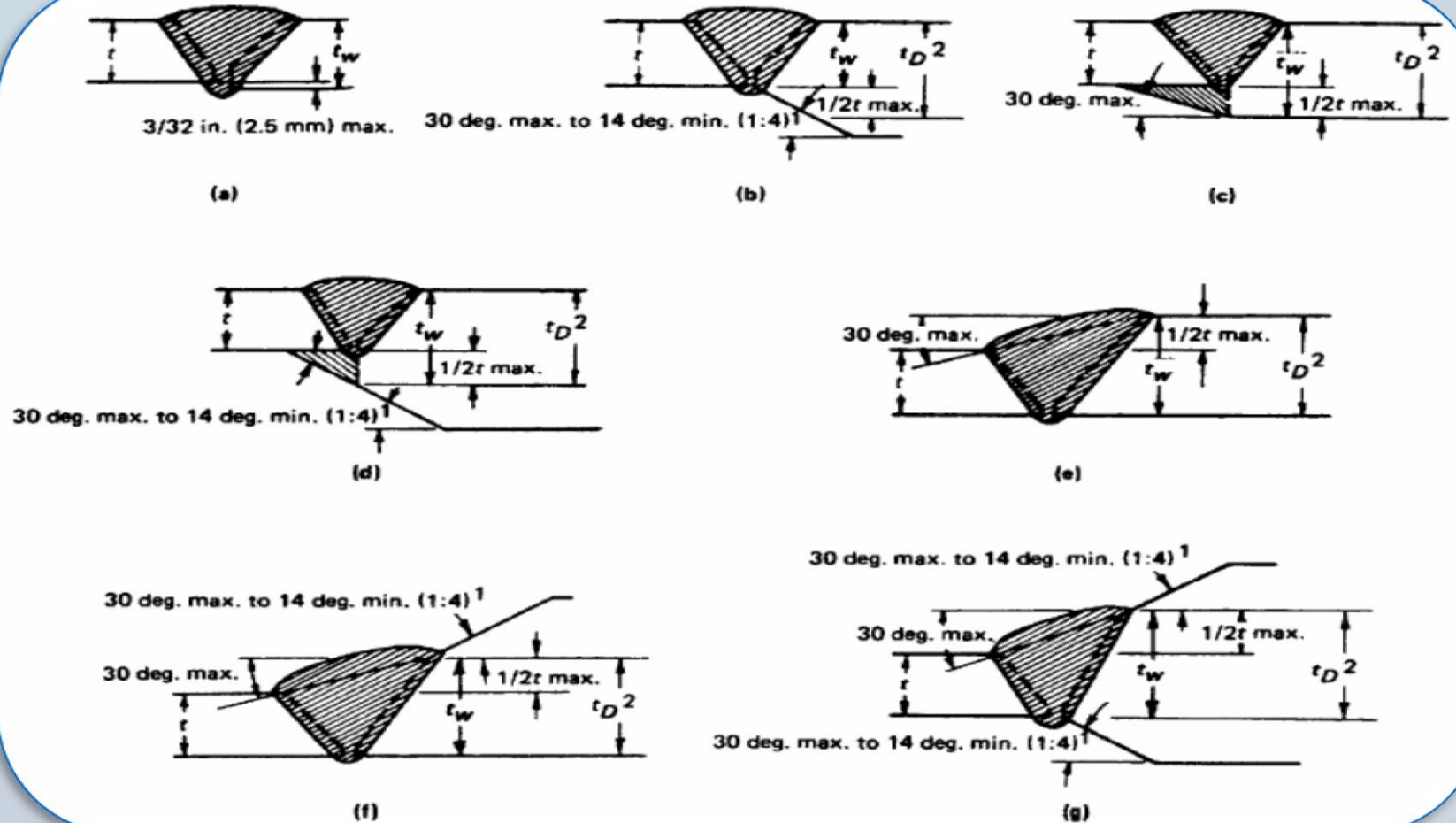
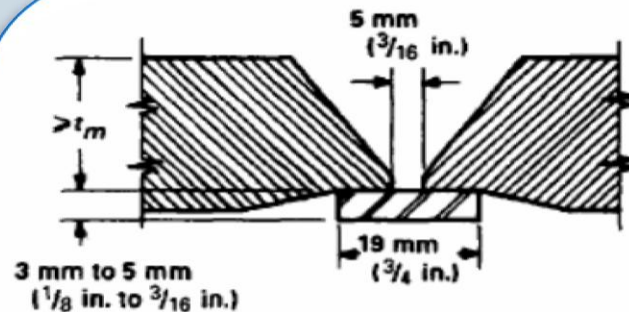
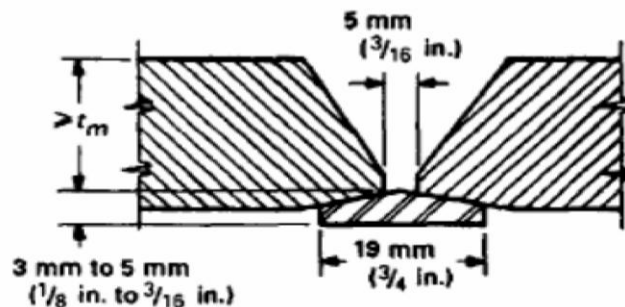


Figure 15. Typical backing rings and consumable inserts (ASME B31.3)



(a) Butt Joint With Bored Pipe Ends and Solid or Split Backing Ring [Note (1)]



(b) Butt Joint With Taper-Bored Ends and Solid Backing Ring [Note (1)]

NOTE:

(1) Refer to ASME B16.25 for detailed dimensional information on welding ends.



(c) Nonmetallic Removable Backing Ring (Refractory)

Typical Consumable Inserts



(d) Square Ring or Round Wire Type



(e) Flat Rectangular Ring



(f) Formed Ring Type



(g) Y-Type

SOCKET WELDS



A socket-welded-type fitting attachment is designed with a recess in its end to permit the pipe to be inserted. The Inspector should confirm that the pipe is withdrawn approximately 1.5 mm (1/16in.) from the bottom of the recess. The gap is needed in order to provide space to permit differential thermal expansion, which occurs during welding and normal operation. Experience has shown that without this gap the potential to develop cracks in the fillet weld is very high due to weld contraction.

It should be noted that this gap should be provided prior to welding only. Nevertheless, if the Inspector notes that the gap has closed after the completion of welding and no cracks have developed; then there should be no worries. The axial gap shall be maximum of 3 mm and minimum of 1.5 mm as per Fig. 328.5.2 C of ASME B 31.3 code (See Figure 16).

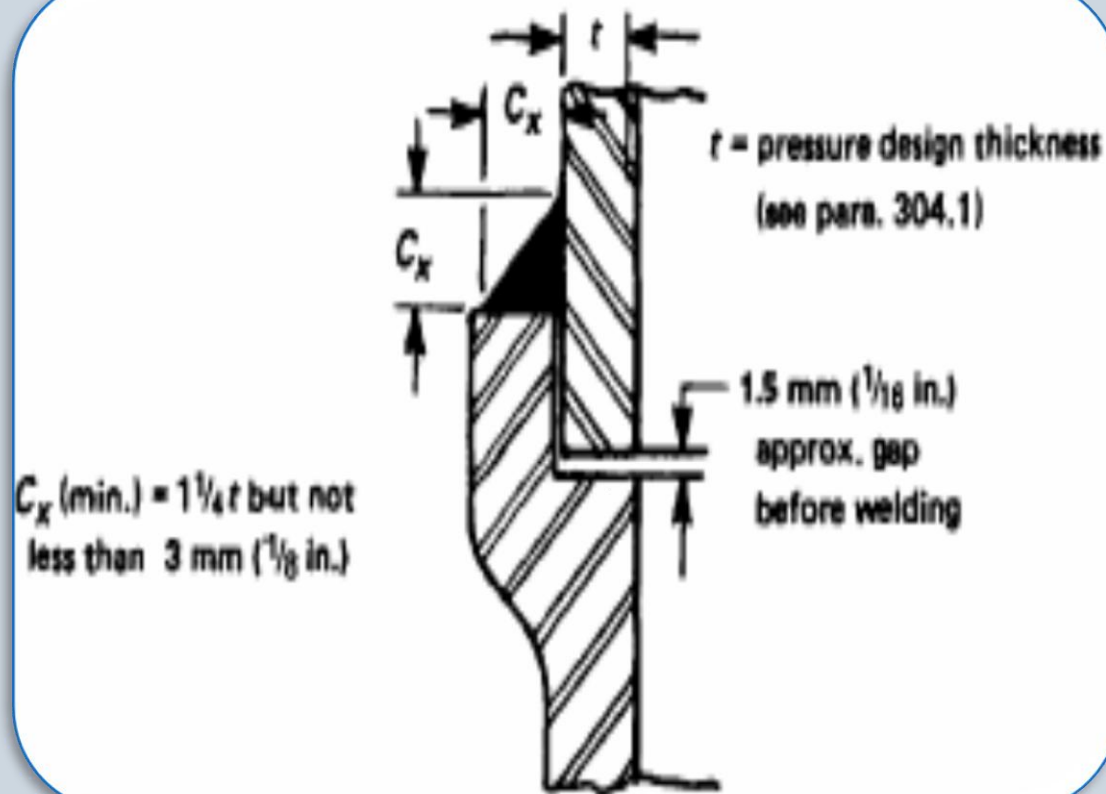


Figure 16. Minimum welding dimensions for socket welding components (ASME B31.3)

Similar to threaded joints, the Inspector should verify that the maximum size of socket-welded joints in hazardous services is 1½ inches for new construction (SAES-L-110). The Inspector should allow for a maximum joint size of 2 inches in hazardous service for maintenance, minor field modifications of existing piping systems, and when necessary to match existing equipment connections.

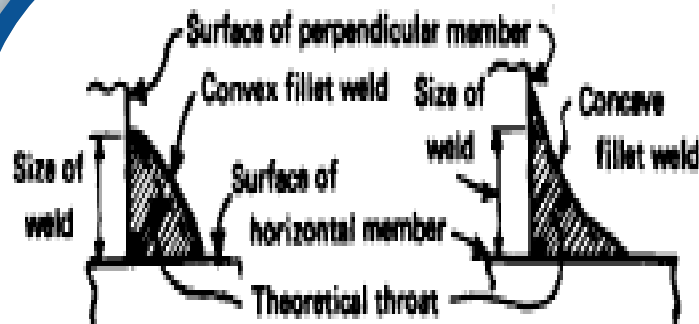
For sour service, the Inspector should not allow socket-welded joints to be used. However, in case they could not be avoided, the maximum size of socket-welded joints shall be 1 inch (SAES-L-110). Generally, socket welded joints should be avoided in any service where crevice corrosion, severe erosion, or cyclic loading may occur.

FILLET WELD

A fillet weld consists of an angular weld bead that joins components positioned normally at a 90° angle to each other. Fillet welds may be concave to slightly convex in shape.

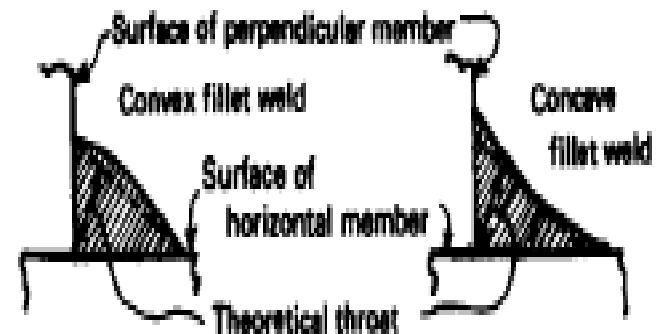
The size of a fillet weld is stated as a leg length of the largest inscribed right isosceles triangle as shown in Figure 17.

Figure 17. Size of fillet weld (ASME B31.3)



Equal Leg Fillet Weld

GENERAL NOTE: The size of an equal leg fillet weld is the leg length of the largest inscribed isosceles right triangle (theoretical throat = $0.707 \times \text{size}$).

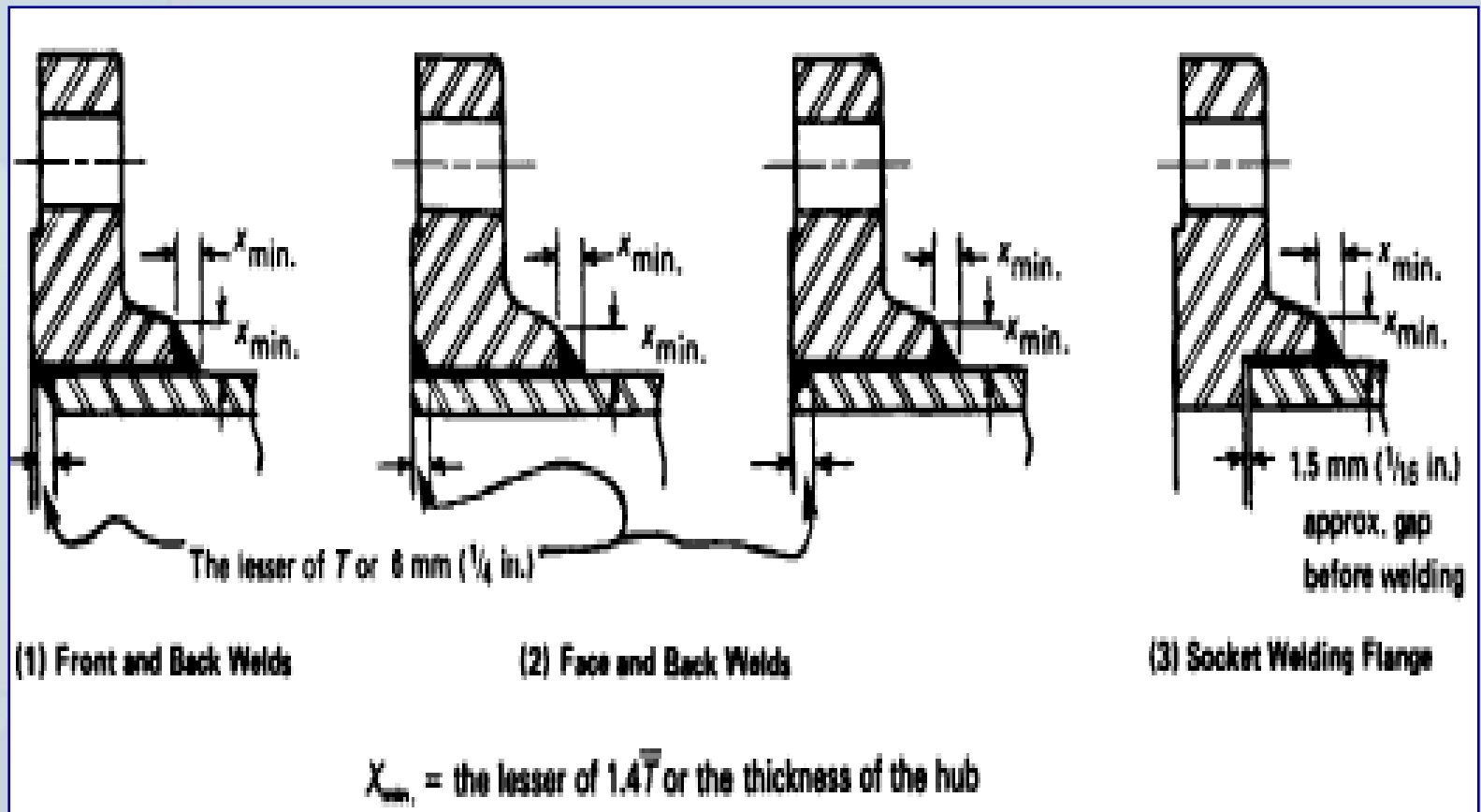


Unequal Leg Fillet Weld

GENERAL NOTE: The size of unequal leg fillet weld is the leg lengths of the largest right triangle which can be inscribed within the weld cross section, e.g., 13 mm x 19 mm ($\frac{1}{2}$ in. x $\frac{3}{4}$ in.).

In piping systems, fillet welds are only used for slip-on flanges (Figure 18), socket welds, and for welding attachments to piping components (e.g., reinforcing pads, supports, etc.).

Figure 18. Fillet welds for slip-on flanges (ASME B31.3)



FLANGED JOINTS

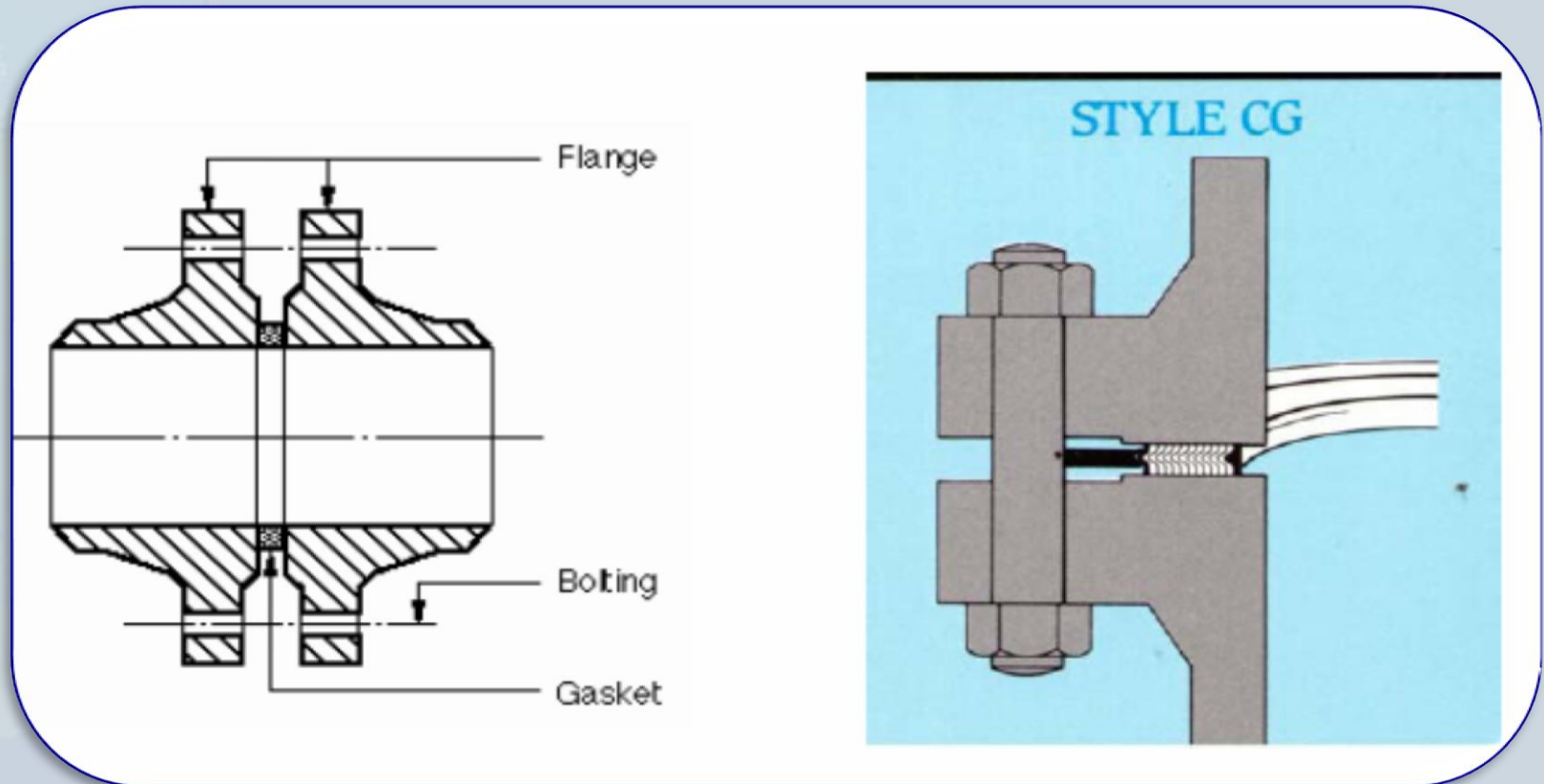


A flange is used to connect a pipe section to a piece of equipment, valve, or another pipe in a way that will permit relatively simple disassembly. Such disassembly may be required for maintenance, inspection or operational reasons. Flange assembly is normally used for pipe sizes above 38 mm (1-1/2 in.)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

There are several standard types of pipe flanges. A flange assembly consists of (See also Figure 19):

- Two flanges*
- A gasket to provide a seal between the flanges*
- Bolting to keep the assembly together*

Figure 19. Flange assembly



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 will also have flanges.

A gasket is a resilient material that is inserted between the flanges and 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. The Inspector must be familiar with the following items as it relates to flanged joints:

- ***Flange standards***
- ***Types of flanges***

- *Types of flange facing*
- *Types of gaskets*
- *Stud bolts and nuts*
- *Jackscrews*
- *Flange bolt-up procedure*
- *Causes of flange leakage*
- *Safety of flanged joint assembly*

Saudi Aramco uses industry standards to define which flanges to be used in 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.

The Inspector should be familiar with the following industry and Aramco standards:

- *ASME B16.5 flanges.*
- *API-605 flanges.*
- *MSS flanges.*
- *ASME B16.47 flanges.*
- *Saudi Aramco Special Flanges, as specified by standard drawings listed in SAES-L-109 and 02-SAMSS-011.*

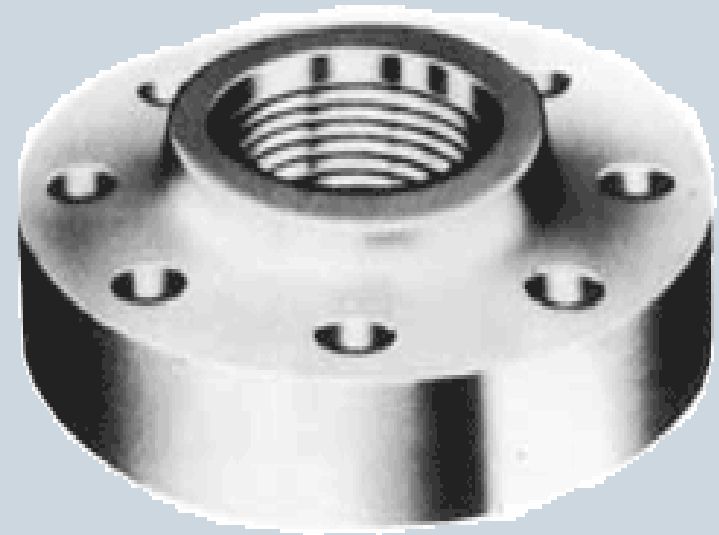
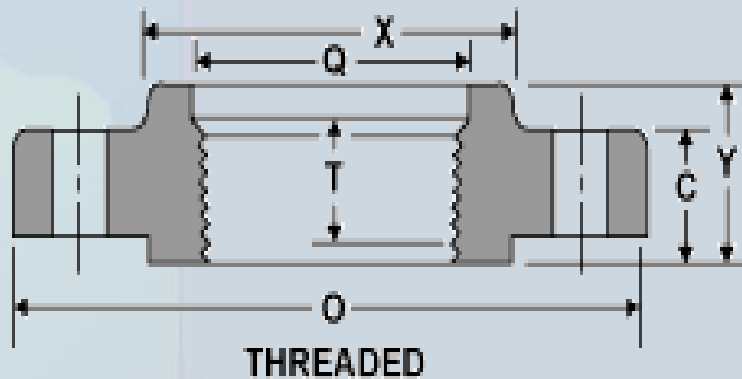
Types of Flanges



THREADED FLANGES

A threaded flange has pipe threads machined into its bore (See Figure 20). The flange is screwed to matching treads on the pipe end. Threaded flanges are used only for small diameter piping systems, up to 50 mm (2 in.) NPS. These flanges are used at locations where pipe disassembly may be required for maintenance, field modifications, or to match specialty fittings and valves.

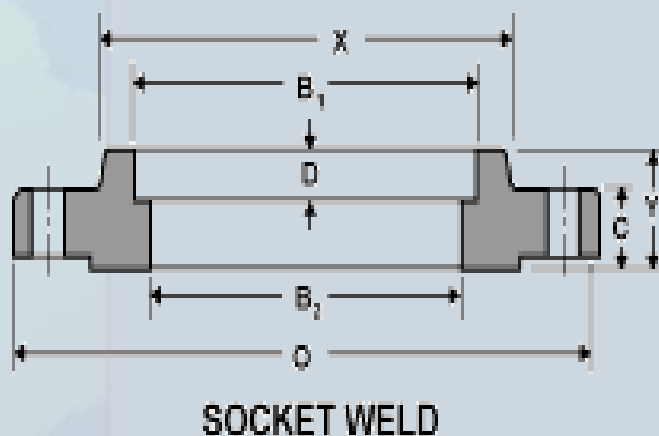
Figure 20. Threaded flanges



SOCKET-WELDED FLANGES

A socket – welded flange has an oversized bore that is partially machined into the end opposite the face (See Figure 21). The pipe is inserted into the socket and the flange fillet is welded to the pipe outside diameter.

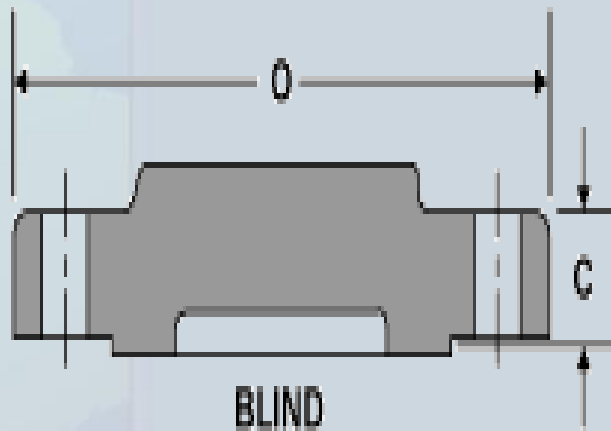
Figure 21. Socket-welded flanges



BLIND FLANGE

A blind flange is a flat metal plate that is used to block the flow in a piping system (See Figure 22). The flange is not attached to the pipe, but bolted to a mating flange. It is used when a pipe end must be blocked from flow, but there still must be a means of internal access.

Figure 22. Blind flanges.



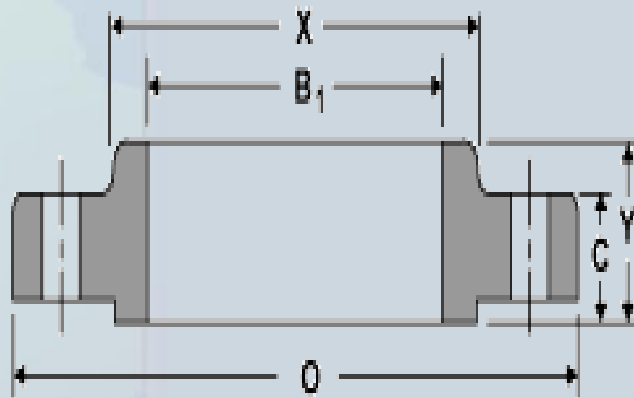
SLIP – ON FLANGES



A slip – on flange has an oversized bore. It is slipped over the pipe outside diameter and projects slightly beyond the pipe end (See Figure 23). The flange is then fillet welded to the pipe outside diameter, and also between the flange bore and the pipe end.

A slip on flange is lighter (i.e., uses less material) and requires less welding to the pipe. However a slip on flange is not suitable for high temperature, cyclic, high pressure or external loading situations.

Figure 23. Slip-on flanges



SLIP-ON



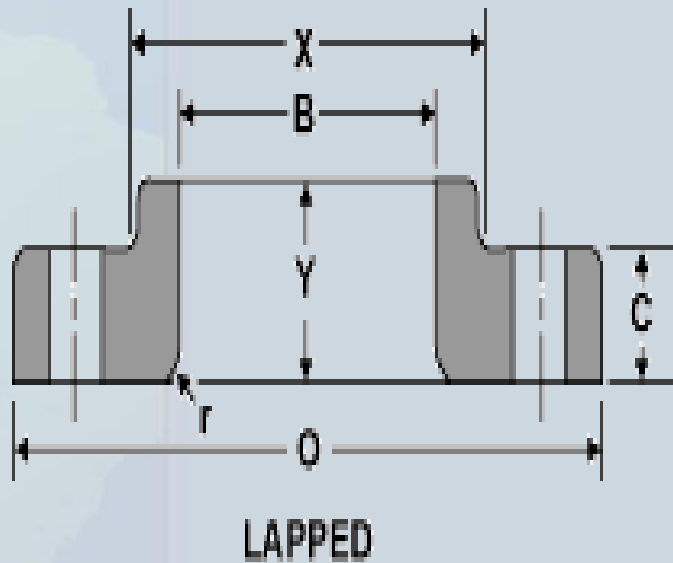
LAPPED FLANGES



A lapped flange (nearly identical to a slip-on flange) is not physically attached to the pipe. It is slipped over a pipe stub that has a flared end, and the stub is welded to the major pipe section. The flared pipe end has a machined face where the gasket is seated. (See Figure 24). The bolting holds the flanges and gaskets together.

Based on SAES – L- 109, Saudi Aramco prohibits the use of lap – joint flanges in severe cyclic conditions

Figure 24. Lapped flanges

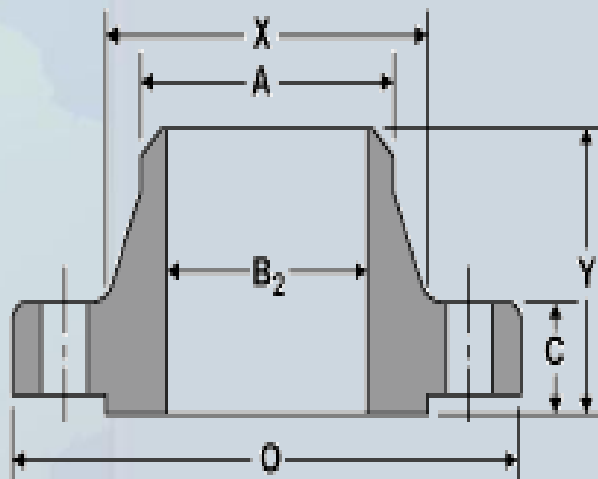


WELDING – NECK FLANGES

A welding – neck flange is the strongest of the 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 (See Figure 25).

A welding – neck flange is the most widely used in refinery services because of its greater strength and ability to be used at high temperature and cyclic service. It is the heaviest and requires the most welding.

Figure 25. Weld-neck flanges



WELD NECK



Types of Flange Facing

The area of a flange where the gasket is positioned is called the face or the 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 is located on the flared pipe stub end not on the flange.

FLAT-FACED FLANGES

In the flat-faced flange, the area where the gasket is located is at the same elevation as the surrounding flange surface. There is no change in elevation in proceeding from the flange inside diameter to its outside diameter (See Figure 26). This provides uniform flange contact with the gasket over a large surface, and limits local flange bending that is caused by bolt load.

A flat face is typically used only for cast or ductile iron flanges, with relatively low-strength material, or when a steel flange must mate 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. The Inspector should confirm that a flat-faced flange with a full-face gasket is used when one or both of the mating flanges are cast iron, aluminum, plastic, or any other material that could be over stressed by the bolt load (SAES-L-109). In addition, flat-face flanges are used for highly corrosive service where contact of fluid with flange facing must be avoided.

Figure 26. Flat faced flange



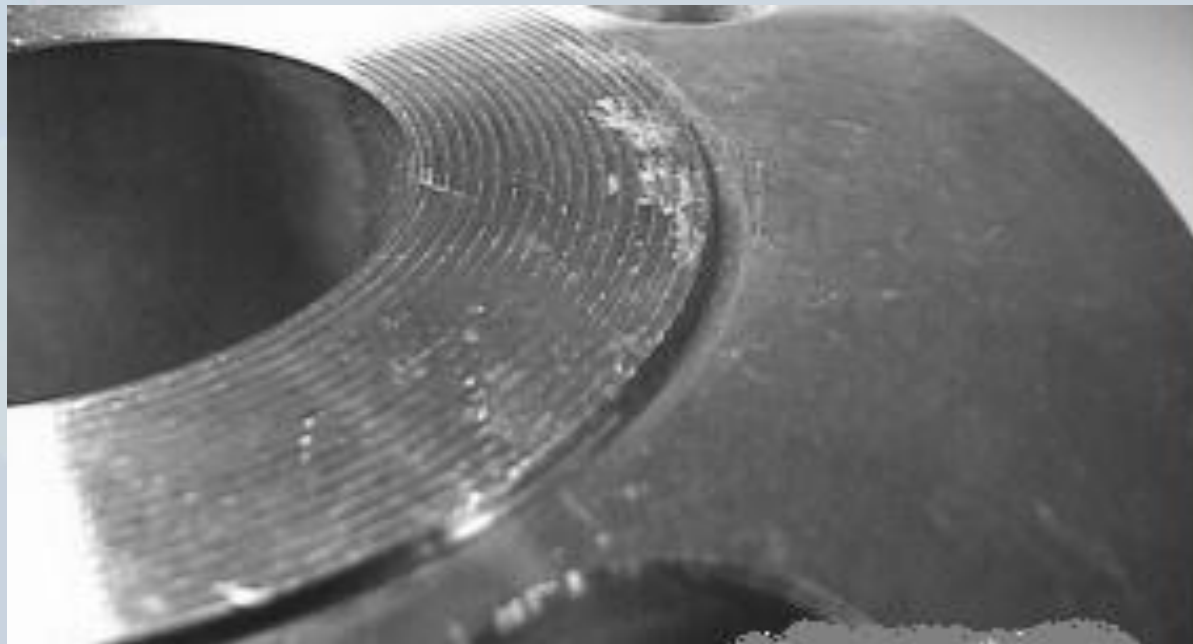
The area where the gasket is located is higher than the surrounding flange surface, typically by 1.5 mm (1/16 in.). This raised-face portion of the flange has a specially machined, serrated finish that is suitable for the typical gasket types used in process plant applications (See Figure 27).

Any gasket type, other than a ring type, may be used with a raised-face flange. The raised face results in much less contact area 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.

The Inspector should check that the raised surface has smooth machine finish, 3.2-6.4 micrometer AARH (arithmetic average roughness height), usually specified for use with spiral-wound gaskets. The Inspector checks for any ridges, scratches, unevenness of the raised face since this will result in possible joint leakage. The Inspector should also verify that the face is free of dirt.

A raised-face flange is used for a very broad range of services, and is the most common type used in Saudi Aramco plants.

Figure 27. Raised-faced flange



RING-JOINT FLANGES



A ring-joint flange face consists of a groove that is machined into the flange end (See Figure 28). The Inspector should verify that the sealing surfaces of the groove are smoothly finished to 63 micro-inch surface roughness. The Inspector also verifies that the surface is free of any detrimental ridges or tool marks. The presence of such surface defects will result in a leaking joint, since a very smooth contact surface is required to achieve 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 gasket combinations will not provide acceptable performance. Typically, these are high-pressure and/or high-temperature services.

Based on SAES-L-109, a ring-joint flange is required for steel flanges of Class 900 and higher, for design temperatures over 480°C (900°F), or for underwater pipelines in Class 300 and higher

Figure 28. Ring joint flange



Gaskets and Gasket Types

The gasket provides the seal in a flange assembly. The Inspector must be familiar with the four general gasket types that are typically used in pipe flanges for process plant and pipeline applications:

- *Spiral wound gaskets*
- *Solid metal ring gaskets*

- *Sheet gaskets*
- *Insulating gaskets (Pikotek)*

The Inspector must verify that the gasket type, rating, and dimension per project specification and service conditions. He checks for damage particularly in the seating element.

SPIRAL-WOUND GASKETS



A spiral-wound gasket is manufactured by alternately winding strips of metal and soft filler material around a mandrel (See Figure 29).

Most spiral-wound gaskets that are used for piping applications are supplied with an outer metal guide or retaining ring. The retaining ring outside diameter is typically sized to just contact the flange bolts, and thus serves as a gasket alignment aid. The retaining ring also acts as a compression limit stop to prevent over-compressing the gasket material during flange bolt-up. An inner retaining ring may also be supplied

The Inspector should be familiar with selection requirements based on SAES-L-109 for spiral-wound gaskets. Per SAES-L-109, spiral-wound Type 316 stainless-steel gaskets with a flexible graphite filler and a carbon steel guide ring are used with raised-faced flanges in most services. This includes most process hydrocarbon and steam services. In an oxidizing environment, the maximum use temperature is limited to 454°C (850°F). For operating temperatures below -45°C (- 50°F), the guide ring shall be Type 304 stainless steel.

Figure 29. Spiral-wound gaskets



The Inspector must also inspect the proper storage requirements for spiral wound gaskets. Per SAEP-351, the Inspector must verify that gaskets are stored flat especially for sizes 24 inches and larger.

METAL RING-JOINT GASKETS



Metal ring gaskets come into two basic shapes, an oval cross section and an octagonal cross-section (See Figure 30).

The octagonal ring seals by surface wedging contact with the flange groove, and the oval ring seals by line contact. Therefore, the oval ring is somewhat more tolerant of slight flange misalignments than the octagonal ring, and still provides a tight seal. In addition, the same bolt load will result in a higher local gasket contact stress and thus a potentially tighter joint with an oval ring. Further, an octagonal ring cannot fit into older ring-joint flanges that have a round bottom groove.

Figure 30. Metallic ring gaskets



Ring-joint gaskets are typically softer than the flange grooves. Therefore, the gasket, rather than the groove, will deform slightly under the applied bolt load. A variety of ring materials are available to suit the particular service needs. The most common materials are iron or soft steel, 4-6% chrome, and stainless steels. A solid metal ring-type gasket is used only with ring-joint-type flanges.

The Inspector should be familiar with SAES-L-109 selection requirements for ring-joint gasket, as follows:

➤ *The soft iron, octagonal ring-joint gaskets shall be used with ASME B16.5, MSS-SP-44, or Saudi Aramco standard ring joint flanges.*

- *For ASME B16.5 ring-joint flanges in corrosive services, a low-carbon steel, and octagonal ring-joint gasket with a Buna-N rubber inner V-Type guard and outer molded-on ring guard shall be used.*
- *For API 6A flanges, low-carbon steel, octagonal, pressure energized ring-joint gaskets in accordance with API 6A Type RX shall be used.*

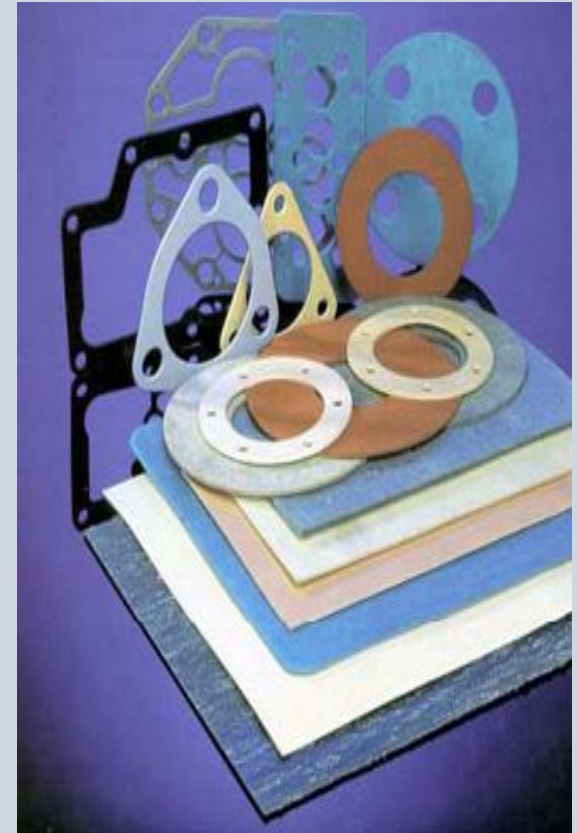
SHEET GASKETS

The most common material used for sheet gaskets is compressed asbestos. However, there has been increasing concern regarding the ultimate availability of sheet asbestos gaskets due to potential worker health and materials disposal issues. Asbestos gaskets will no longer be available within several years, and the use of asbestos should be avoided whenever a suitable substitute is available.

Several alternative sheet gasket materials have been introduced in recent years (See Figure 31). Many of them use synthetic fibers rather than asbestos, along with an elastomeric binder. The binder is a larger percentage of the sheet material in these synthetic fiber gaskets, and thus is a more significant factor in determining acceptable applications.

Non-asbestos sheet gaskets that utilize synthetic fiber with a binder will typically have a lower maximum operating temperature than a compressed asbestos gasket. Of equal importance is that they will have much less fire resistance than an asbestos gasket, so that greater flange leakage could be expected should a fire occur in the vicinity of a flange with a synthetic fiber sheet.

Another non-asbestos sheet-gasket material is composed of flexible graphite. The higher quality flexible graphite sheet gaskets employ a stainless steel sheet insert with the flexible graphite for increased strength. This gasket material has exhibited excellent corrosion resistance in most process plant applications, and has provided good performance at elevated temperatures.



Sheet gaskets may be used with flat or raised-face flanges. The Inspector should be familiar with SAES-L-109 selection requirements for sheet gaskets, as follows:

➤ *Compressed synthetic fiber sheet gaskets with an oil resistant binder, 1.6 mm (0.063 in.) thick, may be used for Class 150 flanges in non-hazardous services up to 230°C (450°F). An example of their use is in lube oil piping.*

- *Synthetic rubber gaskets, ASTM D1418 Class CSM, shall be used for all acid services except nitric acid and oleum. For nitric acid and oleum, ASTM D1418 Class FKM elastomer shall be used for flat-face flanges.*
- *Elastomeric material, 3 mm (1/8 in.) thick, with a Shore A durometer hardness of between 50 and 60, shall be used for full-face gaskets for plastic flanges. For wet chlorine or hypochlorite services, the elastomer shall be ASTM D1418 Class CSM.*

INSULATING GASKETS (PIKOTEK)



Insulating gaskets are used in case for connecting flanges of dissimilar metals, such as, a stainless steel flange to carbon steel flange, or a Cu-Ni flange to carbon steel flange. This is done to prevent possibility of galvanic corrosion. The insulating gasket acts as a barrier between the two dissimilar metals. In order for proper insulation to be effective, the gasket shall be used in association with isolating bolt sleeves and washers. The requirements for these types of gaskets are specified in SAES-L-105 and SAES-L-109.

The most often used type of insulating gasket is the Pikotek gasket. The Pikotek gasket is mostly made up of Teflon seal, glass reinforced epoxy laminated to a 316 stainless steel core. The Inspector should verify that for untreated water services, such as seawater, raw water, Wasia water, etc., use of the Pikotek or any approved equal, must be concurred by the Operating Department.

STUD BOLTS AND NUTS



Bolting for flanged joints (See Figure 32) shall be selected in accordance with ASME B16.5 and ASME B16.47. The Inspector must check the material suitability per SAEP-351 for the service temperature and compatibility with flange material.

SAES-L-109 requires materials for process and general services be ASTM A193 Grade B7 stud bolts with ASTM A194 Grade 2H nuts for service temperatures from minus 20 to plus 450°C.

Materials for low temperature services shall be as follows:

- Stud bolts conforming to ASTM A320 Grade L7 with nuts to ASTM A194 Grade 4 or 7 shall be used for bolt service temperatures from minus 18 to minus 101°C.***
- ASTM A320 Grade L7M studs and A320 Grade 7M nuts may be used for low temperature services from minus 18 to minus 73°C.***

➤ *Under certain circumstances, with approval by the Chairman of Piping Standards Committee in CSD, ASTM A193 Grade B7 bolts with A194 Grade 2H nuts may be used at bolt service temperatures as low as minus 30°C, and A193 Grade B7 bolts with A194 Grade 7M nuts may be used at minus 45°C.*

Materials for upper intermediate temperature services shall be as follows:

- ASTM A193 Grade B7 or B7M studs with A194 Grade 7 or 7M nuts for services up to 450°C.***
- ASTM A193 Grade B16 stud bolts with A194 Grade 7 nuts, for bolt service temperatures from 450 to 510°C. For higher temperatures, contact the Materials Engineering Unit in CSD.***

Materials for sour services shall be as follows:

➤ ***Standard quenched and tempered ASTM A193 Grade B7 stud bolts with 2H nuts shall be used for sour wet services when the bolting is (a) not directly exposed to hydrogen sulfide, (b) not buried or insulated, (c) not equipped with flange protectors, or not deprived of direct atmospheric exposure. ASTM A320 Grade L7 stud bolts with Grade 4 or 7 nuts can be used under the same conditions.***

➤ *Stud bolts conforming to ASTM A193 grade B7M with nuts to A194 Grade 2HM shall be used under conditions of (a) direct exposure to sour environments or when the bolting will be (b) buried or insulated, or (c) equipped with flange protectors, or otherwise deprived of direct atmospheric exposure. ASTM A320 Grade L7M bolts and Grade 7M nuts can be used under the same conditions.*

➤ *Steel machine bolts conforming to ASTM A307 Grade B may be used on flat-faced cast-iron or non-metallic flanges in non-sour environment; nuts shall conform to ASTM A563 Grade D. This bolt/nut combination may be used in sour services when the Grade D nuts are not resulfurized, and the flange materials are deemed suitable by the Materials Engineering Unit of ME&CCD in CSD. Such bolting may be zinc coated or preferably zinc-aluminum (Galvalum) coated.*

➤ *For fluid temperatures below minus 45°C, the selection of bolting material or the bolting design shall include consideration of differential contraction between flanges and bolts such that changes in gasket seating pressure will not result in leakage. Similarly, differential expansion shall be considered at operating temperatures above 300°C.*

Figure 32. Stud bolt and nuts

The Inspector must check the bolts for proper size, dimension and for any physical damage to shanks or threads which would interfere with bolt assembly or performance.



The Inspector must verify that proper lubricant is used. Lubricant for bolts and nuts shall be Jet-Lube SS-30 or other acceptable lubricants listed in Table-SAEP-351-01 (below). In addition, the Inspector must check that no lubricant is used on the gasket seating area.

Table-SAEP-351-01 – Friction Factors for Different Lubricants



Lubricants	Friction Factors	Torque Correction Factor
Moly Graphite	.06	0.67
Tool Joint Compound	.08	0.8
Graphite and Oil (used as the base line for torque values in Table-SAEP-351-02)	.10	1.0
Aerocote #4	.11	1.1
KOPR-KOTE	.11	1.1
EL-PRO C5A	.11	1.1
FEL-PRO C100	.11	1.1
FEL-PRO C102 (commonly called Anti-Seize)	.11	1.1
Jet Lube SS-30	.12	1.2
API BULL 5A2 Thread Compound	.125	1.3
Light Machine Oil as shipped	.15	1.5
Dry Bolts	.2	2

JACKSCREWS

Jackscrews in accordance with Saudi Aramco Standard Drawing AD-036630 or similar Saudi Aramco approved design shall be used to facilitate flange separation for maintenance. Joint assemblies that often require frequent separation include orifice plates, spectacle plates, spacers, screens, and drop-out spools

Piping layout shall be designed such that flanges can be separated without excessive force. The Inspector should verify that the jackscrews are installed to be accessible from both sides of the pipe. For orifice flanges, the Inspector should verify that jackscrews are installed at 3 and 9 o'clock positions for liquid service. When flange separators are used, jackscrews are not required.

FLANGE TOLERANCES

The Inspector must check the flange fit-up to conform to the tolerances given in SAES-L-350:

➤ Flange bolt holes shall be oriented as follows, unless otherwise indicated on the construction drawings:

- a) Flange face vertical -bolt holes to straddle vertical centerlines.***
- b) Flange face horizontal-bolt holes to straddle horizontal centerlines.***

- c) Rotation of flanges, measured as the offset between elevations of bolt holes on opposite sides of a flange centerline, shall not exceed ± 2.4 mm.*
- d) The tilt of a flange measured at the periphery across any diameter shall not exceed 1.6 mm from the square position.*

➤ *For piping over 3-inch NPS and connected to machinery/equipment, flange alignment shall be within the following limits unless piping analysis per SAES-L-120 shows that loads and moments are within the manufacturer's limits for the machinery/equipment nozzle:*

- a) Vertical bolt hole offset: ± 2.4 mm*
- b) Horizontal bolt hole offset: ± 2.4 mm*
- c) Rotational offset: ± 2.4 mm*

- d) Flange face tilt across diameter: 0.025mm per 25 mm (0.001 inch per inch) of flange outside diameter up to a maximum of 0.672 mm (0.030 inch), and 0.254mm (0.010 inch) for all flanges with an outside diameter less than 10 inches.*
- e) Flange face separation, gasket thickness: ± 1.6 mm*
- f) Combination of vertical, horizontal and rotational offset: ± 3.2 mm*

- *In the case where a spectacle plate is installed between two flanges, these tolerances can be increased by 30% except for tolerances for flange face tilt across diameter and flange face separation.*
- *If the tolerances per paragraphs 9.1 through 9.5 cannot be achieved, the actual misalignment and piping layout shall be reviewed and approved by the Chairman of Piping Standards Committee in CSD.*

Note: When a piping flange is aligned to a machinery flange, the machinery alignment should be within the equipment vendor specified tolerances, after the stud bolts of the connecting flanges are removed following the completion of piping assembly.

FLANGE BOLT-UP PROCEDURE



There are various types of tools available to achieve the proper torque value such as impact wrench, torque wrench or a stud tensioner (See Figure 33). Selection of the proper tool depends on the stud bolt size, physical location of the flanged joint, and criticality of the flange. Identifying the proper tools shall be resolved between Contractor, SAPMT, Proponent and Inspection prior to commencing the erection of the piping.

The Inspector shall verify that the manufacturer's instructions are followed for the operation, limitation and maintenance of all torque wrenches used to perform flange bolts tightening. In addition, the Inspector shall keep track of torque wrench calibration performed in accordance with manufacturer's recommendations, or as required by the inspector after consultation with Piping Specialist in Consulting Services Department.

As per the SAEP-351, the Inspector shall ensure the following steps are taken for torque tightening of bolted flanges:

Step 1 *Align flanges and gasket. Forced tightening is not allowed to overcome non acceptable alignment tolerances. Clamp securely in place.*

Step 2 *Apply lubricant to stud threads over length and nut engagement and to face of nut which contacts flange. Ensure that the nuts run freely down the thread of the studs.*

Step 3 *Install all studs and nuts hand tight, ensure that studs pass freely through the flange holes. Position the nut on one end of the stud such that only the crown of the stud projects beyond the face of the nut. The excess stud length should project beyond the nut on the other side.*

Note: By doing this, the nut that is installed nearly flush with the end of the stud can be easily removed since the threads are not coated, and normally have not been subjected to corrosion. The side of the stud with the flush nut should be chosen by taking into consideration factors such as whether one side has better access for maintenance personnel and/or tightening tools, e.g., torque wrench or impact wrench, etc.

Step 4 *Number each stud according to its position in the flange as shown on Figure 34 (Stud tightening sequence).*

Step 5 *Tighten studs per Figure 34 (Stud Bolt Tightening Sequence) with an appropriate tool such as an air impact wrench or equal.*

Step 6 *For joints containing RTJ or Spiral Wound Gaskets, repeat step 5.*

Step 7 *Tighten the stud bolts in stages to obtain the final required torque from the appropriate torque Table-SAEP-351 (below). The first stage should not be more than 30% of the final torque. The final torque shall be within $\pm 5\%$ of the required torque value.*

Apply the torque evenly to each stud following the stud bolt tightening sequence. The final torque must be within $\pm 5\%$ of the required values per Step 5 above.

This approach also helps achieve uniform bolt load around the flange circumference. For the most critical high-temperature or high-pressure flanges, a method that permits measuring the applied load shall be used (i.e., torque wrench or stud tensioner). In this way, there is greater assurance that uniform bolt load is achieved

FOR SUCH APPLICATIONS, A MAXIMUM STUD STRESS DURING BOLT-UP OF 275-345 MPa (40-50,000 PSI) IS THE NORMAL TARGET.



Figure 33. Torque wrenches



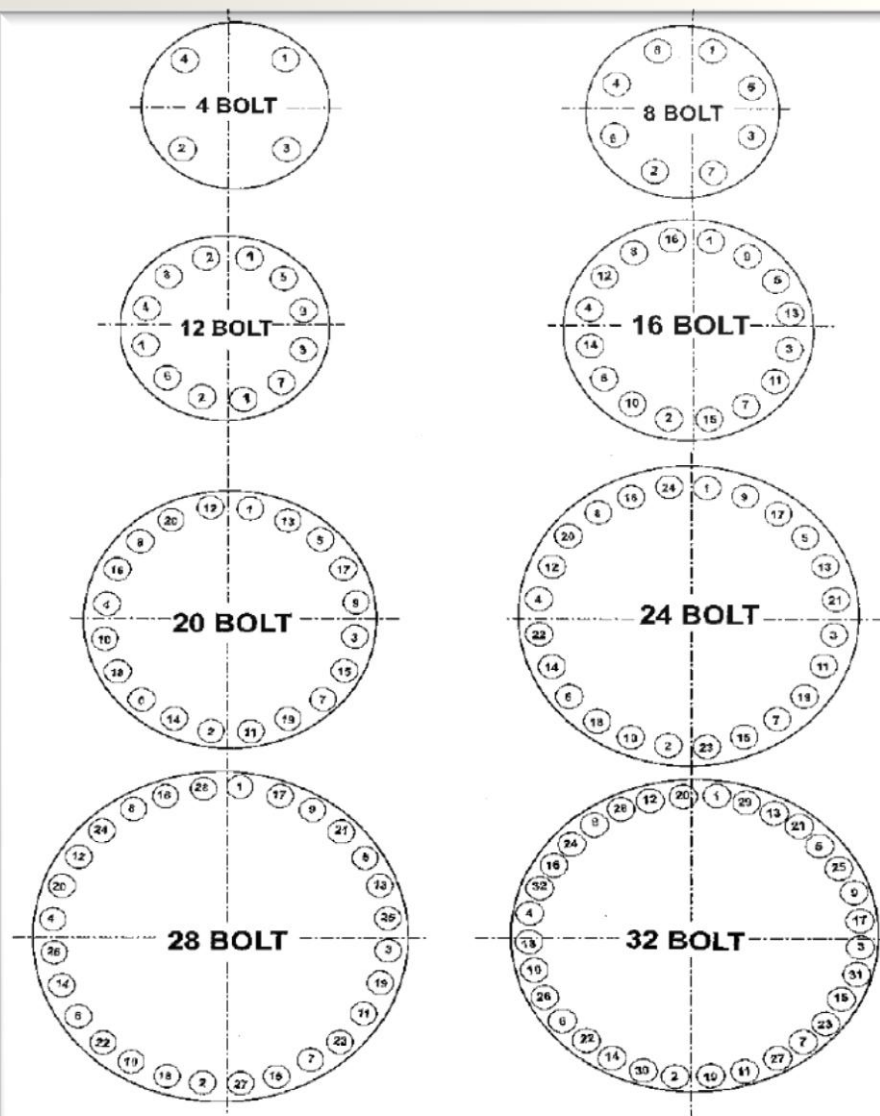


Figure 34. Stud bolt tightening sequence (SAEP-351)

Stud Bolt Size inch	Torque Minimum Ft-Lb	Torque Maximum Ft-Lb
1/2	30	34
9/16	43	49
5/8	60	68
3/4	107	120
7/8	170	190
1	256	287
1-1/8	374	420
1-1/4	524	590
1-3/8	709	798
1-1/2	934	1051
1-5/8	1201	1351
1-3/4	1515	1704
1-7/8	1879	2113
2	2296	2583
2-1/4	3311	3724
2-1/2	4151	5155
2-3/4	6150	6918
3	8033	9037
3-1/4	10,253	11,545
3-1/2	12,872	14,481
3-3/4	15,901	17,888
4	19,356	21,775

Table-SAEP-351-02 - Torque Value for A193 B7 and B7M Stud Bolts with A194 2H and 2HM Nuts

Notes:

- 1)** Torque values based on 0.10 Average Friction Factor and 30,000 psi prestress on stud bolts. A combination of various elements such as the conditions of the threads, the condition of the flange to the nut bearing surface and the type of lubricant used, makes up the friction factor which can vary from .04 to .20 or as much as 500%.
- 2)** Torque values for stainless steel or other alloy stud bolts can be obtained by multiplying the ratio of the specified minimum yield strength (SMYS) of stainless steel stud bolts to A193 B7 stud bolts, to the torque values in the Table-SAEP-351. The SMYS values for all bolting materials are listed in Table-SAEP-351-02 of ASME B31.3 code (Note: SMYS depends on grade, class and size).

Stud Bolt Size inch	Torque Minimum Ft-Lb
1/2	30
5/8	60
3/4	100
7/8	160
1	245
1-1/8	355
1-1/4	500
1-3/8	680
1-1/2	800
1-5/8	1100
1-3/4	1500
1-7/8	2000
2	2200
2-1/4	3180
2-1/2	4400

**Table-SAEP-351-03 –
Torque Values for
Isolating Gaskets
(PIKOTEK) on ASME
B16.5 and ASME B16.47
Series A & B, Class 150
through Class 2500
Flanges**

Note: Torque values based on 30,000 psi tension load and 0.125 Friction Factor from API BULL 5A2 thread compound. See Table-SAEP-351-02 Note (1) for other factors.

Causes of Flange Leakage

Most of the primary causes of flange leakage are directly related to poor inspection or installation. These are summarized below:

Uneven Bolt Stress

An incorrect bolt-up procedure or limited working space near one side of a flange can leave some bolts loose while others crush the gasket. This is especially troublesome in high temperature services, when the heavily loaded bolts relax during operation.

Improper Flange Alignment

Improper flange alignment, especially nonparallel faces, causes uneven gasket compression, local crushing, and subsequent leakage.

Improper Gasket Centering

If a gasket is off-center compared to the flange faces, the gasket will be unevenly compressed and more prone to leakage.

Dirty or Damaged Flange Faces

Dirt, scale, scratches, protrusions, or weld spatter on gasket seating surfaces provide leakage paths or can cause uneven gasket compression that results in leakage.

Excessive Loads in the Piping System at Flange Locations

Excessive piping system forces and moments at flanges can distort them and cause leaks. Common causes of this are inadequate flexibility, using excessive force to align flanges, and improper location of supports or restraints.

Thermal Shock

Rapid temperature fluctuations can cause flanges to deform temporarily, resulting in leakage.

Improper Gasket Size or Material

Using the wrong gasket size or material can result in leakage.

Improper Flange Facing

A rougher flange-surface finish than specified for spiral-wound gaskets can result in leakage.

Note: The principal methods for correcting flange leakage problems are beyond the scope of this course. However, several of them are easily corrected based on the causes of leakage.

Safety of Flanged Joints Assembly

Though it seems flanged joint assembly is very straightforward and 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 workmanship 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 human factor is the main reason for failures in the flanged joints. There are standards and acceptable practices that should be carefully followed to insure safety around the flanged joints.

- *Improper surface finish of the flange facing.*
- *Gasket is not centered.*
- *Uneven bolting torque.*
- *Torque value are either under minimum required or way over to the point that gasket is completely not functional.*
- *Installing the wrong gasket, type or rating*

INSPECT VALVES

Valves are major components of a piping system and require careful attention during the design process. Selecting a valve is based upon the required valve function: to block flow, throttle flow, or prevent flow reversal. There are numerous types of valves. The valve most commonly used (approximately 75% of the time) is the gate valve. SAES-L-008 provides special service limitations and selection requirements for valves.

The 04-SAMSS-series of specifications provides additional valve design requirements. Once a valve is selected, its flange rating class must be specified based on its design pressure/temperature and the MAOP of the class. Finally, the valve must be inspected and tested

04-SAMSS-048 requires that, as a minimum, each valve be tested, examined, and qualified per the industry standard referenced in the purchase order and the applicable 04-SAMSS valve specification. Supplementary requirements are contained within 04-SAMSS-048. API 598, Valve Inspection and Testing, is the basic document used for inspection and testing of gate-, globe-, plug-, ball- check-, and butterfly-type valves. The following highlight requirements that are contained in API 598 and 04-SAMSS-048, plus additional inspection guidelines.

The Inspector must check the following for valves and valve joints:

- ***The finish on flange faces and ring joints.***
- ***Face-to-face dimension.***
- ***Flange outside diameter, bolt circle diameter, bolt hole diameter, flange thickness.***
- ***Body wall thickness (per applicable standard).***
- ***Bevel preparation on welding-end valves.***
- ***Stem diameter.***

- *Threaded ends (size and taper, if required).*
- *Socket-end concentricity and wall thickness (per ANSI B16.11).*
- *For gate valves, with the gate closed, the position of the gate seat rings relative to the body seat rings to confirm sufficient wear travel position.*
- *For soft-sealed gate valves, the height of the soft seal above the metal seats, the width of the soft seal, and the total width of the metal seat outside the soft seal.*

- *Component features as specified in the purchase order (such as stem packing material, bonnet gasket-type, operator-type, soft-seal material, body bleed number, and location).*
- *Materials identification. Obtain chemical and physical test data on steel and alloy steel castings for all valves inspected. All alloys bolting must be identified by markings required by the specifications on the stud or bolt ends, or on nuts.*

➤ *Additional tests conforming to SAMSS requirements, such as hardness or impact testing, may also be required if specified in the purchase order. The minimum testing required by API 598 is a pressure test of the shell, back seat (if any), and seats. Test pressures and durations are specified in API 598, based on valve sizes and the type of test.*

Note: For more information, refer to Valve Inspection Course (PEW-404).

INSPECT SUPPORTS AND RESTRAINTS

Pipe supports are used to support the weight of the piping system and the contents of the system. The supports keep the pipe elevated at a desired height above the ground. The specific number and locations for pipe supports are determined to ensure the following:

- *The pipe stress that is caused by the weight load must be kept within allowable limits.*
- *The pipe must not sag excessively.*
- *Reaction loads at equipment connections must not be excessive.*

When practical, new piping should use existing supports to minimize costs. As much as possible, new piping should be located in existing pipe-ways. Intersecting pipe-ways are located at different elevations to facilitate access and future piping installation. Standard Drawing AC-036207 specifies the minimum spacing of lines that are supported on sleepers or pipe racks.

Restraints control or limit movement of the pipe in one or more directions. Such restraint may be required to reduce thermal expansion reaction loads at equipment connections, or to limit pipe vibration. Some restraints keep the pipe from moving vertically or laterally but allow the pipe to move longitudinally.

Other restraints do not allow the pipe to move in any direction. A support is a specialized type of restraint that prevents pipe movement under vertical weight loading.

GENERAL GUIDELINES

Piping systems should be routed to facilitate their support and restraint, to minimize cost, and to limit additional structural and foundation requirements. The following guidelines should be considered:

- *The piping system should support itself to the extent possible to minimize the amount of additional structural steel that is required to provide support.*

➤ *Piping with excessive flexibility may require the addition of restraints to minimize excessive movement and/or vibration that may be caused by fluid flow, wind, or earthquake. Therefore, piping systems should be designed with only the flexibility needed to accommodate the expected thermal movement without causing excessive pipe stresses or end point reaction loads. Systems should not be overly flexible.*

➤ *Piping that is prone to vibration, such as reciprocating compressor suction and discharge systems, should be supported independently from other piping systems. This independent support keeps the effects of the vibration-prone system confined to that system and directly associated structures. The effects are not transmitted to other systems.*

➤ *Piping that is located in structures should be routed beneath platforms and near major structural members, at points that permit added loading. Routing beneath platforms avoids access interference problems. Routing near major structural members minimizes the need to increase the size of structural members or to provide additional local reinforcement, due to increased bending moment.*

- *When possible, piping should be routed near existing structural members to minimize the need for additional structure and foundations.*
- *The layout of the piping system must consider the safety of personnel who may be near the pipe. Major pieces of equipment, particularly heat exchangers, vessels, and tanks, must be accessible for fire-fighting equipment. Pipe-ways must be routed to provide this access. There must be adequate space under pipe-ways for people to walk and work.*

➤ *For many services, carbon steel has adequate corrosion resistance or a nominal corrosion allowance may be used to account for corrosion. Corrosion allowance is additional thickness that is added to a pipe for corrosion that takes place during service. Carbon steel pipe and piping components are manufactured to various ASTM and API specifications, and they are available in various grades or strength levels.*

A piping system needs supports and restraints to do the following:

- Permit the piping system to function under normal operating conditions without failure of the pipe or associated equipment.***
- Support piping system weight loads to Keep sustained longitudinal pipe stress within allowable limits.***
- Limit pipe sag to avoid process flow problems.***
- Limit loads on connected equipment.***

- *Control or direct thermal movement of the pipe to keep pipe thermal expansion stresses within allowable limits.*
- *Limit loads on connected equipment.*
- *Absorb other loads imposed on piping system to limit loads on connected equipment.*
- *Limit pipe deflection.*
- *Limit resultant pipe stresses.*

Selection of a particular type of support or restraint depends on such factors as the following:

- *Weight load*
- *Restraint load*
- *Clearance available for attachment to pipe*
- *Availability of nearby existing structural steel*
- *Direction of loads to be absorbed or movement to be restrained*
- *Design temperature*
- *Allowance required for thermal movement of pipe*

Types of Supports

This section discusses and illustrates various types of supports and restraints for piping systems.

The two general classes of supports are as follows:

- ❖ *Rigid*
- ❖ *Flexible or resilient*

It is the duty of an Inspector to verify that the right type, location, spacing, alignment of the pipe support is per project drawings. If for practicality the spacing has to be altered, prior approval shall be granted and reviewed by the Piping Standards Committee Chairman or his representative.

The Inspector must confirm that the supports provide for a minimum of 300 mm clearance between bottom of pipe to finished grade per SAES-L-310. In addition, a minimum clearance of 50 mm shall be provided for inspection and freedom of pipe movement between above ground piping crossing with any structure (including pipe support structure). This clearance is also required for above ground piping crossing with another pipe.

RIGID SUPPORTS

Rigid supports are the more common of the two support types. Engineers use rigid supports when weight support is needed and no provision to permit vertical thermal expansion is required. A rigid support does the following:

- Allows lateral movement and rotation.***
- May or may not prevent movement up.***
- Prevents movement down.***

Figures 35 through 39 illustrate some of the rigid support types that are available. The rigid support that is selected for a particular application depends primarily on the following:

- Amount of load to be carried*
- Distance to solid attachment (structure, grade, etc.)*
- Point of attachment to pipe (horizontal or vertical run, elbow, etc.)*

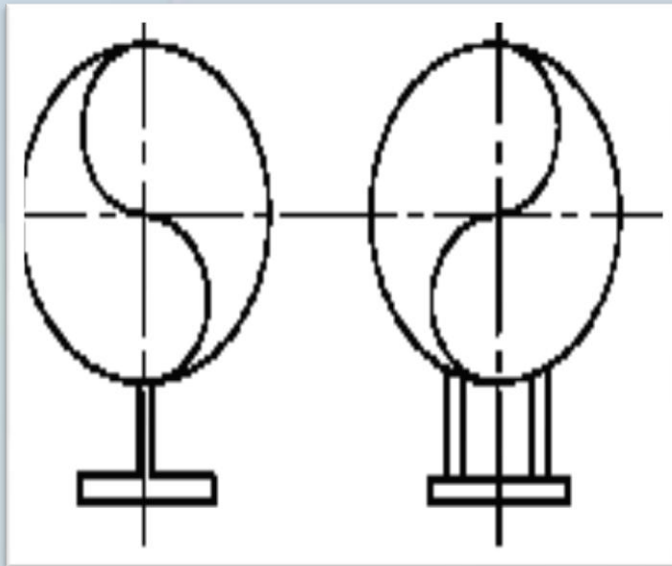


Figure 35. Shoe Support

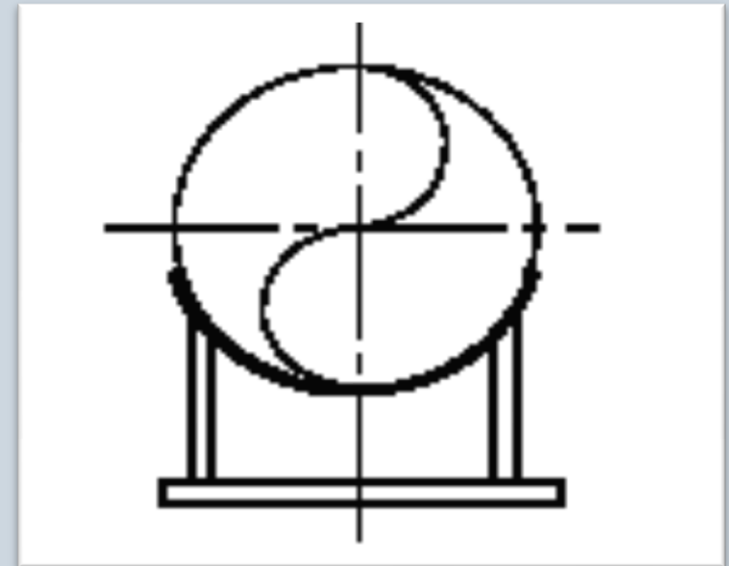


Figure 36. Saddle Support

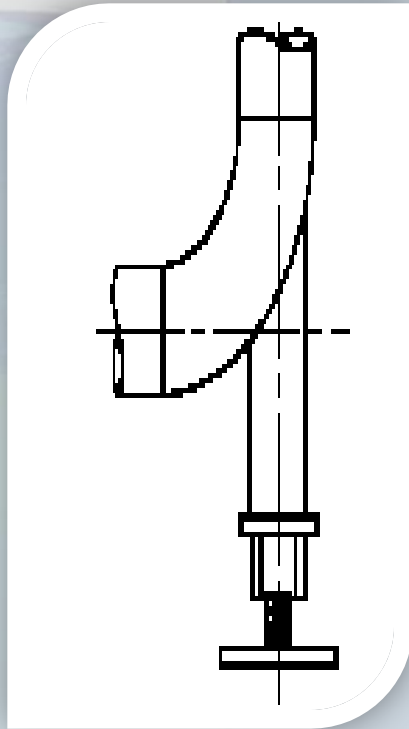


Figure 37. Base Adjustable Support

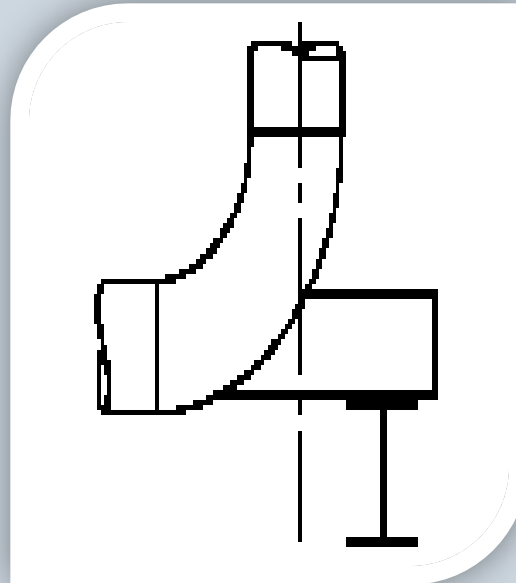


Figure 38. Dummy Support

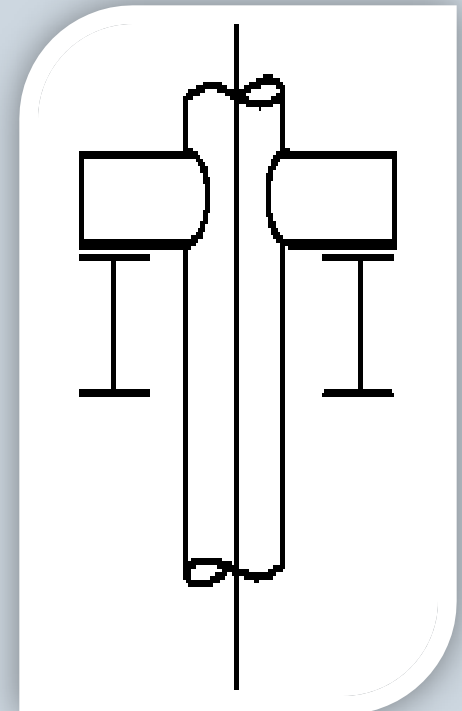


Figure 39. Trunnion

The Inspector must verify that a 6 mm weep hole shall be drilled for all dummy supports. The weep hole shall be located near the base plate for all vertical dummy supports, and near the run pipe at 6 o'clock position for all horizontal dummy supports.

Pipe hangers are also a form of rigid support. Pipe hangers support the pipe from structural steel or other facilities that are located above the pipe and carry the pipe weight load in tension. A pipe hanger rod moves freely parallel and perpendicular to the pipe axis; therefore, thermal expansion is not restricted longitudinally or laterally. The rod does restrict vertical thermal expansion. The rod also must be long enough so that it does not restrict pipe lateral or longitudinal movement.

SAES-L-350 discourages use of hanger rods and suggests that they be replaced with rigid pipe supports. Per SAES-L-350, the Inspector must confirm the following items related to rod hangers:

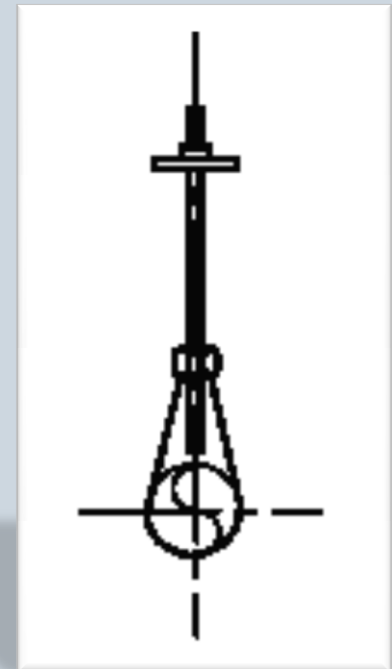
- Rod hangers are not used for lines 12" NPS and larger in liquid service or multi phase flow.***
- All hangers are provided with means for vertical adjustment.***
- Suitable locking devices are used at all threaded connections of the hanger assembly (double nuts).***

➤ *Rod hangers are subjected to tensile loading only.*

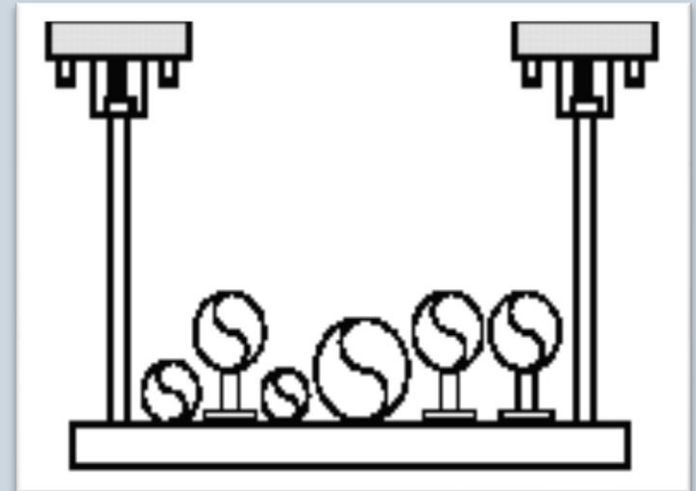
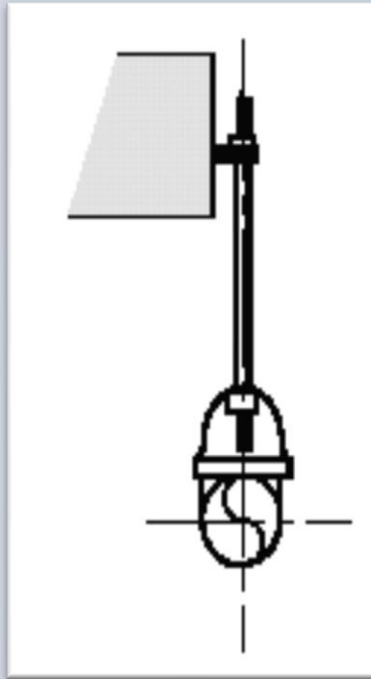
➤ *Practicality for replacing them with rigid pipe supports should be evaluated and implemented, during construction.*

Figures 40 through 42 show some examples of pipe hangers.

Figure 40. Sling-Type Pipe Hanger



**Figure 41. Pipe Hanger Suspended
From Side of Structure**



**Figure 42. Pipe Support Beam
Suspended By Rods**

FLEXIBLE OR RESILIENT SUPPORTS



Flexible or resilient type supports carry the weight load and allow the piping system to move in all three directions. A coil spring that has the correct stiffness and pre-compression to carry the weight load supports the weight. Because the spring is resilient, it permits vertical movement while still carrying the weight. The ability to move vertically allows the support to carry the weight while permitting the pipe to expand and contract as needed for thermal expansion.

The thermal expansion may be due to the heating of the pipe or of a vessel to which the pipe attaches, or both. Two basic types of flexible supports are as follows:

- *Variable load*
- *Constant load*

The type of flexible support selected from standard available models is based on the following factors:

- *Design load*
- *Required movement*
- *Installation geometry*
- *Standard models available*

VARIABLE LOAD FLEXIBLE SUPPORT



The variable load flexible support is the more common of the two types of flexible support. With variable load supports, pipe movement stretches or compresses the spring, changing the load that the spring exerts on the pipe. The spring is selected to provide the correct amount of support load to the pipe throughout the movement range. Figure 43 shows an example of a variable load support.

Load and deflection scale

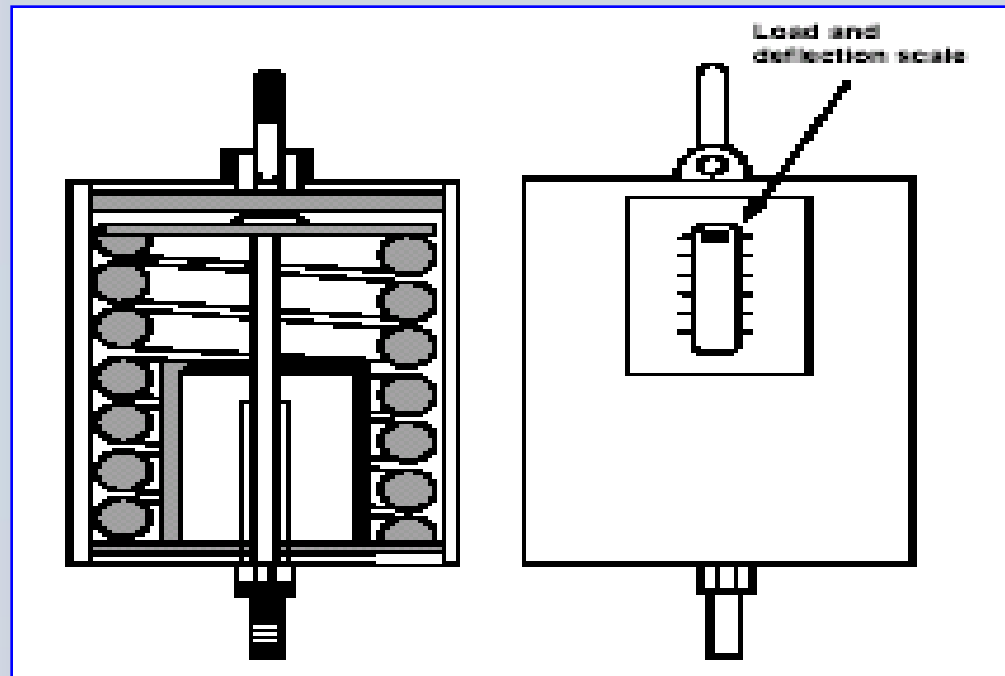
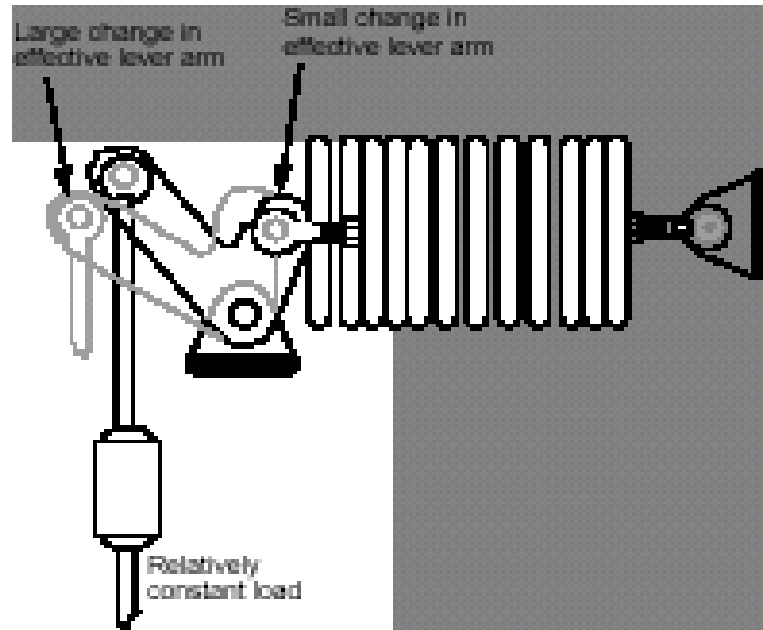


Figure 43. Variable Load Support

CONSTANT LOAD FLEXIBLE SUPPORT

With constant load flexible supports, the load that is exerted by the support on the pipe remains constant throughout the movement range. The use of a variable-length internal-moment arm mechanism accomplishes this constant load. This type of support is required when the load variation caused by the vertical thermal movement in a variable-load-type spring is too large to be accommodated by the piping system, or when the thermal movement is greater than approximately 3 in. (75 mm). Figure 44 shows an example of a constant load support.

Figure 44. Constant Load Support



TYPES OF RESTRAINTS

Restraints have the following two primary purposes in a piping system:

- ❖ They control the unrestricted thermal movement of the pipe by directing or limiting it. Generally, a piping system is totally restrained at its end connections to equipment.***
- ❖ They control, limit, or redirect the thermal movement to reduce the thermal stress in the pipe or the loads exerted due to thermal movement on equipment connections.***

❖ *They absorb loads imposed on the pipe by other conditions. Examples of these other conditions are as follows:*

- *Wind*
- *Earthquake*
- *Slug flow*
- *Water hammer*
- *Flow-induced vibration*

Several different types of restraints may be used. The selection of the type of restraint and its specific design details depends primarily on the following:

- ❖ Direction of pipe movement to be restrained.*
- ❖ Location of the restraint point.*
- ❖ Magnitude of the load to be absorbed.*

One or more types of restraint or support may be combined at one location, depending on the piping system design needs. Three types of restraints are as follows:

- ❖ ***Stops***
- ❖ ***Guides***
- ❖ ***Anchors***

STOPS

Stops are restraints that limit the movement of the pipe in the longitudinal direction. Stops are designed to keep the pipe from moving axially beyond a point or from moving axially at all. Figure 45 shows an example of a stop.



Figure 45. Stop

Guides are types of supports that limit the movement of the pipe perpendicular to the pipe axis in one or more directions while allowing movement along the pipe axis. Pipe rotation may or may not be restricted. Typical applications for guides are as follows:

➤ *Long pipe runs on a pipe rack to:*

- *Control thermal movement.*
 - *Prevent buckling.*
 - *Straight runs down the side of towers to:*
 - *Prevent wind-induced movement.*
 - *Control thermal expansion.*
- Figures 46 through 49 show examples of guides.*

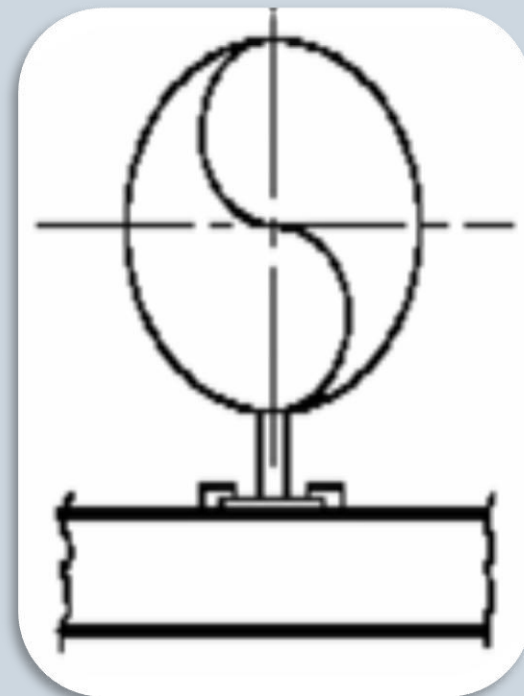


Figure 46. Channel Guide

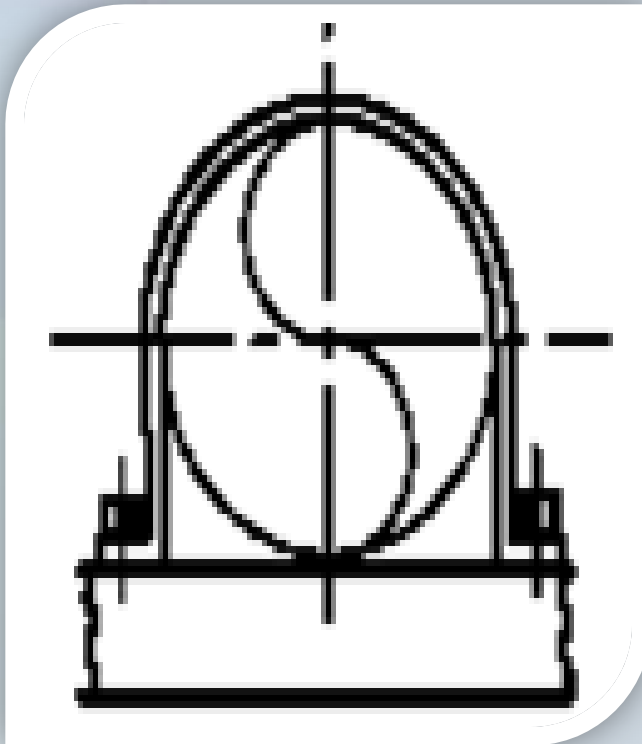


Figure 47. Sleeve Guide

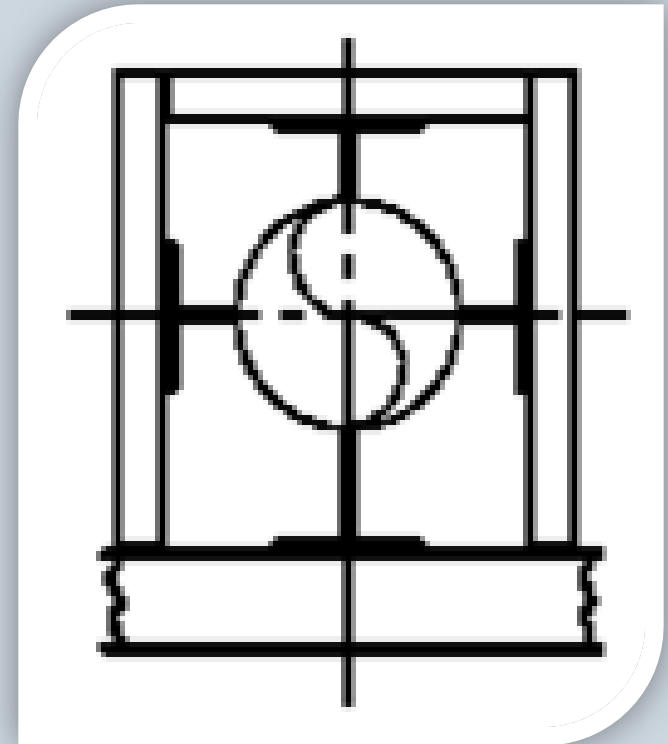


Figure 48. Box-In Guide

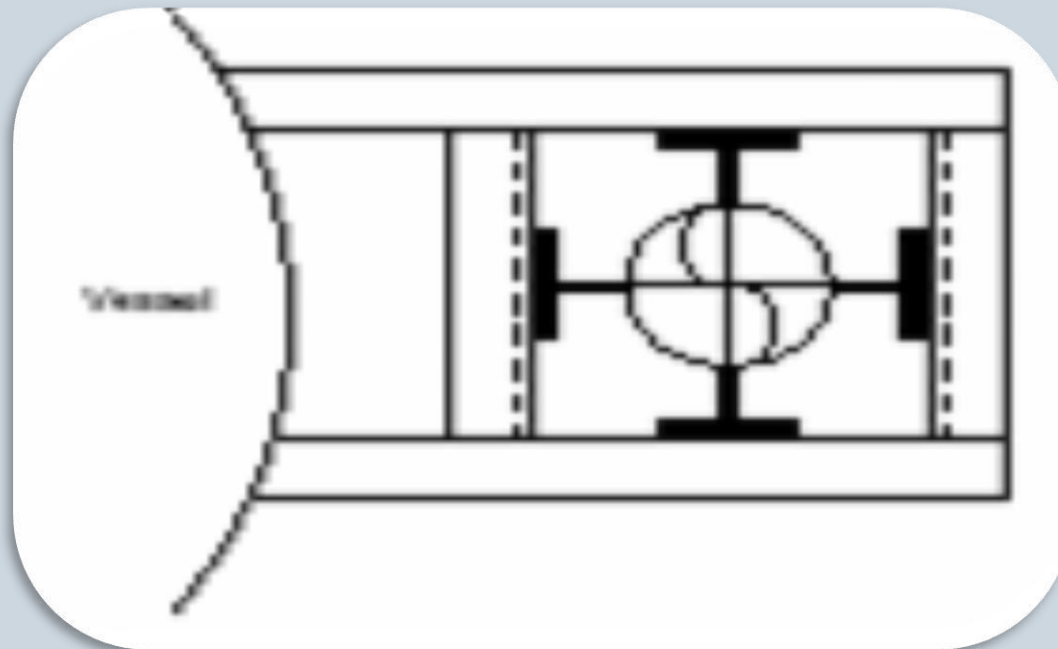


Figure 49. Vertical Box-In Guide on Side of Vessel

ANCHORS

Anchors stop pipe movement in all three translational directions. Engineers use anchors to isolate one section of a piping system from another section in terms of loading and deflection. A total anchor that eliminates all translation and rotation at one location is not as common as one or more restraints that act at a single location. It is difficult to design effective rotational anchors or restraints. Plant piping more commonly uses directional anchors that restrain the pipes only in their translational directions.

Figures 50 through 52 show examples of anchor types that are typically used in aboveground plant piping systems.

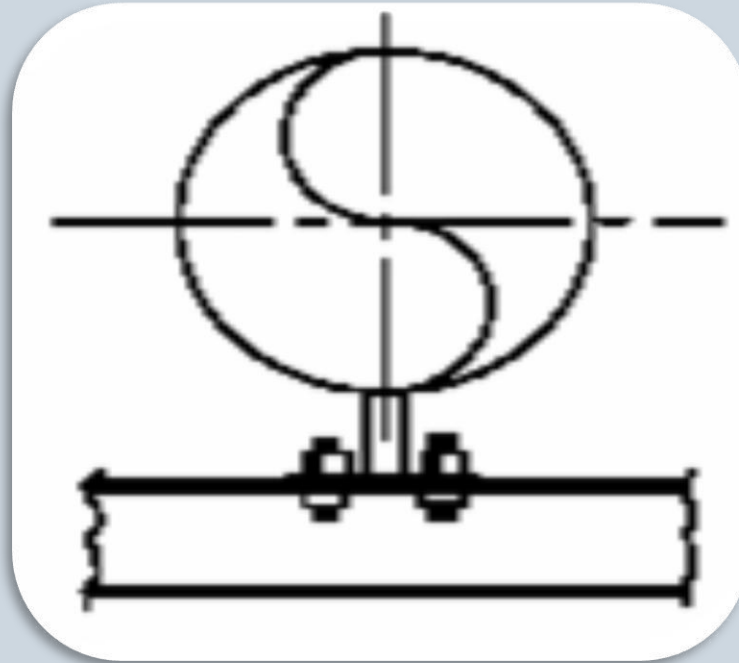


Figure 50. Anchor

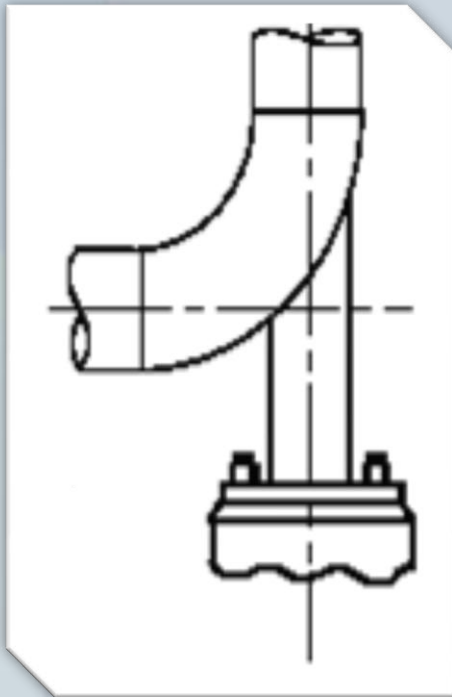


Figure 51. Anchor

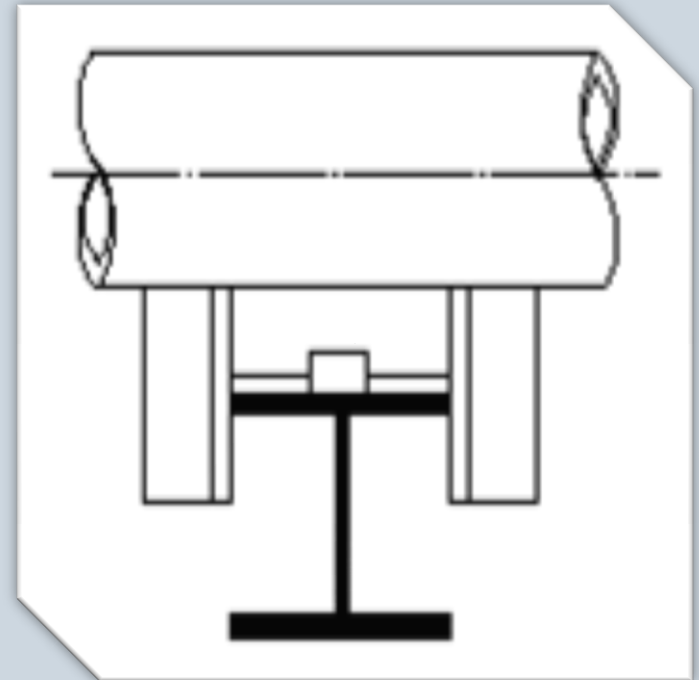


Figure 52. Anchor

Main Content Page Layout•





The End any questions?