

PRESSURE RATINGS FOR PIPES, TUBES AND FITTINGS

WALL THICKNESS CALCULATIONS FOR STRAIGHT PIPE UNDER INTERNAL PRESSURE

The following equations and tables are based on those provided in the Process Piping Specification, ASME B31.3a-2008, ASME Code for Pressure Piping (see Notes for references to source paragraphs and tables in this specification).

Firstly, any one of the following four equations may be used to calculate the 'pressure design wall thickness' (t) of a straight pipe subject to internal pressure.

The equations assume $t < D/6$ (for pipe with $t > D/6$ or $P/SE > 0.385$ additional factors need to be considered). The four alternative equations are:

$$t = \frac{PD}{2(SE + PY)} \quad t = \frac{PD}{2SE} \quad t = \frac{D}{2} \left(1 - \sqrt{\frac{SE - P}{SE + P}} \right) \quad t = \frac{P(d + 2c)}{2[SE - P(1 - Y)]}$$

where:

- t = Pressure design thickness
- d = Inside diameter of pipe. For pressure design calculation, the inside diameter of the pipe is the maximum value allowable under the purchase specification.
- P = Internal design pressure.
- D = Outside diameter pipe as listed in tables of standards or specifications or as measured.
- E = Quality factor. See the table "Basic quality factors 'E' for longitudinal weld joints in stainless steel pipes, tubes and fittings" on page 92.
- S = Stress value for material from the table "Basic allowable stresses 'S' in tension for stainless steels" on page 93.
- Y = Coefficient from table "Values of coefficient 'Y' for $t < D/6$ " on page 92.

Secondly, the minimum required wall thickness t_m of straight sections of pipe is determined in accordance with the following equation.

$$t_m = t + c$$

where:

- t_m = Minimum required thickness, including mechanical, corrosion and erosion allowances.
- c = The sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances.
For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply.
For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5mm (0.02in) in addition to the specified depth of the cut.

The actual minimum thickness for the pipe selected, considering manufacturer's tolerance, shall not be less than t_m

UNITS OF MEASURE FOR CALCULATIONS

It is important to use compatible units for pressure calculations. ASTM and ASME/ANSI specifications are based upon imperial sizes.

PIPE BENDS

The equations above may also be used for pipe bends provided the requirement for minimum wall thickness (t_m) is met.

FURTHER INFORMATION

Refer to ASME B31.3a-2008 paragraph 304 for further details relating to pressure rating and wall thickness calculations applicable to elbows, branch connections, closures, flanges, reducers and other components.

Worked Example:

Taking the simplest equation: $t = \frac{PD}{2SE}$

A. If you wish to calculate what wall thickness should be used in a design for the following situation:

P = Internal Design Pressure – For this example lets say 2000 pounds per square inch = 2ksi

D = Outside Diameter – For this example lets say 4 inch nominal bore = 4.5 inches

S = Stress Value for material from table below taking into account operating temperature – For this example lets take ASTM A312 TP 316L operating at 500°C for which S = 14.4 ksi
(1ksi = 1,000 psi / psi = Pounds Pressure per Square Inch)

E = Quality Factor from table below according to manufacturing specification – For this example we are using ASTM A312 TP 316L Seamless for which E = 1.0

So this gives:
$$t = \frac{2 \times 4.5}{2 \times 14.4 \times 1.0} = 0.313 \text{ inches}$$

Thus we would use 4 inch Nominal Bore Schedule 80S which has a wall thickness of 0.337 inches
If the wall thickness calculation leads to a heavier wall than is available then the pipe diameter must be increased. Depending upon the design of the system this may also reduce the pressure.

B. If you wish to calculate what design pressure could be permitted for the following situation:

D = Outside Diameter – For this example lets say 4 inch nominal bore = 4.5 inches

t = Wall Thickness – For this example lets say Schedule 40S = 0.237 inches

S = Stress Value for material from table below taking into account operating temperature – For this example lets take ASTM A312 TP 316L operating at 500°C for which S = 14.4 ksi
(1ksi = 1,000 psi / psi = Pounds Pressure per Square Inch)

E = Quality Factor from table below according to manufacturing specification – For this example we are using ASTM A312 TP 316L Seamless for which E = 1.0

So this gives:
$$0.237 = \frac{P \times 4.5}{2 \times 14.4 \times 1.0}$$

Thus P = 1.51ksi = 1,510 pounds per square inch

VALUES OF COEFFICIENT 'Y' FOR T<D/6

Materials	Temperature, °F (°C)					
	≤900 (≤482)	950 (510)	1000 (538)	1050 (566)	1100 (593) ≥	1150 (≥621)
Y						
Ferritic Steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steels	0.4	0.4	0.4	0.4	0.5	0.7
Cast Iron	0.0	-	-	-	-	-

NOTES

- The above table and the equations are based on paragraph 304.1 of ASME B31.3a-2008
- The value for Y may be interpolated for intermediate temperatures. For $t > D/6$:

$$Y = \frac{d + 2c}{D + d + 2c}$$

BASIC QUALITY FACTORS 'E' FOR LONGITUDINAL WELD JOINTS IN STAINLESS STEEL PIPES, TUBES AND FITTINGS

Spec. No.	Class/Type	Description	E	Notes
A182	-	Forgings and Fittings	1.00	-
A268	-	Seamless Tube	1.00	-
	-	Electric Fusion Welded Tube, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Tube, Single Butt Seam	0.80	-
A269	-	Seamless Tube	1.00	-
	-	Electric Fusion Welded Tube, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Tube, Single Butt Seam	0.80	-
A312	-	Seamless Pipe	1.00	-
	-	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Pipe, Single Butt Seam	0.80	-
A358	1, 3, 4	Electric Fusion Welded Pipe, 100% radiographed	1.00	-
	5	Electric Fusion Welded Pipe, Spot radiographed	0.90	-
	2	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
A376	-	Seamless Pipe	1.00	-
A403	-	Seamless Fittings	1.00	-
	-	Welded Fitting, 100% radiographed	1.00	1
	-	Welded Fitting, Double Butt Seam	0.85	-
	-	Welded Fitting, Single Butt Seam	0.80	-
A409	-	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Pipe, Single Butt Seam	0.80	-
A430	-	Seamless Pipe	1.00	-
A789	-	Seamless	1.00	-
	-	Electric Fusion Welded Pipe, 100% radiographed	1.00	-
	-	Electric Fusion Welded Tube, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Tube, Single Butt Seam	0.80	-
A790	-	Seamless	1.00	-
	-	Electric Fusion Welded Pipe, 100% radiographed	1.00	-
	-	Electric Fusion Welded Pipe, Double Butt Seam	0.85	-
	-	Electric Fusion Welded Pipe, Single Butt Seam	0.80	-

NOTES

- This table is based on Table A-1B of ASME B31.3a-2008
- 1 An E factor of 1.00 may be applied only if all welds, including welds in the base material, have passed 100% radiographic examination. Substitution of ultrasonic examination for radiography is not permitted for the purpose of obtaining an E of 1.00.

BASIC ALLOWABLE STRESSES 'S' IN TENSION FOR STAINLESS STEELS

ASTM Spec No.	Grade	Min Temp °F (for °C see Notes)	Metal Temperature, °F (°C)										Notes
			Min Temp to 100 (37.8)	300 (149)	500 (260)	700 (371)	850 (454)	1000 (538)	1150 (621)	1300 (704)	1400 (760)	1500 (816)	
			Basic Allowable Stress, S ksi										
A312	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	5.0	1.7	0.8	0.3	1, 2
A376	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	5.0	1.7	0.8	0.3	1, 2
A269	TP304L	-425	16.7	16.7	14.8	13.5	12.8	7.8	4.0	2.1	1.1	0.9	2, 3
A312	TP304L	-425	16.7	16.7	14.8	13.5	12.8	7.8	4.0	2.1	1.1	0.9	-
A358	304L	-425	16.7	16.7	14.8	13.5	12.8	7.8	4.0	2.1	1.1	0.9	2
A269	TP316L	-325	16.7	16.7	14.4	12.9	12.1	11.2	8.8	3.5	1.8	1.0	2, 3
A312	TP316L	-325	16.7	16.7	14.4	12.9	12.1	11.2	8.8	3.5	1.8	1.0	-
A358	316L	-325	16.7	16.7	14.4	12.9	12.1	11.2	8.8	3.5	1.8	1.0	2
A312	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	1, 2, 4
A376	TP321	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	1, 2, 4
A312	TP321H	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	1, 2
A376	TP321H	-325	16.7	16.7	16.1	14.6	14.0	13.5	6.9	3.2	1.9	1.1	-
A268	TP409	-20	20.0	-	-	-	-	-	-	-	-	-	6
A268	TP430Ti	-20	20.0	-	-	-	-	-	-	-	-	-	6, 7
A376	16-8-2H	-325	20.0	-	-	-	-	-	-	-	-	-	5, 6, 8
A268	TP405	-20	20.0	17.7	17.2	16.2	10.4	4.0	-	-	-	-	6
A268	TP410	-20	20.0	17.7	17.2	16.2	10.4	6.4	1.8	-	-	-	6
A268	TP430	-20	20.0	19.6	19.0	17.6	10.4	6.5	2.4	-	-	-	6, 7
A312	TP317L	-325	20.0	20.0	17.7	16.2	15.2	-	-	-	-	-	-
A312	TP310	-325	20.0	20.0	20.0	18.3	14.6	11.0	3.6	0.8	0.4	0.2	4, 6, 10
A358	310S	-325	20.0	20.0	20.0	18.3	14.6	11.0	3.6	0.8	0.4	0.2	2, 4, 5, 6
A409	TP310	-325	20.0	20.0	20.0	18.3	14.6	11.0	3.6	0.8	0.4	0.2	2, 4, 5, 6, 10
A312	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1
A358	321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1, 2
A376	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1, 2
A409	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	5.0	1.7	0.8	0.3	1, 2
A312	TP309	-325	20.0	20.0	20.0	18.3	14.6	10.5	5.0	2.3	1.3	0.7	4, 6, 10
A358	309S	-325	20.0	20.0	20.0	18.3	14.6	10.5	5.0	2.3	1.3	0.7	4, 5, 6, 2
A409	TP309	-325	20.0	20.0	20.0	18.3	14.6	10.5	5.0	2.3	1.3	0.7	2, 4, 5, 6, 10
A312	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	-
A358	347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A376	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A409	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A312	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	-
A358	348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A376	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A409	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	6.1	2.2	1.2	0.8	1, 2
A312	TP310	-325	20.0	20.0	20.0	18.3	14.6	11.0	7.3	3.5	1.6	0.8	4, 6, 10, 11
A358	310S	-325	20.0	20.0	20.0	18.3	14.6	11.0	7.3	3.5	1.6	0.8	2, 4, 5, 6, 11
A430	FP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2
A312	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 4
A358	321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2, 4
A376	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2, 4
A409	TP321	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2, 4
A430	FP321H	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2
A376	TP321H	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	1, 2
A312	TP321H	-325	20.0	20.0	19.3	17.5	16.7	16.2	6.9	3.2	1.9	1.1	-
A430	FP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 5, 8
A430	FP316H	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 5, 8
A269	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 3, 4, 5, 8
A312	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	4, 8
A358	316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8
A376	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8
A409	TP316	-425	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8
A312	TP317	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	4, 8
A409	TP317	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 4, 5, 8

ASTM Spec No.	Grade	Min Temp °F (for °C see Notes)	Metal Temperature, °F (°C)										Notes
			Min Temp to 100 (37.8)	300 (149)	500 (260)	700 (371)	850 (454)	1000 (538)	1150 (621)	1300 (704)	1400 (760)	1500 (816)	
			Basic Allowable Stress, S ksi										
A376	TP316H	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	2, 5, 8
A312	TP316H	-325	20.0	20.0	17.9	16.3	15.7	15.3	9.8	4.1	2.3	1.3	8
A430	FP347	-425	20.0	20.0	18.6	18.2	18.2	18.0	10.5	4.4	2.5	1.3	1, 2
A430	FP347H	-325	20.0	20.0	18.6	18.2	18.2	18.0	10.5	4.4	2.5	1.3	1, 2
A376	TP347H	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2
A312	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	4
A358	347	-425	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2, 4
A376	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2, 4
A409	TP347	-425	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2, 4
A312	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	4
A358	348	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2, 4
A376	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2, 4
A409	TP348	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	1, 2, 4
A312	TP347H	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	-
A312	TP348H	-325	20.0	20.0	19.9	18.6	18.2	18.0	10.5	4.4	2.5	1.3	-
A430	FP304	-425	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 5, 8
A430	FP304H	-325	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 5, 8
A269	TP304	-425	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 3, 4, 5, 8
A312	TP304	-425	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	4, 8
A358	304	-425	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 4, 5
A376	TP304	-425	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 4, 5, 8
A376	TP304H	-325	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 5, 8
A409	TP304	-425	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	2, 4, 5, 8
A312	TP304H	-325	20.0	20.0	17.5	16.0	14.9	13.8	7.7	3.7	2.3	1.4	8
A268	TP443	-20	23.3	21.4	19.4	17.5	15.1	4.5	-	-	-	-	6
A268	TP446	-20	23.3	21.4	19.4	17.5	15.1	4.5	-	-	-	-	6
A789	S32304	-60	29.0	26.3	24.9	-	-	-	-	-	-	-	9
A790	S32304	-60	29.0	26.3	24.9	-	-	-	-	-	-	-	9
A789	S31803	-60	30.0	28.9	27.2	-	-	-	-	-	-	-	9
A790	S31803	-60	30.0	28.9	27.2	-	-	-	-	-	-	-	9
A789	S32900	-20	30.0	-	-	-	-	-	-	-	-	-	9
A790	S32900	-20	30.0	-	-	-	-	-	-	-	-	-	9
A789	S32750	-20	38.7	33.1	31.4	-	-	-	-	-	-	-	9
A790	S32750	-20	38.7	33.1	31.4	-	-	-	-	-	-	-	9

NOTES

- This table is based on Table A-1A of ASME B31.3a-2008.
- For specified minimum tensile and yield strengths refer to the individual ASTM specifications on pages 2-63.
- Minimum temperatures in °C: -20°F = -29°C, -60°F = -51°C, -325°F = -199°C, -425°F = -254°C
- 1 For temperatures above 538°C (1000°F), these stress values may be used only if the material has been heat treated at a temperature of 1093°C (2000°F) minimum.
- 2 When the material has not been solution heat treated, the minimum temperature shall be -29°C (-20°F) unless the material is impact tested.
- 3 Must be verified by tensile test.
- 4 For temperatures above 538°C (1000°F), these stress values apply only when the carbon content is 0.04% or higher.
- 5 For temperatures above 538°C (1000°F), these stress values may be used only if the material has been heat treated by heating to a minimum temperature of 1038°C (1900°F) and quenching in water or rapidly cooling by other means.
- 6 This steel is intended for use at high temperatures; it may have low ductility and/or low impact properties at room temperature after being used at higher temperatures.
- 7 If the chemical composition of this Grade is such as to render it hardenable, qualification under P-No.6 is required.
- 8 Increasingly tends to precipitate intergranular carbides as the carbon content increases above 0.03%.
- 9 This steel may develop embrittlement after service at approximately 316°C (600°F) and higher temperature.
- 10 This material when used below -29°C (-20°F) shall be impact tested if the carbon content is above 0.10%.
- 11 The stress values above 538°C (1000°F) shall be used only when the micrograin size, is No. 6 or less (coarser grain). Otherwise, the lower stress values listed for the same material, specification, and grade shall be used.