PIPE THICKNESS CALCULATIONS AS PER ASME B31.3

Calculation of minimum wall thickness of a given pipe diameter and selection of actual thickness is one of the most basic design considerations for any projects. The designers need to find out the required piping thickness as per ASME B31.3 to resist internal line pressure. The important equation for calculation of pipe thickness (t < D/6) is:.

$$t = \frac{P\,D}{2(S\,E\,W + P\,Y)}$$

$$t_m = t + c$$

t = Pressure design thickness, as calculated in accordance with internal pressure or external pressure.

c = Sum of mechanical allowances (thread or grove depth) plus corrosion and erosion allowance.

D = Outside diameter of the pipe as listed in tables of standards or specifications or as mentioned.

E = Quality factor from Table A-1B.

P = Internal Design Pressure gauge.

S = Allowable stress value for material from Table A-1.

t_m = Minimum required thickness, including mechanical, corrosion and erosion allowances.

W = Weld strength reduction factor in accodance with Table 302.3.5.

Y = Coefficient from Table 304.1.1.

Let us calculate for the following scenario:

- Material of Construction: Carbon Steel - ASTM A106 Gr.B
- NPS(Nominal Pipe Size) - 2 inch
- Type of Pipe(SMLS/EFSW) - SMLS(Seamless)
- Design Pressure(psi) - 275 Psig
- Design Temperature - 100 °F
- Mechanical, Corrosion and erosion allowance - 1.5 mm
- Mill Tolerance - 12.5% of the thickness

Given Data:

We know from the problem scenario,
P = 145 Psig
T= 100°F
NPS = 2 inch
Outer diameter = 60.33 mm

Now, refer to the table A-1 of ASME B31.3 to get the Allowable Stress (S) for our material Carbon Steel (ASTM A 106 Gr.B).
From the table, For our Problem Scenario.
T=100°F , Material = ASTM A106 Gr. B
The allowable stress , S= 20 ksi or 20000 psi.

ASME B31.3-2020

Table A-1 Basic Allowable Stresses in Tension for Metals (Cont'd)

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	Type/ Grade	UNS No.	Class/ Condition/ Temper	Size, in.	P-No. (5)	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress, S, ksi, at Metal Temperature, °F [Notes (1), (4a)]	
									Tensile	Yield	Min. to 100	200
Carbon Steel — Pipes and Tubes												
...	A53	B	K03005	...	...	1	(57) (59)	B	60	35	20.0	20.0
...	A106	B	K03006	...	...	1	(57)	B	60	35	20.0	20.0
...	A333	6	K03006	...	...	1	(57)	-50	60	35	20.0	20.0
...	A334	6	K03006	...	...	1	(57)	-50	60	35	20.0	20.0
...	A369	FPB	K03006	...	...	1	(57)	-20	60	35	20.0	20.0
...	A381	Y35	...	...	...	1	...	A	60	35	20.0	20.0
...	API 5L	B	...	...	...	1	(57) (59) (77)	B	60	35	20.0	20.0
...	A139	C	K03004	...	...	1	(8b)	A	60	42	20.0	20.0
...	A139	D	K03010	...	...	1	(8b)	A	60	46	20.0	20.0
...	API 5L	X42	...	...	...	1	(55) (77)	A	60	42	20.0	20.0
...	A381	Y42	...	...	...	1	...	A	60	42	20.0	20.0
...	A381	Y48	...	...	...	1	...	A	62	48	20.7	20.7

Table A-1 Basic Allowable Stresses in Tension for Metals (Cont'd)

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress, *S*, ksi, at Metal Temperature, °F [Notes (1), (4a)]															
300	400	500	600	650	700	750	800	850	900	950	1,000	1,050	1,100	Type/ Grade	Spec. No.
Carbon Steel — Pipes and Tubes (Cont'd)															
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	B	A53
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	B	A106
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	6	A333
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	6	A334
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	FPB	A369
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	Y35	A381
20.0	19.9	19.0	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5	1.6	1.0	B	API 5L
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	C	A139
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	D	A139
20.0	20.0	...	...	...	...	...	...	...	...	...	...	...	...	X42	API 5L
20.0	20.0	...	...	...	...	...	...	...	...	...	...	...	...	Y42	A381

Quality Factors for Longitudinal Weld joints in Pipes(E) are used in Pressure Design and applied at Longitudinal and Spiral Weld Joints and for Castings. The maximum value of quality factors is 1.0. Since our pipe is seamless without any welds, our value will be 1.
The value of E can be found from Table A-1B of ASME B31.3.

Table A-1B Basic Quality Factors for Longitudinal Weld Joints in Pipes and Tubes, E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j [Note (2)]	Appendix A Notes
Carbon Steel				
API 5L	...	Seamless pipe	1.00	...
		Electric fusion welded pipe, 100% radiographed	1.00	...
		Electric resistance welded pipe	0.85	...
		Electric fusion welded pipe, double butt seam	0.95	...
		Continuous welded (furnace butt welded) pipe	0.60	...
A53	Type S	Seamless pipe	1.00	...
	Type E	Electric resistance welded pipe	0.85	...
	Type F	Furnace butt welded pipe	0.60	...
A106	...	Seamless pipe	1.00	...
A134	...	Electric fusion welded pipe, single butt, straight or spiral (helical) seam	0.80	...
A135	...	Electric resistance welded pipe	0.85	...
A139	...	Electric fusion welded pipe, straight or spiral (helical) seam	0.80	...
A179	...	Seamless tube	1.00	...
A333	...	Seamless pipe	1.00	...
		Electric resistance welded pipe	0.85	...
A334	...	Seamless tube	1.00	...
A369	...	Seamless pipe	1.00	...
A381	...	Electric fusion welded pipe, 100% radiographed	1.00	...
		Electric fusion welded pipe, spot radiographed	0.90	(19)
		Electric fusion welded pipe, as manufactured	0.85	...
A524	...	Seamless pipe	1.00	...
A587	...	Electric resistance welded pipe	0.85	...
A671	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A672	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A691	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...

Weld Joint Strength Reduction Factor(W): The weld joint strength reduction factor, W, is the ratio of the nominal stress to cause the failure of a weld joint to that of the corresponding base material for an elevated temperature condition of the same duration. It only applies at weld locations in longitudinal or spiral (helical seam) welded piping components. Weld Joint Strength Reduction Factors are used because at elevated temperatures the weld joint creep rupture strength can be lower than the base metal. The value of W can be found in table 302.3.5. It is applicable only for welded pipes. For our problem, the pipe is seamless so, the value is W=1.

Table 302.3.5 Weld Joint Strength Reduction Factor, *W*

Steel Group	Component Temperature, T_c, °C (°F)														
	≤427 (≤800)	454 (850)	482 (900)	510 (950)	538 (1,000)	566 (1,050)	593 (1,100)	621 (1,150)	649 (1,200)	677 (1,250)	704 (1,300)	732 (1,350)	760 (1,400)	788 (1,450)	816 (1,500)
Carbon Steel	1	1	1	1	1	1	1	...	...	...	...	...	...	...	...
CrMo [Notes (1)–(3)]	1	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	...	...	...	...	...	...
CSEF (N + T) [Notes (3)–(5)]	...	...	...	1	0.95	0.91	0.86	0.82	0.77	...	...	...	...	...	...
CSEF [Notes (3) and (4)] (Subcritical PWHT)	...	...	1	0.5	0.5	0.5	0.5	0.5	0.5	...	...	...	...	...	...
Autogenous welds in austenitic stainless grade 3xx and N088xx and N066xx nickel alloys [Note (6)]	...	...	...	1	1	1	1	1	1	1	1	1	1	1	1
Austenitic stainless grade 3xx and N088xx nickel alloys [Notes (7) and (8)]	...	...	...	1	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64	0.59	0.55	0.5
Other materials [Note (9)]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

The factor "Y" depends on temperature. At elevated temperatures, factor Y increases leading to a decrease in the calculated required pipe wall thickness.

Refer to Table 304.1.1 of ASME B31.3 for finding the value of Y, It is Valid for t < D/6 and materials shown below The value of Y may be interpolated for intermediate temperatures. For material A106 Gr. B, Y is given 0.4.

Table 304.1.1 Values of Coefficient *Y* for *t* < *D*/6

Material	Temperature, °C (°F)							
	482 (900) and Below	510 (950)	538 (1,000)	566 (1,050)	593 (1,100)	621 (1,150)	649 (1,200)	677 (1,250) and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel alloys UNS Nos. N06617, N08800, N08810, and N08825	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
Gray iron	0.0	...	...	...	...	...	...	...
Other ductile metals	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Steps for calculation:

Step 1. Insert all the values in the Pipe Thickness equation.

$$t = \frac{P\,D}{2(S\,E\,W + P\,Y)}$$

$$t = \frac{(275)\ (60.33)}{\{2(20000 \times 1 \times 1 + 275 \times 0.4)\}}$$

$$t = 0.41 \text{ mm}$$

Step 2: Add the corrosion allowance to the calculated thickness..

$$t_m = t + c$$
$$t_m = 0.41 + 1.5$$
$$t_m = 1.91 \text{ mm}$$

Step 3: Add the mill tolerance to the t_m

The above tm is the thickness required after 12.5% of mill tolerance. It means the specified thickness by the designer may decrease up to 12.5% during the manufacturing process. So, it is the designer's duty to provide additional cushion of 12.5% for the tolerance. Even after reducing 12.5%, pipe thickness should not be less than t_m

Add the Mill Tolerance 12.5% to the t_m

100% -12.5% = 87.5% = 1.91 mm

$\mathbf{t_{required}}$ = 1.91/ 0.875 = 2.18 mm

Nominal Thickness after Mill tolerance

$\mathbf{t_{required} = 2.18\ mm}$

Step 4: Check the ordering thickness available in ASME B36.10M which is near to our thickness.

Table 1 Dimensions and Weights of Welded and Seamless Wrought Steel Pipe (Cont'd)

NPS [Note (1)]	Customary Units: Outside Diameter, in.	Customary Units: Wall Thickness, in.	Customary Units: Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	SI Units: Outside Diameter, mm	SI Units: Wall Thickness, mm	SI Units: Plain End Mass, kg/m
2	2.375	0.065	1.61	...	5	50	60.3	1.65	2.39
2	2.375	0.083	2.03	...	...	50	60.3	2.11	3.03
2	2.375	0.109	2.64	...	10	50	60.3	2.77	3.93
2	2.375	0.125	3.01	...	30	50	60.3	3.18	4.48
2	2.375	0.141	3.37	...	...	50	60.3	3.58	5.01
2	2.375	0.154	3.66	STD	40	50	60.3	3.91	5.44
2	2.375	0.172	4.05	...	...	50	60.3	4.37	6.03
2	2.375	0.188	4.40	...	...	50	60.3	4.78	6.54
2	2.375	0.218	5.03	XS	80	50	60.3	5.54	7.48
2	2.375	0.250	5.68	...	...	50	60.3	6.35	8.45
2	2.375	0.281	6.29	...	...	50	60.3	7.14	9.36
2	2.375	0.344	7.47	...	160	50	60.3	8.74	11.11
2	2.375	0.436	9.04	XXS	...	50	60.3	11.07	13.44