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Pressure Design of Pipe Fittings and Practical Applications (ASME B31.3/B16.11/B16.9/B16.25)

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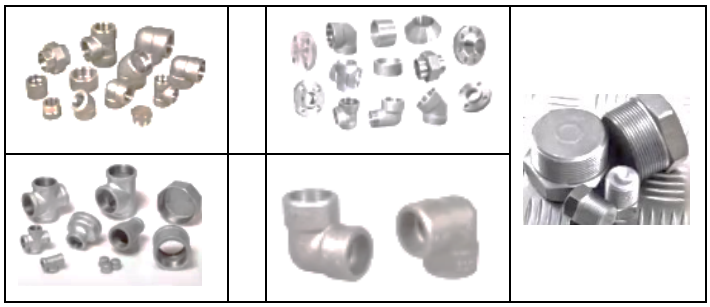
As per Menon (2021, p. 14) [1], Pipe fittings are piping components that help in changing the direction of the flow such as elbows and bends, changing the size of the pipe such as reducer and swage nipple, connecting different components such as coupling and unions, stopping the flow such as caps and plugs, branching such as O-let, weldolet, sockolet, elbowlet, threadolet, nipolet, latrolet and sweepolet, Tee, Reducing Tee, cross and bush. This paper will focus on the pressure design of the components listed in table 326.1 Component Standard of ASME B31.3[4] which helps in finding the standard that is determined by the code for fittings and the application of those standards related to the method used for manufacturing fittings and connection types.



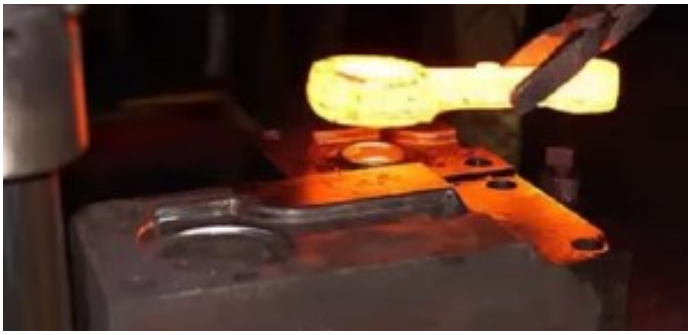
Keywords **— Forged Fittings, Wrought Fittings, Piping Material Specification (PMS), Pipe Class, Flange Rating**

I. INTRODUCTION

This article aims to familiarize readers with standards for size and class of forged fittings, as well as the pressure design of wrought butt-welding. This article also focuses on specifying the class and thickness of fittings based on ASME B31.3[4] and the related standards specified by the code.

II. FITTINGS

Forged Steel Fittings: "Forged Steel Fittings" are pipe fittings that are made from forged Carbon Steel material. Forging Steel is a process by which the strength of the fittings is increased and strong fittings are created. Carbon Steel is heated to molten temperatures and placed in dies.



The heated steel is then machined into forged steel fittings. Small sized fittings are manufactured via this method as this does not need huge pressure hammering. These fittings will be connected to other piping components with socket weld or threaded connections.

Wrought Steel Fittings: Wrought Steel Fittings are made from cut plates and pipes. The process is continued by:

- Forming
- Sizing
- Heat treating
- Beveling

Commonly large size fittings are manufactured with this method. These fittings are connected to other piping components with butt weld connections.

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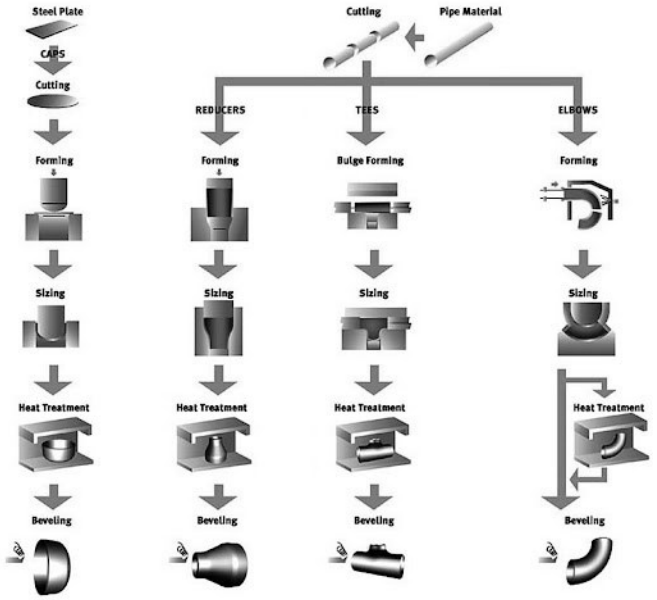
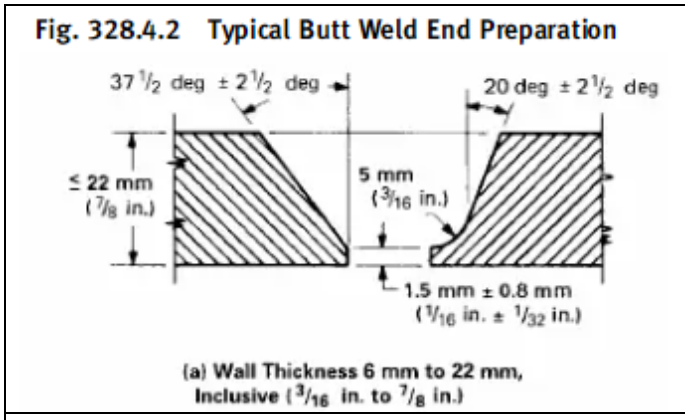
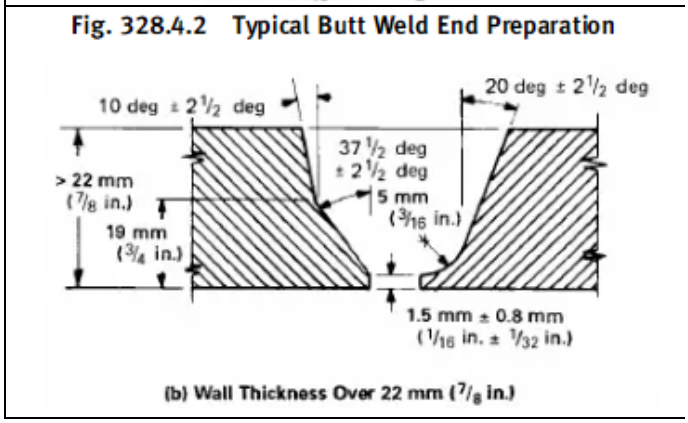


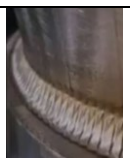
III. END CONNECTION TYPES

Butt Welded End Connection: The end of two components is prepared in accordance with ASME B16.25[5] and Fig. 328.4.2 (Typical Butt Weld End Preparation) of ASME B31.3[4].

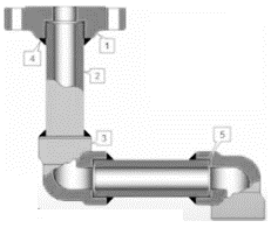




The end connections are aligned and temporarily secured with tack welds. After tack welding, a groove weld permanently joins the connections. This method is common for pipe sizes NPS 2" and larger, as aligning and welding smaller pipes can be challenging, especially with SMAW (Shielded Metal Arc Welding). However, TIG (Tungsten Inert Gas) or MIG (Metal Inert Gas) welding techniques enable the use of butt welding for smaller pipe sizes.

Tack Weld	Groove Weld – NPS 2" and above	TIG/MIG – To connect small pipe size together using Butt Welding
		

Socket Welded End Connection: Socket welded fittings have a slightly larger inner diameter than the pipe's outer diameter. The pipe is inserted into the socket and a weld secures the connection around the circumference. This method is typically used for smaller pipe sizes, providing a reliably leak-free permanent connection. See the figure below for a typical socket welded connection arrangement.

	1. Socket Weld Flange 2. Pipe 3. Socket Weld Elbow 4. Fillet Weld 5. Expansion Gap

Threaded End Connection: Piping components typically feature a female threaded end, accommodating a matching male threaded pipe. Successful connections require both the fitting and pipe to adhere to the same threading standards, such as ASME B16.11 [2]. See the figure below for typical male and female threaded components.

	A typical ASME threaded female and male concentric reducer

Flanged Connection: Two pipes or pipe to equipment (nozzle) are connected together using flange and bolts.

	A flanged type valve connects to flange

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IV. PRESSURE DESIGN OF FITTINGS

Pressure Design of Forged Fittings: ASME B16.11[2] provides the basis of pressure design of forged fittings that connects to other piping components with socket welding or threaded.

Paragraph 2.1 of ASME B16.11[2] designates the fittings as various classes:

Class 2000, 3000 and 6000	Threaded end fittings
Class 3000, 6000 and 9000	Socket end weld fittings

Paragraph 2.1.1 of ASME B16.11[2] provides the basis of rating for the schedule of pipe corresponding to each class designation of fittings for rating purposes is shown on Table 7, 8 and 9 of ASME B16.11[2].

Table 7 Types of Fittings by Class Designation and NPS Size Range

	Socket-Welding			Threaded		
	Class Designation			Class Designation		
Description	3000	6000	9000	2000	3000	6000
45-deg, 90-deg elbows, tees, crosses, couplings, half-couplings, caps, bosses, and couplets	⅛-4	⅛-2	½-2	⅛-4	⅛-4	⅛-4
	⅛-4	⅛-2	½-2	⅛-4	⅛-4	⅛-4
	⅛-4	⅛-2	½-2	...	⅛-4	⅛-4
	⅛-4	⅛-2	½-2	...	⅛-4	¼-2
Street elbows	...	...	...	...	⅛-2	⅛-2
Square, hex, round plug, hex, and flush bushing	...	...	...	⅛-4 [Note (1)]	⅛-4 [Note (1)]	⅛-4 [Note (1)]
	...	...	...	⅛-4 [Note (1)]	⅛-4 [Note (1)]	⅛-4 [Note (1)]

NOTE: (1) Plugs and bushings are not identified by class designation. They may be used for ratings up to Class 6000 designation.

Table 8 Correlation of Fittings Class With Schedule Number or Wall Designation of Pipe for Calculation of Ratings

Class Designation of Fitting	Type of Fitting	Pipe Used for Rating Basis [Note (1)] Schedule No.	Wall Designation
2000	Threaded	80	XS
3000	Threaded	160	...
6000	Threaded	...	XXS
3000	Socket-welding	80	XS
6000	Socket-welding	160	...
9000	Socket-welding	...	XXS

NOTE: (1) This Table is not intended to restrict the use of pipe of thinner or thicker wall with fittings. Pipe actually used may be thinner or thicker in nominal wall than that shown in Table 8. When thinner pipe is used, its strength may govern the rating. When thicker pipe is used (e.g., for mechanical strength), the strength of the fitting governs the rating.

Table 9 Nominal Wall Thickness of Schedule 160 and Double Extra Strong Pipe

	Schedule 160		XXS	
NPS	mm	in.	mm	in.
⅛	3.15	0.124	4.83	0.190
¼	3.68	0.145	6.05	0.238
⅜	4.01	0.158	6.40	0.252

The thickness of pipe will determine the class designation of forged fittings. The pipe thickness calculation is the most important part of pressure design of piping components as the thickness of pipe is critical in the pressure design of other piping components. In the above-mentioned tables, the correlation a fittings class with a schedule number or wall designation of pipe for calculation of rating, the class of forged fittings can be determined based on pipe thickness and type of connection. In Table 8 of ASME B16.11[2], 3 classes are listed for threaded connection which are Class 2000, Class 3000 and Class 6000. Class 2000 is not a popular class, i.e., forged threaded fittings are available in the market in the Class 3000 and Class 6000. The rating of the threaded forged fitting shall be Class 3000 if the wall thickness of the connected pipe is schedule 160 or less. The Class is dimensionless, nevertheless pound (lbs) is used most of the times while referring to the class. The Class number does not reveal the pressure or temperature it can sustain. The design pressure and temperature were already considered during the wall thickness calculation after which relying to the selected thickness of the pipe is by specifying the rating for forged fittings.

In Socket Welded forged fittings, a pipe with wall thickness equal to the schedule number 80 or equivalent wall designation or Extra Strong (XS) and less, the pipe class is Class 3000. For pipe with thickness greater than schedule number 80 and up to schedule number 160, the pipe class is Class 6000. For pipe with schedule number greater than 160, the pipe class is Class 9000.

For the class of forged fittings range of size, refer to Table 7 of ASME B16.11[2] except street elbows, threaded fittings are available for NPS 4" and less in Class 3000 and Class 6000. Street elbows are only available up to NPS equal to 2", however threaded connection can be used where the code allows to do so which is paragraph 314 of ASME B31.3[4], Threaded Joints.

Street elbows, square, hex and round plugs, hex and flush bushing are not available in socket welding connection type, i.e., these fittings can be used in threaded connection. Other fittings 45 Degree, 90 Degree elbows, Tee's, Crosses, Couplings, Half Couplings and caps are available in NPS 1/8 to 4" size range is available in class designation Class 3000. In class 6000 and class 9000, the fittings are available in size range of NPS 2" and less. Note that socket welding fittings are used in sizes below NPS of 2" typically. It is preferred to used Butt Welding fittings for NPS 2" and larger. Where the code permits threaded forged fittings can be used up to NPS 4", however same as the socket weld threaded forged fittings are popular in NPS 1-1/2" and lower.

Pressure Design of Factory-Made Wrought Butt-Welding Fittings

For pressure design of factory-made wrought butt-welding fittings, reference shall be made to paragraph 2.1 of ASME B16.9[3] which states "For the allowable pressure rating for fittings designated in accordance with this standard may be calculated as for straight seamless pipe of equivalent material as shown by comparison of composition and mechanical properties in the respective material specification in accordance with the rules established in the applicable section of ASME B31, code for pressure piping. For the calculation, applicable data for pipe size, wall thickness, and material that are equivalent to that of the fittings shall be used. Pipe Size, Wall thickness and Schedule Number and material identity on the fittings are in lieu of pressure rating markings." It means that butt-welding fittings has the same thickness of the connected pipe, therefore the thickness of butt-welding fittings should be specified as per pipe's schedule.

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V. CLASS AND THICKNESS OF FITTINGS

Specifying Class and Thickness of Fittings

This section will focus on how to specify the class and thickness of fittings based on ASME B31.3[4] and the related standards specified by the code. Prior to that some light needs to be thrown on the material

Carbon Steel (CS)	Ferrous Material with Carbon content up to 2% of weight. In addition to Carbon (C), Manganese (Mn), Silicon (Si), Phosphorous (P), Sulphur (S) and other alloys forms the chemical composition of Carbon Steel (CS). CS are used in manufacturing different piping components. ASTM has specified the standard for the manufacturing processes. Fittings are manufactured by two methods – Forged and Wrought.	ASTM A-105A/105M-03 is the standard specification for Carbon Steel forgings for piping applications
		ASTM A-234/A 234M – 04 is the standard specification for the piping fittings of Wrought Carbon Steel and Alloy Steel for moderate and high temperature services.

In addition to Carbon Steel (CS), piping components are also manufactured by Low Temperature Carbon Steel (LTCS), Low Alloy Steel (AS), High Alloy Steel (Stainless Steel) and non-Ferrous material. In these cases, the form of product with a specified ASTM standard per material.

Applying the Class and Thickness to Pressure Design of Forged Fittings

90 Degree Elbow	NPS: 1-1/2” Material: ASTM A-105 Corrosion Allowance: 1mm	Based on ASME B16.11[2], the thickness of pipe that is associated with the forged fittings determines their class, i.e., the Design Pressure and Temperature have already been implemented through the wall thickness calculation of the pipe used for the determination of forged fittings. There is no need to consider them again

Piping Material Specification (PMS)

Piping Material Specification (PMS) is used for categorizing piping materials. PMS includes classes which are used to categorize piping components with the same conditions, i.e., the piping components that are categorized in a class have the same material design pressure and temperature as well as corrosion allowance (CA). Therefore, when the pipe class needs to be specified, or rating of forged fittings, firstly refer to the class of the project PMS where components are categorized in, then find the thickness that is specified for the target pipe size. Each component in the PMS is described in a complete abbreviation and clear manner as piping components will be purchased based on this description. The PMS is always inserted in the catalogue of the 3D modeling software, therefore all details of components such as manufacturing procedures, preparation material standard, dimensional standard etc. are detailed. Per table 8 of ASME B16.11[2], for thickness equal to schedule number 80 and less, class of forged fittings with socket weld connections will be 3000 lbs (class 3000). If it’s a forged fitting with threaded connection, the same criterial that was followed for socket weld connection should be followed to determine the class.

Applying the Class and Thickness to Pressure Design of Wrought Fittings

90 Degree Elbow	NPS: 1-1/2” Material: ASTM 234 Gr. WPB Corrosion Allowance: 1mm	The thickness of Wrought Fittings is same as the thickness of pipe as mentioned above previously in the article.

VI. CONCLUSION

By utilizing this article, the end user will get familiarized with references for the size and class of forged fittings along with the pressure design of wrought butt-welding fittings. This article also adds to the user’s knowledge on piping issues focusing on Piping Material Specification (PMS) document that plays an important role in the piping engineering field.

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