As published in the February and March 2007 issues of Chemical Engineering Magazine

With regard to material of construction, the ongoing evolution of technology has raised expectations throughout industry…

William M. (Bill) Huitt
W. M. Huitt Co.

This is the first in a series of three articles that will cover a wide range of piping topics. Topics that will cross industry lines to include chemical, petroleum refining, pharmaceutical, and other industries as well. It will be the intent of these articles to address questions and misunderstandings as they relate to industry on a general basis.

"Pipe is pipe". This is a euphemism (jargon if you will) quite often used among piping designers and engineers. Taken at face value, this is a true statement…pipe is certainly pipe. However, taken in context, it means that no matter which industry you work in when designing piping systems it's all the same. And in that context it could not be further from the truth.

The pharmaceutical industry, in its current state of growth, is a relative new comer to design, engineering and construction compared to the oil refining, bulk chemical, pulp & paper and nuclear industries. As a frame of reference the American Society of Mechanical Engineers (ASME) was established in 1880; the American Petroleum Institute (API) was established in 1919; 3-A Standards (for food & dairy) were first developed in the 1920's; the ASME committee for BPVC (Boiler Pressure Vessel Code) Section III for nuclear power was proposed in 1963; Semiconductor Equipment and Materials Institute (SEMI) was established in 1973; the International Society of Pharmaceutical Engineers (ISPE) was established in 1980; and ASME Biopharmaceutical Equipment (BPE) issued its first Standard in 1997. Prior to ASME-BPE much of the 3-A piping Standards were plagiarized to facilitate design of pharmaceutical facilities.

While some of the above Standards Committees, and their resulting Codes and Standards, are specific to a particular industry others are more generalized in their use and are utilized across the various industries.

As an example, Not only does the design and construction of a large pharmaceutical facility require the need for pharmaceutical based Standards, Codes, Guidelines and Industry Practices such as those generated by ISPE and ASME-BPE, it also requires those Standards created for other industries as well. Meaning that, when designing and constructing a bulk pharmaceutical finishing facility, or a bulk Active Pharmaceutical Ingredient (API) facility the engineers and constructors will also be working under some of the same standards and guidelines as they would when designing and building in other industries such as a petroleum refinery or bulk chemical facility.

It is not that the pharmaceutical industry itself is young, but the necessary engineering standards and practices are. Within the past fifteen or so years, industry practice, including dimensional standards for high purity fittings, were left to the resources of the pharmaceutical Owner or their engineering firm (engineer of record). The same applies to construction methods and procedures, including materials of construction. These requirements were basically established for each project and were very dependent upon what the Owner's personnel and the engineering firm brought to the table. Industry standards did not exist.

With regard to material of construction, the ongoing evolution of technology has raised expectations throughout industry, but even more so in the pharmaceutical, biopharmaceutical and semiconductor industries.

For instance, out of the research and development that went into the Hubble Space Telescope came new methodology and technology to better measure and define the all too tangible limits of surface roughness required in material used in hygienic fluid service contact piping. This is of particular interest to the pharmaceutical, biopharmaceutical and semiconductor industries, where cross-contamination at the molecular level cannot be tolerated in many cases. This requires surfaces to be very cleanable.

Surface roughness used to be expressed as polish numbers (ie, #4 or #7) then grit numbers such as 150, 180 or 240). The problem with either of these two methods lay in their subjectivity and their generality. These indicators were not specific enough and the accept/reject result relied too much on a subjective visual verification. There will be more on surface finish requirements in Part II.

With acute awareness of the ongoing problems currently faced in the pharmaceutical industry and, for altogether different reasons, the semiconductor industry, various Standards organizations have taken steps to alleviate the consistent problems that have plagued the industry in the past with high purity welding issues, standardization of fittings, and guidelines for industry practice. We will discuss some of the finer points of these issues and in some cases what these Standards organizations, are doing to promote and consolidate some of the better thinking in this industry and in this field.

In these early paragraphs it seems as though I am singling out the pharmaceutical industry as the focal point of these discussions. As you will see this is not true. And in saying pharmaceutical I do mean to include biopharmaceutical (biopharm) as well.

In making an example of the pharmaceutical industry it is simply an attempt on my part to utilize its relative newness in the development of its own particular brand of standards to give the reader a sense of standards development and how these standards evolve.

This article and the two that follow will address metallic piping topics including a discussion on hygienic piping. While non-metallic piping is worthy of discussion it is too broad a topic to try and capture here and will not be a part of these articles. Some of the points that will be covered in this and the following articles are topics such as:

1. ASME flange ratings, is it 150 and 300 pound flange or is it Class 150 and Class 300 flange?
2. Does the 150, 300, etc. actually mean anything or is it simply an identifier?
3. In forged fittings, is it 2000 pound and 3000 pound, or is it Class 2000 and Class 3000?
4. How do you determine which Class of forged fitting to select for your specification?
5. Corrosion allowance in piping; how do you determine and then assign corrosion allowance?
6. How do you select the proper bolts and gaskets for a service?
7. How is pipe wall thickness determined?
8. What is MAWP?
9. What is Operating and Design Pressure?
10. What is Operating and Design Temperature?
11. How do Design Pressure and Temperature relate to a PSV set point and leak testing?
12. What Code should you be designing under?
13. What kind of problems can you expect with sanitary clamp fittings?
14. How do you alleviate those problems with sanitary clamp fittings?
15. What is ASME-BPE?
16. How does ASME B31.3 and ASME-BPE work in concert with one another?
17. What is ASME BPE doing to bring accreditation to the pharmaceutical Industry?
18. Design is the culmination and application of industry standards and industry requirements that take into account constructability along with maintenance and operational needs. These points will be covered as well.

We will first of all lay some groundwork by beginning with the basics of general piping. By understanding the basic elements of piping the designer and engineer can improve their decision making in the material selection process and system design effort. These articles will also make clear a number of misconceptions with regard to terminology and general practices.

What we will try to avoid is a lot of in-depth discussion and elaborate analysis on specific points. What I would like to achieve is a general discussion on many topics rather than finite rhetoric on only a few.

With that said, this first article is entitled:

Piping Design Part I – The Basics

This article will not attempt to cover all of the various types of piping components and joints that are available in industry today. To keep the discussion focused we will discuss only that segment of joints, fittings and components most frequently used in general piping design.

Neither will we duplicate the dialog of previous articles that have provided excellent commentary on segments of this same topic. Articles such as the one written by John C. Cox and published by Chemical Engineering for their January 2005 edition titled “Avoid Leakage in Pipe Systems”. John provides a concise and descriptive narrative on threaded and compression type connections. And the article by Trinath Sahoo published by Chemical Engineering for their June 2005 edition titled “Gaskets: The Weakest Link”. In his article Trinath gives the reader some excellent insight into the mechanics of gasket selection and design.

PIPE FLANGES

Pipe flanges are used to mechanically connect pipe sections to other pipe sections, inline components, and equipment. Flanges also allow pipe to be assembled and disassembled without cutting or welding, eliminating the need to issue a burn card for cutting and welding when dismantling is required. In providing a breakable joint, flanges unfortunately provide a potential leak path for the service fluid contained in the pipe. Because of this, as in all other joints, they need to be minimized where possible.

The most prevalent flange standards to be used in industry are based on requirements of the American Society of Mechanical Engineers (ASME) Standards. These include:

B16.1 – Cast Iron Pipe Flanges and Flanged Fittings,
B16.5 - Pipe Flanges and Flanged Fittings (NPS 1/2 through NPS 24),
B16.24 – Cast Copper Alloy Pipe Flanges and Flanged Fittings,
B16.36 – Orifice Flanges,
B16.42 – Ductile Iron Pipe Flanges and Flanged Fittings,
Large Diameter Steel Flanges (NPS 26 through NPS 60)
B16.47 – Large Diameter steel flanges (NPS 26 through NPS 60)

NPS, indicated above, is an acronym for Nominal Pipe Size.

Flanges are available with various contact facings (the flange-to-flange contact surface) and methods of connecting to the pipe itself. The flanges under B16.5 are available in a variety of styles and pressure classifications. The different styles, or types, are denoted by the way each connects to the pipe itself and/or the type of face. The type of pipe-to-flange connections consist of Threaded, Socket Welding (or Socket Weld), Slip-On Welding (or Slip-On), Lapped (or Lap Joint), Welding Neck (or Weld Neck), and Blind.

Threaded Flange

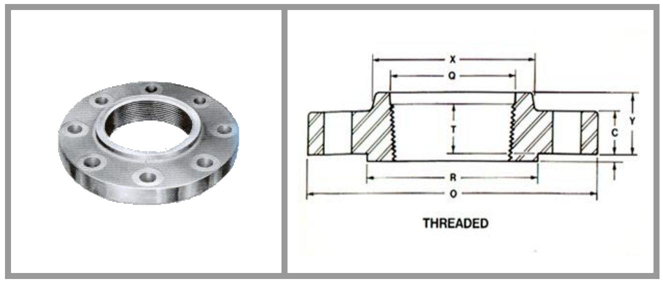


Figure 1

The Threaded flange, through Class 400, is connected to threaded pipe in which the pipe thread conforms to ASME B1.20.1. For threaded flanges in Class 600 and higher the length through the hub of the flange exceeds the limitations of ASME B1.20.1. ASME B16.5 requires that when using threaded flanges in Class 600 or higher Schedule 80 or heavier pipe wall thickness be used, and that the end of the pipe be reasonably close to the mating surface of the flange. Note that the term “reasonably close” is taken, in context, from Annex A of ASME B16.5, it is not quantified.

In order to achieve this “reasonably close” requirement the length of the thread has to be longer and the diameters of the smaller threads become smaller than that indicated in ASME B1.20.1. When installing Threaded flanges Class 600 and higher, ASME B16.5 recommends using power equipment to obtain the proper engagement. Simply using arm strength with a hand wrench is not recommended.

The primary benefit of threaded flanges is in eliminating the need for welding. In this regard Threaded flanges are sometimes used in high-pressure service in which the operating temperature is ambient. They are not suitable where high temperatures, cyclic conditions or bending stresses can be potential problems.

Socketweld Flange

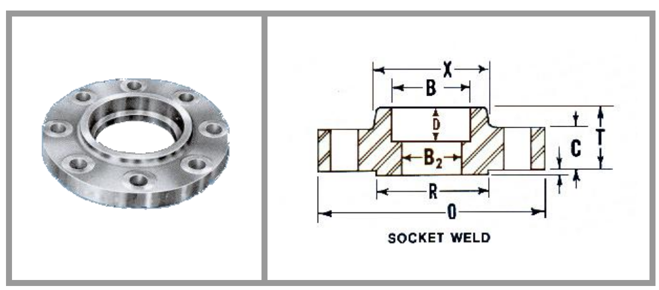


Figure 2

The Socketweld flange is made so that the pipe is inserted into the socket of the flange until it hits the shoulder of the socket. The Pipe is then backed away from the shoulder approximately 1/16” before being welded to the flange hub.

If the pipe were resting against the shoulder (*This is the flat shelf area depicted in Fig. 2 as the difference between* *diameters B and B_2*) of the socket joint during welding, heat from the weld would expand the pipe longitudinally into the shoulder of the socket forcing the pipe-to-flange weld area to move. This could cause the weld to crack.

The Socketweld flange was initially developed for use on small size, high-pressure piping in which both a back-side hub weld and an internal shoulder weld was made. This provided a static strength equal to the Slip-On flange with a fatigue strength 1.5 times that of the Slip-On flange.

Because the two-welds were labor intensive it became the practice to weld only at the hub of the flange. In doing this it relegated the socketweld flange to be more frequently used for small pipe sizes (NPS 2” and below) in non-high-pressure, utility type service piping. The Socketweld flange is not approved above Class 1500.

Slip-On Flange

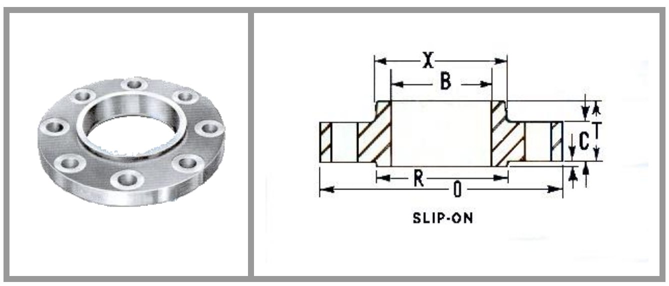


Figure 3

Unlike the Socketweld flange, the Slip-On flange allows the pipe to be inserted completely through its hub opening. Two welds are made to secure the flange to the pipe. One fillet (pronounced “fill-it”) weld is made at the hub of the flange and a second weld is made at the inside diameter of the flange near the flange face.

The end of the pipe is offset from the face of the flange by a distance equal to the lesser of the pipe wall thickness or 1/4” plus approximately 1/16”. This is to allow for enough room to make the internal fillet weld without damaging the flange face.

The Slip-On flange is a preferred flange for many applications because of its initial lower cost, the reduced need for cut length accuracy and the reduction in end prep time. However, the final installed cost is probably not much less than that of a Weld Neck flange.

The strength of a Slip-On flange under internal pressure is about 40% less than that of a Weld Neck flange. The fatigue rate is about 66% less than that of a Weld Neck flange. The Slip-On flange is not approved above Class 1500.

Lap Joint Flange

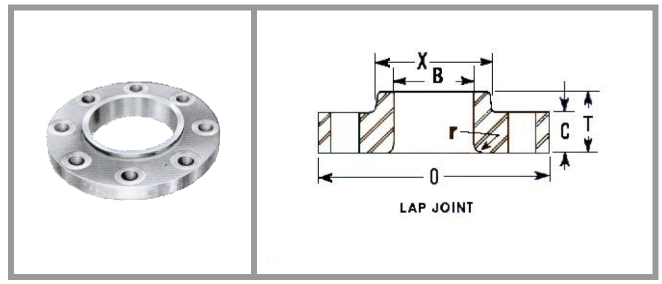


Figure 4

The Lap Joint flange requires a companion lap joint, or Type A stub-end (ref. Fig. 5) to complete the joint. The installer is then able to rotate the flange. This allows for quick bolthole alignment of the mating flange during installation without taking the extra precautions required during prefabrication of a welded flange.

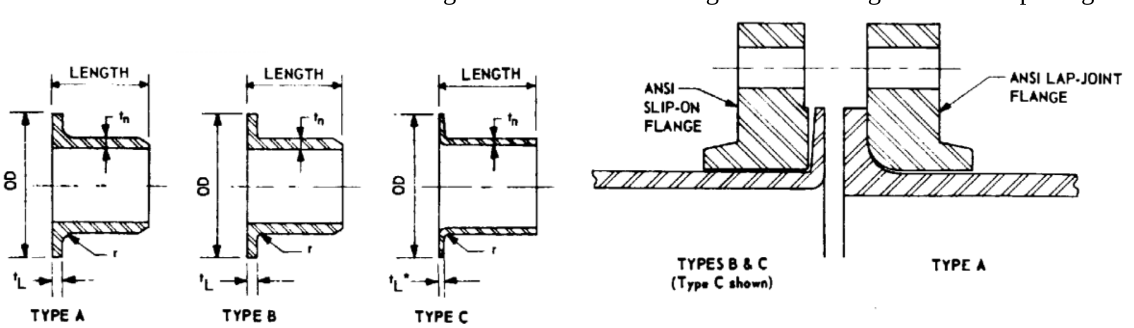
Their pressure holding ability is about the same as a Slip-On flange. The fatigue life of a Lap Joint/stub-end combination is about 10% that of a Weld Neck flange, with an initial cost that is a little higher than that of a Weld Neck flange.

The real cost benefit in using a Lap Joint flange assembly is realized when installing a stainless steel or other costly alloy piping system. In many cases the designer can elect to use a stub-end specified with the same material as the pipe, but use a less costly, e.g. carbon steel, Lap Joint Flange. This prevents the need of having to weld a more costly compatible alloy flange to the end of the pipe.

Just a quick word about stub-ends; they are actually prefabricated or cast pipe flares that are welded directly to the pipe. They are available in three different types: Type A, (which is the lap-joint stub-end), Type B and Type C (ref. Fig. 5).

Type A (Fig 5) is forged or cast with an outside radius where the flare begins. This radius conforms to the radius on the inside of the Lap-Joint flange. The mating side of the flare has a serrated surface.

Type B (Fig. 5) is forged or cast without the radius where the flare begins. It is used to accommodate the Slip-On flange or Plate flange as a back-up flange.



Type C (Fig 5) is fabricated from pipe using five suggested methods indicated in ASME B31.3. The most prevalent of these is the machine flare. This is done by placing a section of pipe into a flaring machine, flaring the end of the pipe and then cutting it to length.

As you can see in the assembly detail of Fig. 5, stub-end types B & C have no radius at the flare while Type A does. This allows it to conform to the Lap-Joint flange. Due to the radius of the type A stub-end, a slip-on flange would have a poor fit, creating non-uniform loading of the flare face as well as an undesirable point load at the radius of the flare.

Weld Neck Flange

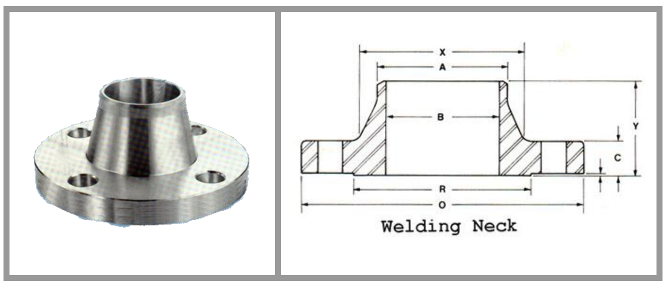


Figure 6

The reinforcement area of the Weld Neck flange distinguishes it from other flanges. This reinforcement area is formed by the added metal thickness, which tapers from the hub of the flange to the weld end. The bore of the flange needs to be specified in order to obtain the same wall thickness at the weld end as the pipe it will be welded to. This will give it the same ID bore as the pipe.

The Weld Neck flange is actually the most versatile flange in the ASME stable of flanges. Much of its use is for fitting-to-fitting fabrication in which the flange can be welded directly to a fitting, such as an elbow, without the need for a short piece of pipe, as would be required with a Slip-On flange. It can be used in low-pressure, non-hazardous fluid services as well as high-pressure, high-cyclic and hazardous fluid services.

While the initial cost of the Weld Neck flange may be higher than that of a Slip-On flange the installed cost reduces that differential. And for conditions of possible high thermal loading, either cryogenic or elevated temperatures, the Weld Neck flange would be essential.

Blind Flange

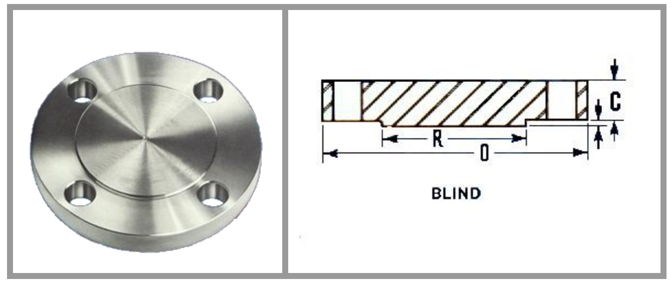


Figure 7

While the Blind flange is used to cap off the end of a pipeline or a future branch connection it is also used for other purposes. It can be drilled and tapped for a threaded reducing flange or machined out for a Slip-On reducing flange. The reduced opening can be either on-center or eccentric.

Flange Pressure Ratings

ASME B16.5 flange pressure ratings have been categorized into material groupings. These groupings are formulated based on both the material composition and the process by which the flange is manufactured.

The available pressure Classifications under ASME B16.5 are: 150, 300, 400, 600, 900, 1500 and 2500. The correct terminology for this designation is Class 150, Class 300, etc. The term 150 pound, 300 pound, etc. is a carry over from the old ASA (American Standards Association) Classification. ASA is the precursor to the American National Standards Institute (ANSI).

Taking a quick step back, ANSI was founded as a committee whose responsibility was to coordinate the development of standards and to act as a standards traffic cop for the various organizations that develop standards. Its basic function is not to develop standards, but rather to provide accreditation of those standards

Originating as the American Engineering Standards Committee (AESC) in 1918, ANSI had, over its first ten years, outgrown its Committee status and in 1928 was reorganized and renamed as the American Standards Association (ASA). In 1966 the ASA was reorganized again under the name of the United States of America Standards Institute (USASI). In 1969 ANSI adopted its present name.

While the B16 and B31 Standards have previously carried the ASA and ANSI prefix with its various Standards titles ASME has always been the administrative sponsor in the development of those standards. In the 1970's the prefix designation changed to ANSI/ASME and finally to ASME.

Referring to ANSI B16. or ANSI B31.* is no longer correct. Instead it is correct to refer to a standard as ANSI/ASME B16.* in that it indicates an*

ANSI accredited ASME standard. Or you can simply refer to the standard as ASME B16. or ASME B31.*.*

Development of ASME B16.5 began in 1920. In 1927 the American Tentative Standard B16e was approved. This eventually became what we know today as ASME B16.5. Until the 1960's the pressure Classifications, as addressed earlier, were referred to as 150 pound, 300 pound, etc. It was at this point the pressure Classification was changed to the Class designation. These designations have no direct correlation with pounds of pressure. Rather, they are a factor in the pressure rating calculation found in B16.5. In Part II of this series, we will discuss how these designations are factored into the design of the flange.

Flange Pressure Ratings

Flanges, whether manufactured to ASME (American Society of Mechanical Engineers), API (American Petroleum Institute), MSS (Manufacturers Standardization Society), AWWA (American Water Works Association) or any other Standard, are grouped into pressure ratings. In ASME these pressure ratings are a sub-group of the various material groups designated in B16.5.

Figure 8 represents one of the Tables from the Table 2 series in ASME B16.5. This is a series of Tables that lists the Working Pressures of flanges based on material groupings, temperature and Classification.

There are 34 Tables segregated into three material Categories of Carbon and low alloy steels, austenitic stainless steels, and nickel alloys. These are further segregated into more defined material sub-groups. Figure 8 shows Table 2-1.1, which indicates, in reverse sequence, sub-category 1 of material group 1 (carbon and low alloy steels).

If you had an ASME B16.5, Class 150, ASTM A105 flange this is the table you would use to determine the Working Pressure limit of the flange. To find the Working Pressure of the above mentioned flange enter the column of this table designated as 150 then move down the column to the operating temperature. For intermediate temperatures,

PIPE FLANGES AND FLANGED FITTINGS ASME B16.5-1996

TABLES 2
PRESSURE–TEMPERATURE RATINGS FOR GROUPS 1.1 THROUGH 3.16 MATERIALS

TABLE 2-1.1 RATINGS FOR GROUP 1.1 MATERIALS

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

Figure 8 – Table 2-1.1 from ASME B16.5

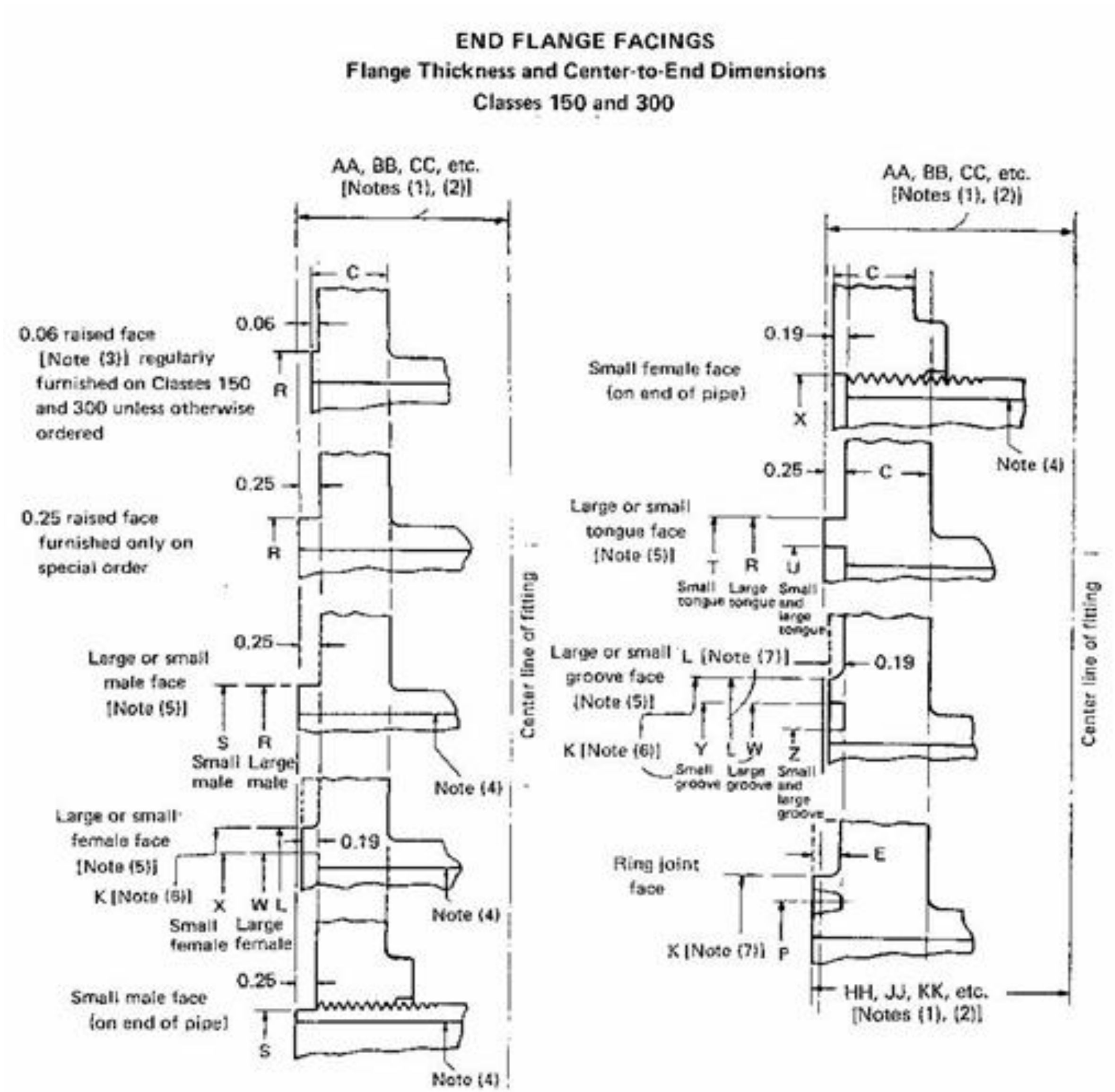


Figure 9 – Flange Facings from ASME B16.5

linear interpolation is permitted.

In the previous paragraph you will notice that I indicated "operating temperature" when looking to determine the Working Pressure of a flange. 'Operating' and 'working' are synonymous. The indication of a working pressure and temperature of a fluid service is the same as indicating the operating pressure and temperature.

There exists some confusion in this area. That confusion becomes apparent when the engineer is determining design pressure and temperature and applying that to the flange rating. On the surface there appears to be a conflict between rating a flange for design conditions when Table 2 only indicates working pressures.

Operating and design pressures and temperatures will be explained in more detail in Article 2. For now I will explain that every service should have an operating pressure/temperature and a design pressure/temperature. A design condition is the maximum coincidental pressure and temperature condition that the system is expected or allowed to see. This then becomes the condition to which you should design for, and to which the leak test is based on, not the operating condition.

Tables 2, as it indicates, represents the working or operating pressures of the flange at an indicated temperature for a specific Class. The maximum hydrostatic leak test pressure for a Class 150 flange in Table 2-1.1 is 1.5 times the rated working pressure at 100°F, or 285 x 1.5 = 427.5 rounded off to the next higher 25 psi, or 450 psig.

We can extrapolate that piece of information to say that since hydrostatic leak test pressure is based on 1.5 x design pressure the working pressure limit given in the Table 2 matrix ostensibly becomes the design pressure limit.

When working with ASME B31.3 Category D fluid services, and initial service leak testing is performed, the working pressure limit then remains the working pressure limit because testing is performed at operating or working pressures. In saying that however, there are caveats that address the fact that not all Category D fluid services should waive the hydrostatic leak test for an initial service leak test. These conditions, such as steam service, will also be discussed in a subsequent article.

Category D fluid services are those fluid services that are nonflammable, nontoxic and not damaging to human tissue. Category D fluids additionally do not exceed 150 psig and 366º F.

In initial service leak testing the test fluid is the service fluid. Leak testing occurs during or prior to initial operation of the system. As the service fluid is introduced to the piping system and brought to operating pressure, in pressure increments, all joints are observed for possible leaks. If no leaks are detected the pipeline simply remains in service.

Other ASME B31.3 fluid services may be expected to operate at one set of conditions, but are designed for another set. For those systems, which might include periodic steam-out (cleaning, sterilization, sanitization) or passivation, you therefore want to base your flange rating selection on those more extreme, periodic design conditions. To clarify periodic in this context, the sanitization process can be done as frequently as once per week and last for one to one and half shifts in duration.

Flange Facing & Surface Finishes

Standard flange facing designations (ref. Fig. 9) are as follows: Flat Face, Raised Face, Ring Joint, Tongue and Groove, Large and Small Male and Female, Small Male and Female (on end of pipe), Large and Small Tongue and Groove. The height of the raised face for Class 150 and 300 flanges is 0.06”. The height of the raised face for Class 400 and above is 0.25”.

Across industry, not discounting the lap-joint flange and stub-end combination, the two most widely used flange facings are the flat face and the raised face.

The surface finish of standard raised face and flat face flanges has a serrated concentric or serrated spiral surface finish with an average roughness of 125 μin to 250 μin. The cutting tool used for the serrations will have a 0.06 in. or larger radius and there should be from 45 to 55 grooves per inch.

BOLTS, NUTS & GASKETS

Sealing the flange joint, and as you will see further in this article, the hygienic clamp joint, is paramount in providing integrity to the overall piping system. This is achieved with the use of bolts, nuts and gaskets. Making the right selection for the application can mean the difference between a joint with integrity and one without.

ASME B16.5 provides a list of appropriate bolting material for ASME flanges. The bolting material is grouped into three strength categories; high, intermediate and low, which are based on the minimum yield strength of the specified bolt material.

The High Strength category includes bolt material with a minimum yield strength of not less than 105 ksi. The Intermediate Strength category includes bolt material with a minimum yield strength of between 30 ksi and 105 ksi. The Low Strength category includes bolt material with a minimum yield strength no greater than 30 ksi.

As defined in ASME B16.5, the High Strength bolting materials "…may be used with all listed materials and all gaskets". The Intermediate Strength bolting materials "…may be used with all listed materials and all gaskets, provided it has been verified that a sealed joint can be maintained under rated working pressure and temperature”. The Low Strength bolting materials "…may be used with all listed materials but are limited to Class 150 and Class 300 joints", and can only be used with selected gaskets as defined in ASME B16.5.

ASME B31.3 further clarifies in para. 309.2.1, "Bolting having not more than 30 ksi specified minimum yield strength shall not be used for flanged joints rated ASME B16.5 Class 400 and higher, nor for flanged joints using metallic gaskets, unless calculations have been made showing adequate strength to maintain joint tightness". B31.3 additionally states in para. 309.2.3, “…If either flange is to the ASME B16.1 (*cast iron*), ASME B16.24 (*cast copper alloy*), MSS SP-42 (*valves with flanged and buttweld ends*), or MSS SP-51 (*cast flanges and fittings*) specifications, the bolting material shall be no stronger than low yield strength bolting unless: *(a)* both flanges have flat faces and a full face gasket is used: or, *(b)* sequence and torque limits for bolt-up are specified, with consideration of sustained loads, displacement strains, and occasional loads (see paras. 302.3.5 and 302.3.6), and strength of the flanges.

In specifying flange bolts, as well as the gasket, it is necessary, not only to consider design pressure and temperature, but fluid service compatibility, the critical nature of the fluid service and environmental conditions all in conjunction with one another.

To better understand the relationship of these criteria I will list and provide some clarification for each:

1. The coincident of design pressure and temperature is what determines the pressure Class of a flange set. That, in turn, along with flange size, will determine the number and size of the flange bolts. The flange Class will also determine the compressibility range of the gasket material.
2. Fluid service compatibility will help determine the gasket material.
3. The critical nature of the fluid will determine the degree of integrity required in the joint. This will help determine bolt strength and material as well as gasket type.
4. Environmental conditions will also help determine bolt material (Corrosive atmosphere, wash-down chemicals, etc.).

What this ultimately means is that all of the variables that come together in making up a flange joint have to do so in a complementary fashion. Simply selecting a gasket based on material selection and not taking into account the pressure rating requirement could provide a gasket that would get crushed under necessary torque requirements rather than withstand the bolt load and create a seal.

Selecting a low strength bolt to be used with a Class 600 flange joint with proper gasketing will require the bolts to be torqued beyond their yield point, or at the very least beyond their elastic range. To explain this briefly; bolts act as springs when they are installed and loaded properly. In order for the flange joint to maintain a gasket seal it requires dynamic loading. Dynamic loading of flange bolts allows expansion and contraction movement in and around the joint while maintaining a seal. This is achieved by applying sufficient stress to the bolt to take it into the material's elastic range.

If the bolts are not stressed sufficiently into their elastic range any relaxation in the gasket could reduce the sealing ability of the joint. To the other extreme, if the bolts were stressed beyond their elastic range and into the plastic range of their material of construction the same issue applies, they will lose their dynamic load on the gasket. In this case, if they do not shear they will take a set. Any relaxation in the gasket will then result in the reduction or elimination of the joints sealing ability.

With regard to the nut, it should be selected to compliment the bolt. Actually the bolt material specification will steer you, either partially or completely, into the proper nut selection.

ASTM A307, a material standard for bolts in the low-strength category, states that the proper grade for bolts to be used for pipe flange applications is Grade B. A307 goes further to state that when used for pipe flanges Grade B bolts require a Heavy Hex Grade A nut under ASTM A563. In writing a pipe spec that includes the A307 bolt you would not need to specify the nut since it is already defined in A307.

However, ASTM A193, alloy and stainless steel bolts, goes only so far when it states that nuts shall conform to ASTM A194, but there are several grades of A194 nuts to select from. This is an example of where the matching nut is not always explicitly called out in the ASTM Standard. Because the ASTM Standards are inconsistent in that regard the spec-writer must make sure it is covered in a specification.

You can see from this bit of information that all four components, flanges, bolts, nuts and gaskets have to be selected in conjunction with one another in order for the joint assembly to perform in a way that it is expected to for a given application.

Pipe, Tube & Fittings

One of the big differences between pharmaceutical and semi-conductor piping and other industrial piping, is the requirements of high purity, or hygienic fluid services. These requirements, as dictated by current Good Manufacturing Practices (cGMP) and defined and quantified by the ISPE and ASME-BPE, are stringent with regard to the manufacture, documentation, fabrication, installation, qualification, validation and quality control of hygienic piping systems and components.

The man-hours required in generating, maintaining and controlling the added documentation required for hygienic fabrication and installation is in the range of 30% to 40% of the overall cost of fabrication and installation. Part II in this series will get more into the requirements of hygienic fabrication and where that added cost comes from.

For now we will stay with general pipe and fittings. In an attempt at keeping this article concise we will only cover those fittings that are predominantly used throughout industry, both in process and in utility services.

Pipe fittings are manufactured by the following processes: cast, forged and wrought.

Cast Fittings

Cast fittings are provided in cast iron, malleable iron, steel, stainless steel, brass, bronze, and other alloy material as follows:

Cast Iron: Cast iron threaded fittings, under ASME B16.4, are available in Class 125 and Class 250 for sizes NPS 1/4" through 12". Cast iron flanged fittings, under ASME B16.1, are available in Class 25, 125 and 250 in sizes NPS 1" through 48".

Malleable Iron: Malleable iron fittings, under ASME B16.3, are available in Class 150 and Class 300 in sizes NPS

1/8” though 6” for Class 150 and 1/4” through 3” for Class 300.

It needs to be noted here that Classifications such as 150 and 300 are not universal throughout the ASME Standards. They are specific to the Standard that they are associated with. You cannot automatically transfer the pressure/temperature limits of a flange joint in ASME B16.5 to that of a fitting in B16.3.

Cast Steel: Cast steel, stainless steel and alloy steel flanged fittings, under ASME B16.5, are available in Class 150, 300, 400, 600, 900, 1500 & 2500 in sizes 1/2” though 24”.

Cast Brass: Cast Brass and bronze threaded fittings, under ASME B16.15, are available in Class 125 and 250, in sizes NPS 1/8” through 4” for Class 125 and 1/4” through 4” for Class 250.

Cast Copper: Cast copper solder joints, under ASME B16.18, are available in sizes 1/4” through 6”.

Forged Fittings

Before getting into forged fittings I would like to explain the difference between forged and wrought fittings. There seems to be some vague misconception of what the term forged means and what the term wrought means and how it applies to pipe fittings.

The term forging actually comes from the times when metal was worked by hand. A bar of steel would be placed into a forge and heated until it reached its plastic state, at which time the metal would be pulled out of the forge and hammered into some desired shape. Today forging metal basically means working the metal by means of hydraulic hammers to achieve the desired shape.

As a small bit of trivia, up until the late 1960’s, when mills stopped producing it, wrought iron was the choice of ornamental iron workers. It is still produced in Europe, but most of what we see manufactured as wrought iron in the U.S. is actually various forms of steel made to look like wrought iron.

True wrought iron is corrosion resistant, has excellent tensile strength, welds easily and in its plastic range is said to be like working taffy candy. What gives wrought iron these attributes is the iron silicate fibers, or “slag” added to the molten iron with a small percentage of carbon, whereas cast iron, with a high carbon content, is more brittle and not as easily worked.

The smelters, where the iron ore was melted to produce wrought iron, were called bloomeries. In a bloomery the process does not completely melt the iron ore, rather the semi-finished product was a spongy molten mass called a bloom, derived from the red glow of the molten metal, which is where the process gets its name. The slag and impurities were then mechanically removed from the molten mass by twisting and hammering which is where the term wrought originates.

Today forged and wrought are almost synonymous. If we look in ASTM A234 - *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service* we can see in Para 4.1 and in Para 5.1 that wrought fittings made under A234 are actually manufactured or fabricated from material pre-formed by one of the methods listed previously, which includes forging. In ASTM A961 - *Standard Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves and Parts for Piping Applications* the definition for the term *Forged* is, “*the product of a substantially compressive hot or cold plastic working operation that consolidates the material and produces the required shape. The plastic working must be performed by a forging machine, such as a hammer, press, or ring rolling machine, and must deform the material to produce a wrought structure throughout the material cross section.*”

The difference therefore between forged and wrought fittings is that forged fittings, simply put, are manufactured from bar, which while in its plastic state is formed into a fitting with the use of a hammer, press or rolling machine. Wrought fittings, on the other hand, are manufactured from killed steel, forgings, bars, plates and seamless or fusion welded tubular products that are shaped by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. In simpler terms wrought signifies “worked”. There are exceptions in the manufacture of both, but that is the general difference.

Something worth noting at this point concerns the ASTM specifications. In quoting from ASTM A961 I was quoting from what ASTM refers to as a General Requirement Specification, which is what A961 is. A General Requirement Specification is a specification that covers requirements that are typical for multiple individual Product Specifications. In this case the individual Product Specifications covered by A961 are A105, A181, A182, A360, A694, A707, A727 and A836.

The reason I point this out is that many designers and engineers are not aware that when reviewing an A105 or any of the other ASTM individual Product Specifications you may need to include the associated General Requirement Specification in that review. Reference to a General Requirement Specification can be found in the respective Product Specification.

Forged steel and alloy steel socketweld and threaded fittings, under ASME B16.11, are available in sizes NPS 1/8” through 4”. Forged socketweld fittings are available in pressure rating Classes 3000, 6000 and 9000. Forged threaded fittings are available in pressure rating Classes 2000, 3000 and 6000.

What I see quite often, and this includes all of the industries I have been associated with, is a misapplication of pressure rating in these fittings. This leads me to believe that the person specifying components does not fully understand the relationship between the pressure Class of these fittings and the pipe they are to be used with.

In ASME B16.11 is a table that associates, as a recommendation, fitting pressure Class with pipe wall thickness, as follows:

Table 1 – Correlation of Pipe Wall Thickness & Pressure Rating

Pipe Wall Thk.	Threaded	Socketweld
80 or XS	2000	3000
160	3000	6000
XXS	6000	9000

The ASME recommendation is based on matching the I.D. of the barrel of the fitting with the I.D. of the pipe. The shoulder of the fitting (the area of the fitting that the end of the pipe butts against), either socketweld, as shown in Fig. 10, or threaded, is approximately, allowing for fabrication tolerances, the same width as the specified mating pipe wall thickness.

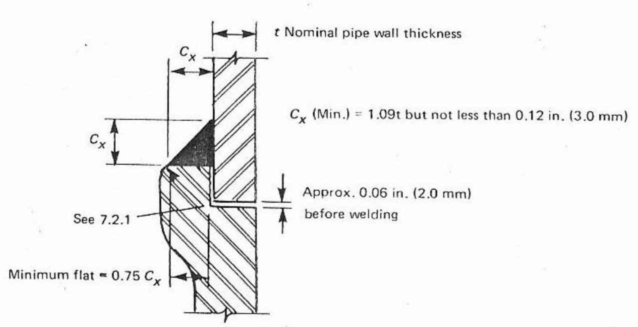


Figure 10 – Socket Weld Fitting Joint from ASME B16.11

As an example, referring to Table 1, if you had a specified pipe wall thickness of Sch. 160 the matching threaded forged fitting would be a Class 3000, for socketweld it would be a Class 6000. The fitting pressure Class is selected based on the pipe wall thickness. Referring to Fig. 10, you can readily see that by not matching the fitting Class to the pipe wall thickness it will create either a recessed area or a protruding area the length of the barrel of the fitting, depending on which side you error on. For forged reinforced branch fittings refer to MSS Standard SP-97 – *Integrally Reinforced Forged Branch Outlet Fittings - Socket Welding, Threaded and Buttwelding Ends*.

Wrought Fittings

Wrought Steel Butt Weld Fittings under ASME B16.9 (standard radius 1.5D elbows and other fittings) are available in sizes 1/2” through 48”. Wrought Steel Butt Weld Fittings under B16.28 (short radius 1D elbows), are available in sizes 1/2” through 24”. There is no pressure/temperature rating classification for these fittings. In lieu of fitting pressure classifications both B16.9 and B16.28 require that the fitting material be the same as or comparable to the pipe material specification and wall thickness. Under ASME B16.9, given the same material composition, the fittings will have the same allowable pressure/temperature as the pipe. ASME requires that the fittings under B16.28, short radius elbows, be rated at 80% of that calculated for straight seamless pipe of the same material and wall thickness.

These fittings can be manufactured from seamless or welded pipe or tubing, plate or forgings. Laterals, because of the elongated opening cut from the run pipe section are rated at 40% of that calculated for straight seamless pipe of the same material and wall thickness. If a full strength lateral is required either the wall thickness of the lateral itself can be increased or a reinforcement pad can be added at the branch to compensate for the loss of material at the branch opening.

Wrought copper solder joint fittings, under ASTM B88 and ASME B16.22, are available in sizes 1/4” through 6”. These fittings can be used for brazing as well as soldering.

The pressure/temperature rating for copper fittings are based on the type of solder or brazing material and the tubing size. It will vary too, depending on whether the fitting is a standard fitting or a DWV (Drain, Waste, Vent) fitting, which has a reduced pressure rating.

As an example, using alloy Sn50, 50-50 Tin-Lead Solder, at 100ºF, fittings 1/2” through 1” have a pressure rating of 200 psig and fittings 1½” through 2” have a pressure rating of 175 psig. DWV fittings 1½” through 2” have a pressure rating of 95 psig.

Using alloy HB, which is a Tin-Antimony-Silver-Copper-Nickel (Sn-Sb-Ag-Cu-Ni) solder, having 0.10% maximum Lead (Pb) content, at 100ºF, fittings 1/2” through 1” have a pressure rating of 1035 psig and fittings 1½” through 2” have a pressure rating of 805 psig. DWV fittings 1½” through 2” would have a pressure rating of 370 psig.

As you can see, within the same type of fitting, there is a significant difference in the pressure ratings of soldered joints depending on the type of filler metal composition. Much of the difference is in the temperature at which the solder or brazing filler metal fully melts. This is referred to as its liquidus state. The temperature at which it starts to melt is referred to as its solidus temperature, the higher the liquidus temperature the higher the pressure rating of the joint.

Pipe and Tubing

The catch-all terminology for pipe and tubing is tubular products. This includes pipe, tube and their respective fittings. Piping itself refers to a system of pipe, fittings, flanges, valves, bolts, gaskets and other in-line components that make up an entire system used to convey a fluid. The simple distinction between pipe and tubing is that tubing is thin-walled pipe with a different size for size diameter.

Tubular products can basically be grouped into three broad classifications: pipe, pressure tube and mechanical tube.

Based on user requirements the above classifications come in various types such as Standard Pipe, Pressure Pipe, Line Pipe, Water Well Pipe, Oil Country Tubular Goods, Conduit, Piles, Nipple Pipe and Sprinkler Pipe. The two types that we are mainly interested in are Standard and Pressure Pipe. Distinguishable only from the standpoint of use, Standard Pipe is intended for low pressure, non-volatile use, whereas Pressure Pipe is intended for use in higher integrity services. These are services in which the pipe is required to convey high pressure volatile or non-volatile liquids and gases at sub-zero or elevated temperatures.

The following represents a combined description of Standard and Pressure Pipe.

Pipe: Pipe is manufactured to a NPS in which the OD of a given nominal size remains constant while any change in wall thickness is reflected in the pipe ID. Pipe wall thicknesses are specified by Schedule (Sch.) numbers 5, 10, 20, 30, 40, 60, 80, 100, 120, 140 and 160. Add the suffix ‘s’ when specifying stainless steel or other alloys. Wall thickness is also specified by the symbols Std. (Standard), XS (Extra Strong) and XX (Double Extra Strong).

Pipe NPS 12” and smaller has an OD that is nominally larger than that specified. Pipe with a NPS 14” and larger has an OD equal to the size specified.

Tubing: Steel and alloy tubing is manufactured to an OD equal to that specified. Meaning that 1/4” tubing will have a 1/4” OD, 2” tubing will have a 2” OD. Copper tubing, accept for ACR (Air-Conditioning & Refrigeration) tubing, which has an OD equal to that specified, has an OD that is always 1/8” larger than the diameter specified. As an example, 1/2” tubing will have a 5/8” OD, 1” tubing will have a 1 1/8” OD.

Wall thickness for tubing is specified in the actual decimal equivalent of its thickness.

Pipe is manufactured in three basic forms: cast, welded and seamless. Tubing is manufactured in two basic forms: welded and seamless.

Cast Pipe: Cast pipe is available in four basic types: white iron, malleable iron, gray iron and ductile iron. White iron has a high carbon content in the carbide form. The lack of graphite gives it its light colored appearance. Carbides give it a high compressive strength and a hardness that provides added resistance to wear, but leave it very brittle.

Malleable iron is white cast iron that has been heat treated for added ductility. By reheating white cast iron in the presence of oxygen containing materials such as iron oxide, and allowing it to cool very slowly, the free carbon forms small graphite particles. This gives malleable iron excellent machinability and ductile properties along with good shock resistant properties.

Gray iron is the oldest form of cast iron pipe and is synonymous with the name cast iron. It contains carbon in the form of flake graphite, which gives it its gray identifying color. Gray cast iron has virtually no elastic or plastic properties, but has excellent machining and self-lubricating properties due to the graphite content

Ductile iron is arguably the most versatile of the cast irons. It has excellent ductile and machinable properties while also having high strength characteristics.

Welded Steel Pipe and Tubing: Referring to pipe in the following also includes tubing.

Welded steel pipe is manufactured by Furnace Welding or by Fusion Welding. Furnace Welding is achieved by heating strip steel, also referred as skelp, to welding temperature then forming it into pipe. The continuous weld, or buttweld, is forged at the time the strip is formed into pipe. This is a process generally used to manufacture low cost pipe 3 ½” and below.

Fusion Welded pipe is formed from skelp that is cold rolled into pipe and the edges welded together by resistance welding, induction welding or arc welding. Electric resistance welding (ERW) can be accomplished by flash welding, high-frequency or low-frequency resistance welding. A scarfing tool is used to remove upset material along the seam of flash-welded pipe.

Flash welding produces a high strength steel pipe in NPS 4” through 36”. Low-frequency resistance welding can be used to manufacture pipe through NPS 22”. High-frequency resistance welding can be used to manufacture pipe through NPS 42”.

High-frequency induction welding can be used for high rate production of small NPS pipe. This is a cleaner form of welding in which scarfing, or the cleaning of upset material along the seam, is normally not required.

Arc welding the longitudinal seam of production pipe is accomplished with submerged arc welding (SAW), inert gas tungsten arc welding (GTAW) also called tungsten inert gas welding (TIG), or gas shielded consumable metal arc welding (MIG).

As you will see in Part II, the type of weld seam used in the manufacture of pipe is a factor when calculating the Pressure Design Thickness (*t*) of the pipe wall. It reduces the overall integrity of the pipe wall by a percentage given in ASME B31.3 based on the type of longitudinal seam weld.

Seamless Steel Pipe and Tubing: Referring to pipe in the following also includes tubing.

Seamless steel pipe, using various extrusion and mandrel mill methods, is manufactured by first creating a tube hollow from a steel billet, which is a solid steel round. The billet is heated to its hot metal forming temperature then pierced by a rotary piercer or by a press piercer creating the tube hollow, which will have a larger diameter and thicker wall than its final pipe form. The tube hollow is then hot-worked by the Mandrel Mill Process, Mannesmann Plug-Mill Process, or Ugine Sejournet Extrusion Process.

Upon completion of these processes the pipe is referred to as hot-finished. If further work is required to achieve more accuracy in the diameter, wall thickness or improve its finish the pipe can be cold-finished, or cold-worked. When the pipe is cold-finished it will require heat treating to remove stress in the pipe wall created when worked in its cold state.

There are also two forging processes used in the manufacture of large diameter (10 to 30 inch) pipe with heavy wall thickness (1.5 to 4 inch). The two forging methods are called Forged and Bored, and Hollow Forged.

Other Material and Systems

We have touched on just some of the key points of steel pipe and fittings. What I have not touched on are plastic lined pipe systems and non-metallic piping including proprietary piping systems. The area of non-metallic piping is certainly worth including in the context of piping. However, we will keep these articles focused on metallic piping material. Non-metallic piping merits a discussion on its own, and should not be relegated to a paragraph or two here.

However, since plastic lined pipe is steel pipe with a liner and is so widely used in the various industries I will touch on some of its key points.

Lined Pipe Systems: Lined flex hoses were first developed in 1936 by Resistoflex followed by lined pipe, which did not come to the industry until 1956 by way of the same company. When first introduced, plastic line pipe filled a large fluid handling gap in industry, but brought with it some technical issues.

As other manufacturers such as Dow and Peabody Dore' began producing lined pipe and fittings industry standards for lined pipe did not exist. Consequently, there were no standard fitting dimensions and the availability of size and type of fittings would vary from one company to another, and still, to a much lesser degree, does to this day.

Due to the autonomous nature of lined pipe manufacturing during its initial stages the pipe designer would have to know early in the design process which manufacturer they were going to use. Particularly in fitting make-up situations, you needed to know in advance what those make-up dimensions were going to be, and thus the fitting manufacturer.

While not having industry standard dimensions was a design problem other operational type problems existed as well. Some of the fluid services these line pipe systems were specified for, and still are, would normally be expected to operate under a positive pressure, but at times would phase into a negative pressure. The liners in these early systems were not necessarily vacuum rated and at times would collapse under the negative internal pressure, plugging the pipeline.

There was an added problem when gaskets were thrown into the mix. Gaskets were not normally required unless frequent dismantling was planned, and many firms, both engineers and manufacturers, felt more secure in specifying gaskets at every joint. When required, the gasket of choice, in many cases, was an envelope type gasket made of PTFE (polytetrafluoroethylene) with an inner core of various filler material,Viton (a DuPont trade name) or EPDM.

These gaskets had a tendency to creep under required bolt torque pressure at ambient conditions. From the time a system was installed to the time it was ready to hydrotest the gaskets would, on many occasion, creep, or relax to the point of reducing the compressive bolt load of the joint enough to where it would not stand up to the hydrotest pressure. Quite often leaks would become apparent during the fill cycle prior to testing.

There also exists the problem of permeation with regard to PTFE liner material and of Internal and External Triboelectric Charge Generation and Accumulation (static electricity). But, due to the diligent efforts of the line pipe and gasket industries these types of problems have either been eliminated or controlled, and some are still being pursued.

Fitting dimensions have been standardized through ASTM F1545 in referencing ASME B16.1 (cast iron fittings), B16.5 (steel fittings) and B16.42 (ductile iron fittings). You will need to read Note 3 under Sub-Para. 4.2.4, which states, “Center-to-face dimensions include the plastic lining.” Meaning, the dimensions given in the referenced ASME standards are to the bare metal face of the fittings. However, when lined fittings are manufactured the metal casting is modified to accommodate the liner thickness being included in that same specified center-to-face dimension.

With regard to vacuum rating, liner specifications are greatly improved, but you will need to check the vacuum ratings of available pipe and fittings with each tentative manufacturer. This provision will vary from manufacturer to manufacturer depending on size, fitting, liner type, pressure and temperature.

Gasket materials such as Garlock's Gylon gasket, which is a PTFE/Silicate composite, and W. L. Gore's Universal Pipe Gasket, which is a 100% expanded PTFE, have been developed to reduce the creep rate in a gasket material that is compatible with virtually the same fluid services that lined pipe systems are usually selected for.

Permeation issues with PTFE liners (it also exists, to a lesser extent, with other liner material) have been accommodated more than resolved with the use of vents in the steel pipe casing, the application of vent components at the flange joint, and increased liner thickness.

Internal and external charge accumulation, known as static electricity, or triboelectric charge accumulation, is the result of an electrical charge generation unable to dissipate. If the electrical charge generation is allowed to continually dissipate to ground then there is no charge build-up and no problem. This is what occurs with steel pipe in contact with a flowing fluid. Charge generation has a path to ground and does not have an opportunity to build up.

With regard to thermoplastic lined pipe there are two issues to be considered: external charge accumulation and internal charge accumulation.

This is an issue that requires experience and expertise in order to analyze a particular situation. What we will do in Part II of this series is provide you with basic information that will at least allow you to be familiar with the subject, and help you to understand the issues.

Standard sizes of plastic lined pipe and fittings range from NPS 1" through 12". Edlon, a lined pipe manufacturer, also manufactures larger diameter pipe and fittings from NPS 14" through 24", and when requested can manufacture spools to 144" diameter.

Hygienic Piping

Hygienic is a term defined in ASME-BPE as: "*of or pertaining to equipment and piping systems that by design, materials of construction, and operation provide for the maintenance of cleanliness so that products produced by these systems will not adversely affect animal or human health*."

While system components such as tube, fittings, valves and the design itself, with regard to hygienic conditions, can translate to the Semi-Conductor industry the term hygienic does not. It pertains strictly to the health aspects of a clean and cleanable system for the pharmaceutical industry. The semi-conductor industry requires a high, or in some cases higher, degree of cleanliness and cleanability than hygienic systems in the pharmaceutical industry, for altogether different reasons.

A term that can more appropriately be interchanged between these two industries is high-purity. This implies a high degree of cleanliness and cleanability without being implicitly connected with one industry or the other.

For what is referred to as product contact material, the surface roughness, dead-leg minimums and an easily cleanable system are all imperative. Because of this the pharmaceutical industry had to make a departure from the 3-A standards it plagiarized early on in order to develop a set of guidelines and standards that better suit its industry. Enter ASME-BPE.

ASME-BPE has taken on the task of providing a forum for engineers, pharmaceutical manufacturers, component and equipment manufacturers, and inspectors in an effort to develop consensus standards for the industry where none existed before. I won't go further with this except to say that, to the handful of engineers undaunted by the task ahead of them, in approaching ASME about the need to create another standards committee, and the perseverance to see it through; my hat goes off to you.

Hygienic piping was, up until just recently, referred to as sanitary piping. Because this term has been so closely associated with the plumbing industry and sanitary drain piping it is felt by the pharmaceutical industry that the change in terminology to hygienic is more appropriate.

In both the pharmaceutical and semiconductor industries the need for crevice free, drainable systems is a necessity. This translates into weld joint quality, mechanical joint design requirements, interior pipe surface roughness limits, system drainability and dead-leg limitations.

Slope, welding, dead-legs and surface roughness will be discussed in Part II. This article will concentrate on the basic aspects of the fittings.

Fittings

There are two basic types of fitting joints in hygienic piping: welded and clamp. Welded fittings, unlike standard buttweld pipe fittings, have an added tangent length to accommodate the orbital welding machine. The orbital welding machine allows the welding operator to make consistent high quality autogenous welds. Autogenous welds are welds made without filler metal. Fusion is made between the parent metals of the two components being welded by means of tungsten inert gas welding; more on welding in Part II.

Figure 11 - Fittings Ready To Be Orbital Welded
Compliments of ARC Machines, Inc.

Figure 11 is an example of an orbital, or automatic, welding machine mounted on its work-piece. In this example it happens to be a 90° elbow being welded to a cross. You can see by this example why the additional straight tangent section of automatic weld fittings is needed. That extra length provides a mounting surface for attaching the automatic welding machine.

The clamp connection is a mechanical connection whose design originated in the food and dairy industry, but whose standardization has been under development by ASME-BPE. Due to a lack of definitive standardization most companies that use this type connection require in their specifications that both the ferrule, the component that the clamp fits on, and the clamp itself come from the same manufacturer. This is to ensure a competent fit.

There are no specific dimensions and tolerances for the clamp assembly, except for that which is being developed by ASME-BPE. Currently it is possible to take a set of ferrules from one manufacturer, mate them together with a gasket, attach a clamp from a different manufacturer and tighten up on the clamp nut. In some cases you can literally rotate the clamp by hand about the ferrules. Meaning, there is no force being applied on the joint seal.

For those of you unfamiliar with the clamp joint, it is the clamp that applies the force that holds the ferrules together. The fact that this can occur begs the need for standardization to a greater degree than what currently exists.

We'll get into this in greater detail in Part II, but another issue that currently exists with the clamp joint is gasket intrusion into the pipe ID due to inadequate compression control of the gasket.

Gasket intrusion is a problem in pharmaceutical service for two reasons: 1. Depending on the hygienic fluid service and the gasket material the gasket protruding into the fluid stream can break down and slough off into the fluid flow, contaminating the hygienic fluid. 2. The intrusion of the gasket into pipe ID on a horizontal line can also cause fluid hold-up. This can result in the loss of residual product, cause potential cross-contamination of product, and promote microbial growth.

The reason I mention this here, and I won't go into it any further until Part II, is because there are manufacturers that are attempting to overcome these issues by improving on the concept of the clamp joint.

Two manufactures, Swagelok and The Neumo Ehrenberg Group, represented in the US by VNE, have, what I would consider, well developed re-designs of the standard hygienic clamp assembly.

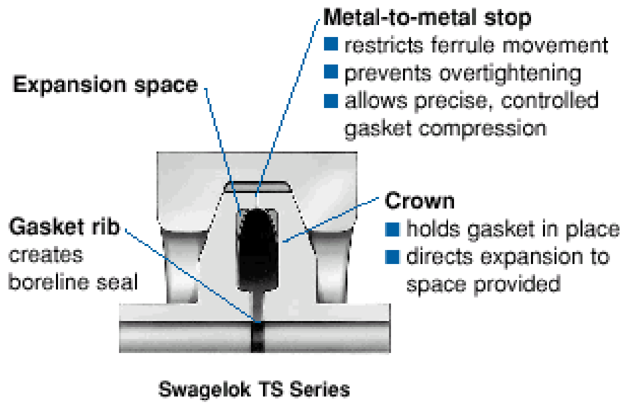


Figure 12 – Swagelok TS Series Profile
Compliments Swagelok Company

Swagelok has developed what they call their TS series fittings. These ferrules (Fig. 12) have a design that provides compression control of the gasket while also controlling the creep tendency inherent in, arguably, the most prevalent gasket material used in high purity piping, Teflon.

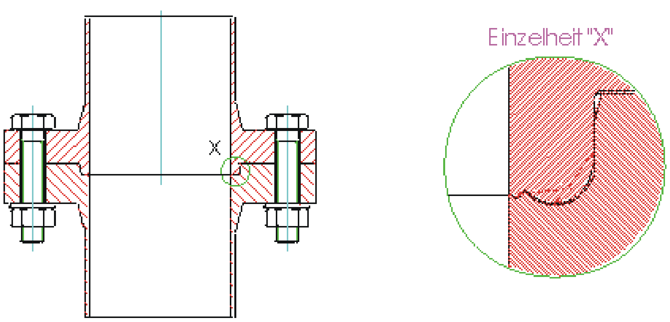


Figure 13 – Maxpure Connect S
Compliments Neumo Ehrenberg Group

The Neumo Ehrenberg Group manufactures a clamp joint (also provided as a bolted connection) that does not require a gasket (Fig. 13). This type of joint, called the Connect-S under their newly formed MaxPure label of fittings, is currently in use in Europe. While this connection alleviates the issues that are present with a gasketed joint added care would need to be applied in its handling. Any scratch or ding to the faced part of the sealing surface could compromise its sealing integrity. Nevertheless this is a connection design worth consideration.

In this first article we have covered a few of the basics, which will provide us with a little more insight when we discuss the more in-depth topics of piping Codes, piping design, and fabrication of pipe in Part II.

Future Articles

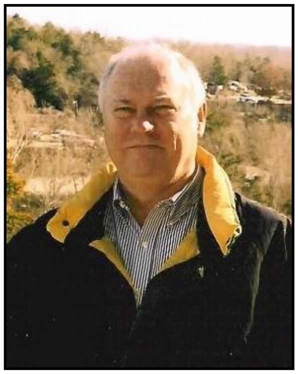
What we have discussed so far is just some of the basics of general piping. While there is a great deal left unsaid we will provide further clarification as we move through the next two articles.

The next article, titled "Piping Design Part II – Code, Design and Fabrication", will cover the more specific aspects of Code governance, engineering in pipe design and fabrication as it relates to welding, assembly and installation.

The third article in this series, titled "Piping Design Part III – Installation, Cleaning, Testing and Verification", will wrap up the series by discussing the four title points.

Acknowledgement:
I wish to thank Earl Lamson, senior Project Manager with Eli Lilly and Company, for taking time out of a busy schedule to read through the draft of this article. He obliged me by reviewing this article with the same skill, intelligence and insight he brings to everything he does. His comments kept me concise and on target.

About the author:



W. M. (Bill) Huitt has been involved in industrial piping design, engineering and construction since 1965. Positions have included design engineer, piping design instructor, project engineer, project supervisor, piping department supervisor, engineering manager and president of W. M. Huitt Co. a piping consulting firm founded in 1987. His experience covers both the engineering and construction fields and crosses industrial lines to include petroleum refining, chemical, petrochemical, pharmaceutical, pulp & paper, nuclear power, biofuel, and coal gasification. He has written numerous specifications, guidelines, papers, and magazine articles on the topic of pipe design and engineering. Bill is a member of ISPE (International Society of Pharmaceutical Engineers), CSI (Construction Specifications Institute) and ASME (American Society of Mechanical Engineers). He is a member of three ASME-BPE subcommittees, several Task Groups, an API Task Group, and sets on two corporate specification review boards. He can be reached at:

W. M. Huitt Co.
P O Box 31154
St. Louis, MO 63131-0154
(314)966-8919
wmhuitt@aol.com
www.wmhuitt.com