ME 423: FLUIDS ENGINEERING

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Lecture-29 (09/12/2024)

Pipe Analysis

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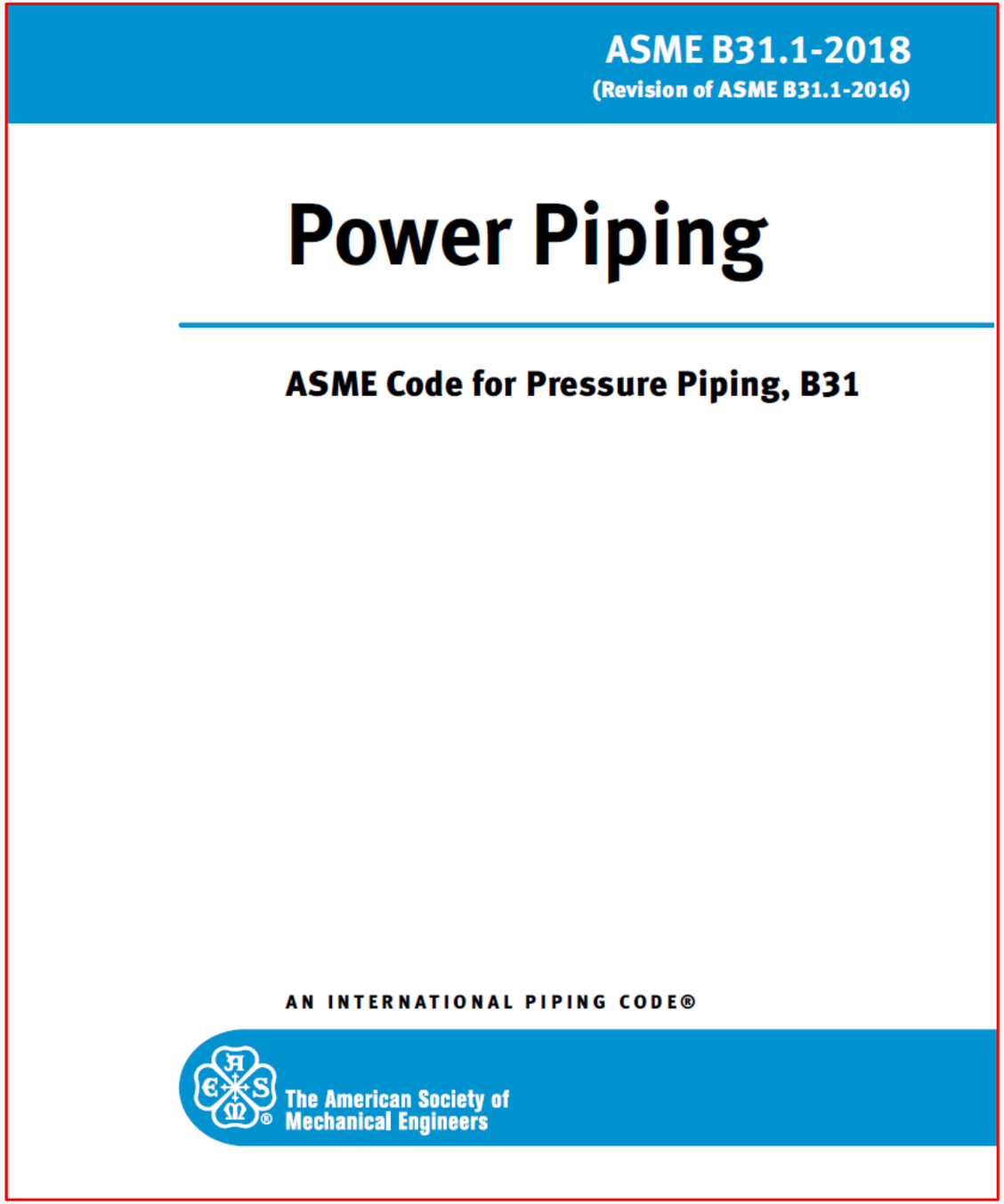
ASME B31

B31.1	Power Piping: piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems
B31.3	Process Piping: piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals
B31.4	Pipeline Transportation Systems for Liquids and Slurries: piping transporting products that are predominately liquid between plants and terminals and within terminals, pumping, regulating, and metering stations
B31.5	Refrigeration Piping and Heat Transfer Components: piping for refrigerants and secondary coolants
B31.8	Gas Transmission and Distribution Piping Systems: piping transporting products that are predominately gas between sources and terminals, including compressor, regulating, and metering stations; and gas gathering pipelines
B31.9	Building Services Piping: piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in B31.1
B31.12	Hydrogen Piping and Pipelines: piping in gaseous and liquid hydrogen service, and pipelines in gaseous hydrogen service



Bangladesh Gas Safety Rules

প্রাকৃতিক গ্যাস নিরাপত্তা বিধিমালা, ১৯৯১

[২০০৩ সাল পর্যন্ত সংশোধিত]

Petroleum Act, 1934 (XXX of 1934) এর Sections 4, 14(2), 21, 29(1) এবং 30(2), বিদ্যুৎ, জ্বালানি ও খনিজ সম্পদ মন্ত্রণালয়ের ১৬ই নভেম্বর ১৯৮৯/২রা অগ্রহায়ন ১৩৯৬ তারিখের এস. আর. ও. ৩৮৯-আইন/৮৯ নং প্রজ্ঞাপনসহ পঠিতব্য-তে প্রদত্ত ক্ষমতাবলে সরকার নিম্নরূপ বিধিমালা প্রণয়ন করিল যাহার প্রাক-প্রকাশনা উক্ত Act এর Sections 29(2) এর বিধান মোতাবেক করা হইয়াছিল :

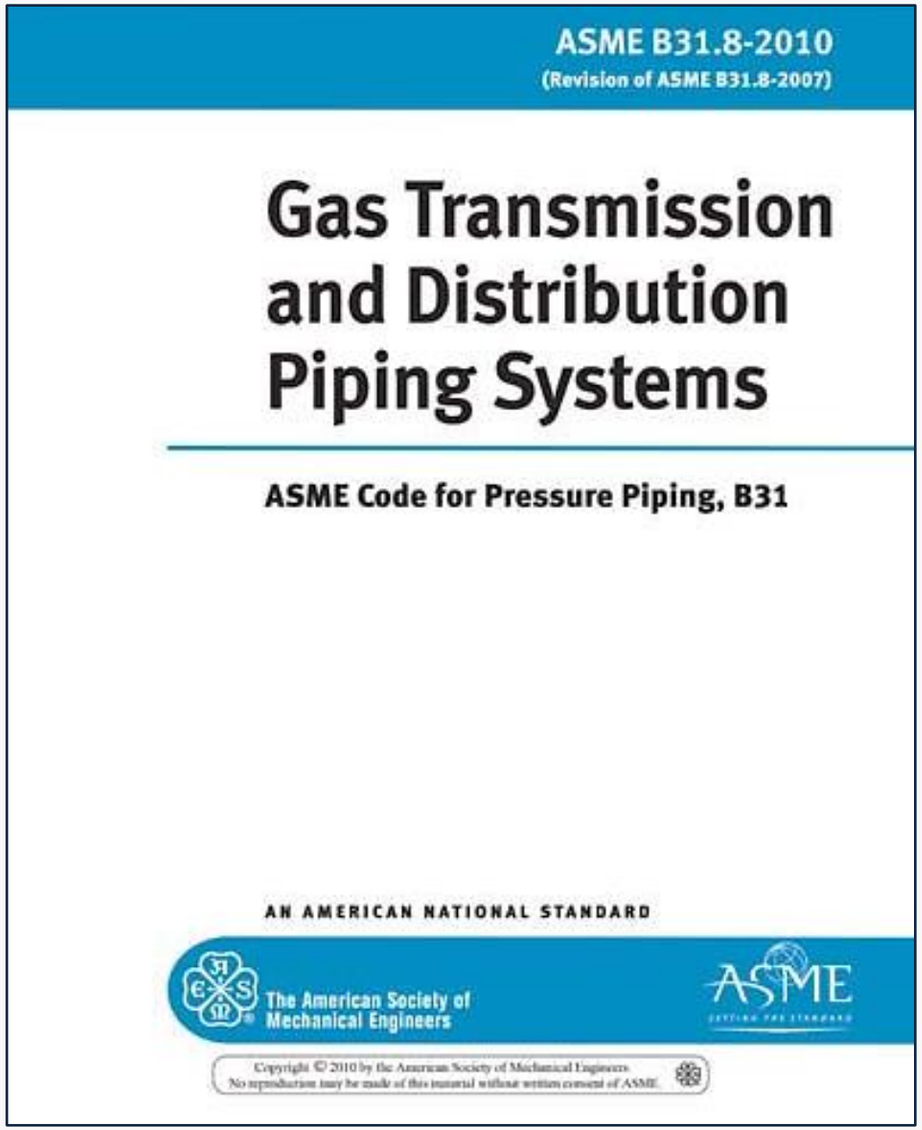
প্রথম পরিচ্ছেদ : প্রারম্ভিক

১। **সংক্ষিপ্ত শিরোনাম ।-** এই বিধিমালা প্রাকৃতিক গ্যাস নিরাপত্তা বিধিমালা, ১৯৯১ নামে অভিহিত হইবে।

২। **সংজ্ঞা।-** (১) "আমেরিকান কোড" অর্থ গ্যাস সঞ্চালন ও পাইপিং সিস্টেম বিষয়ে আমেরিকান ন্যাশনাল স্ট্যান্ডার্ড ইনস্টিটিউট কর্তৃক প্রণীত কোড নং ~~ANSI B 31.8;~~ ASME B31.8

(২) "উচ্চ চাপ" অর্থ গ্যাসের এমন চাপমাত্রা যাহা গেজের পরিমাপে কোন পাইপ লাইনের প্রতি বর্গ সেন্টিমিটারে ৭ কেজি বা ততোধিক ;

(৩) "কম্প্রেসর স্টেশন [১][বা বুস্টার স্টেশন]" অর্থ সঞ্চালন লাইন, বিতরণ লাইন বা গ্যাসাধারের গ্যাসের চাপ বৃদ্ধির জন্য স্থাপিত কেন্দ্র ;



Bangladesh Natural Gas Safety Rules 1991 (amended up to 2003)

ASME B31.8 (2010)

According to Bangladesh Natural Gas Safety Rules 1991 (amended up to 2003) and ASME B31.8 (2010) code and standard [para 841.1]:

The design pressure for steel gas piping systems or the nominal wall thickness for a given design pressure shall be determined by the following formula:

$$P = \left(\frac{2St}{D}\right) \times E \times F \times T$$

or

$$t = \left(\frac{PD}{2S}\right) \times \frac{1}{E \times F \times T}$$

where

P= design pressure, psig

S = specified minimum yield strength (SMYS), psi, stipulated in the specification under which the pipe was purchased **(Mandatory Appendix-D)**

t = nominal wall thickness, in.

D = nominal outside diameter of pipe, in.

E = longitudinal joint factor obtained from **Table 841.1.7-1**

F = design factor obtained from **Table 841.1.6-1**

T = temperature derating factor obtained from **Table 841.1.8-1**

MANDATORY APPENDIX D
SPECIFIED MINIMUM YIELD STRENGTH FOR STEEL PIPE COMMONLY USED IN PIPING SYSTEMS[1]

Table D-1 Specified Minimum Yield Strength for Steel Pipe Commonly Used in Piping Systems

Spec. No.	Grade	Type [Note (1)]	SMYS, psi	(MPa)
API 5L [Note (2)]	A25	BW, ERW, S	25,000	(172)
API 5L [Note (2)]	A	ERW, S, DSA	30,000	(207)
API 5L [Note (2)]	B	ERW, S, DSA	35,000	(241)
API 5L [Note (2)]	×42	ERW, S, DSA	42,000	(290)
API 5L [Note (2)]	×46	ERW, S, DSA	46,000	(317)
API 5L [Note (2)]	×52	ERW, S, DSA	52,000	(359)
API 5L [Note (2)]	×56	ERW, S, DSA	56,000	(386)
API 5L [Note (2)]	×60	ERW, S, DSA	60,000	(414)
API 5L [Note (2)]	×65	ERW, S, DSA	65,000	(448)
API 5L [Note (2)]	×70	ERW, S, DSA	70,000	(483)
API 5L [Note (2)]	×80	ERW, S, DSA	80,000	(552)
ASTM A 53	Type F	BW	25,000	(172)
ASTM A 53	A	ERW, S	30,000	(207)
ASTM A 53	B	ERW, S	35,000	(241)
ASTM A 106	A	S	30,000	(207)
ASTM A 106	B	S	35,000	(241)
ASTM A 106	C	S	40,000	(276)
ASTM A 134	. . .	EFW	[Note (3)]	
ASTM A 135	A	ERW	30,000	(207)
ASTM A 135	B	ERW	35,000	(241)
ASTM A 139	A	EFW	30,000	(207)
ASTM A 139	B	EFW	35,000	(241)
ASTM A 139	C	EFW	42,000	(290)
ASTM A 139	D	EFW	46,000	(317)
ASTM A 139	E	EFW	52,000	(359)

Table D-1 Specified Minimum Yield Strength for Steel Pipe Commonly Used in Piping Systems (Cont'd)

Spec. No.	Grade	Type [Note (1)]	SMYS, psi	(MPa)
ASTM A 381	Class Y-52	DSA	52,000	(359)
ASTM A 381	Class Y-56	DSA	56,000	(386)
ASTM A 381	Class Y-60	DSA	60,000	(414)
ASTM A 381	Class Y-65	DSA	65,000	(448)
ASTM A 984	35	ERW	35,000	(241)
ASTM A 984	50	ERW	50,000	(345)
ASTM A 984	60	ERW	60,000	(414)
ASTM A 984	70	ERW	70,000	(483)
ASTM A 984	80	ERW	80,000	(552)
ASTM A 1005	35	DSA	35,000	(241)
ASTM A 1005	50	DSA	50,000	(345)
ASTM A 1005	60	DSA	60,000	(414)
ASTM A 1005	70	DSA	70,000	(483)
ASTM A 1005	80	DSA	80,000	(552)
ASTM A 1006	35	LW	35,000	(241)
ASTM A 1006	50	LW	50,000	(345)
ASTM A 1006	60	LW	60,000	(414)
ASTM A 1006	70	LW	70,000	(483)
ASTM A 1006	80	LW	80,000	(552)

Table 841.1.7-1 Longitudinal Joint Factor, *E*

Spec. No.	Pipe Class	*E* Factor
ASTM A 53	Seamless	1.00
	Electric-Resistance-Welded	1.00
	Furnace-Butt Welded, Continuous Weld	0.60
ASTM A 106	Seamless	1.00
ASTM A 134	Electric-Fusion Arc-Welded	0.80
ASTM A 135	Electric-Resistance-Welded	1.00
ASTM A 139	Electric-Fusion Arc-Welded	0.80
ASTM A 333	Seamless	1.00
	Electric-Resistance-Welded	1.00
ASTM A 381	Submerged-Arc-Welded	1.00
ASTM A 671	Electric-Fusion-Welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 672	Electric-Fusion-Welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 691	Electric-Fusion-Welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 984	Electric-Resistance-Welded	1.00
ASTM A 1005	Double Submerged-Arc-Welded	1.00
ASTM A 1006	Laser Beam Welded	1.00
API 5L	Electric Welded	1.00
	Seamless	1.00
	Submerged-Arc Welded (Longitudinal Seam or Helical Seam)	1.00
	Furnace-Butt Welded, Continuous Weld	0.60

Table 841.1.6-1 Basic Design Factor, *F*

Location Class	Design Factor, *F*
Location Class 1, Division 1	0.80
Location Class 1, Division 2	0.72
Location Class 2	0.60
Location Class 3	0.50
Location Class 4	0.40

Table 841.1.8-1 Temperature Derating Factor, *T*, for Steel Pipe

Temperature, °F (°C)	Temperature Derating Factor, *T*
250 (121) or less	1.000
300 (149)	0.967
350 (177)	0.933
400 (204)	0.900
450 (232)	0.867

AMERICAN STANDARD STEEL PIPE ASME B36.10

Nominal Size		Outside Diameter	Nominal Wall Thickness & Weight for Welded & Seamless Steel Pipe ASME B36.10												Dimensions (mm) *Weight (kg/m)*	
DN	NPS	mm	STD	EXTRA STRONG	XX STRONG	SCHED. 10	SCHED. 20	SCHED. 30	SCHED. 40	SCHED. 60	SCHED. 80	SCHED. 100	SCHED. 120	SCHED. 140	SCHED. 160
6	1/8	10.3	1.73 *0.37*	2.41 *0.47*	-	-	-	-	SAME AS STANDARD W.T. (Std. W.T.)	-	SAME AS EXTRA STRONG W.T. (X.S.)	-	-	-	-
8	1/4	13.7	2.24 *0.63*	3.02 *0.80*	-	-	-	-		-		-	-	-	-
10	3/8	17.1	2.31 *0.84*	3.20 *1.10*	-	-	-	-		-		-	-	-	-
15	1/2	21.3	2.77 *1.27*	3.73 *1.62*	7.47 *2.55*	-	-	-		-		-	-	-	4.78 *1.95*
20	3/4	26.7	2.87 *1.69*	3.91 *2.20*	7.82 *3.64*	-	-	-		-		-	-	-	5.56 *2.90*
25	1	33.4	3.38 *2.50*	4.55 *3.24*	9.09 *5.45*	-	-	-		-		-	-	-	6.35 *4.24*
32	1 - 1/4	42.2	3.56 *3.39*	4.85 *4.47*	9.7 *7.77*	-	-	-		-		-	-	-	6.35 *5.61*
40	1 - 1/2	48.3	3.68 *4.05*	5.08 *5.41*	10.15 *9.56*	-	-	-		-		-	-	-	7.14 *7.25*
50	2	60.3	3.91 *5.44*	5.54 *7.48*	11.07 *13.44*	-	-	-		-		-	-	-	8.74 *11.11*
65	2 - 1/2	73.0	5.16 *8.63*	7.01 *11.41*	14.02 *20.39*	-	-	-		-		-	-	-	9.53 *14.92*
80	3	88.9	5.49 *11.29*	7.62 *15.27*	15.24 *27.67*	-	-	-		-		-	-	-	11.13 *21.35*
90	3 - 1/2	101.6	5.74 *13.57*	8.08 *18.63*	-	-	-	-		-		-	-	-	-
100	4	114.3	6.02 *16.07*	8.56 *22.32*	17.12 *41.03*	-	-	-		-		-	11.13 *28.32*	-	13.49 *33.54*
125	5	141.3	6.55 *21.77*	9.53 *30.97*	19.05 *57.43*	-	-	-		-		-	12.7 *40.28*	-	15.88 *49.11*
150	6	168.3	7.11 *28.26*	10.97 *42.56*	21.95 *79.22*	-	-	-		-		-	14.27 *54.20*	-	18.26 *67.56*
200	8	219.1	8.18 *42.55*	12.7 *64.64*	22.23 *107.92*	-	6.35 *33.31*	7.04 *36.81*		10.31 *53.08*		15.09 *75.92*	18.26 *90.44*	20.62 *100.92*	23.01 *111.27*
250	10	273.1	9.27 *60.31*	12.7 *81.55*	25.4 *155.15*	-	6.35 *41.77*	7.8 *51.03*		XS *81.55*	15.09 *96.01*	18.26 *114.75*	21.44 *133.06*	XXS *155.15*	28.58 *172.33*
300	12	323.9	9.53 *73.88*	12.7 *97.46*	25.4 *186.97*	-	6.35 *49.73*	8.38 *65.20*	10.31 *79.73*	14.27 *108.96*	17.48 *132.08*	21.44 *159.91*	XXS *186.97*	28.58 *208.14*	33.32 *238.76*
350	14	355.6	9.53 *81.33*	12.7 *107.10*	-	6.35 *54.59*	7.92 *67.90*	Std.W.T. *81.33*	11.13 *94.55*	15.09 *126.70*	19.05 *158.10*	23.83 *194.96*	27.79 *224.65*	31.75 *253.56*	35.71 *281.70*
400	16	406.4	9.53 *93.27*	12.7 *123.30*	-	6.35 *62.64*	7.92 *77.83*	Std.W.T. *93.27*	XS *123.30*	16.66 *160.12*	21.44 *203.53*	26.19 *245.56*	30.96 *286.64*	36.53 *333.19*	40.49 *365.35*
450	18	457	9.53 *105.16*	12.7 *139.15*	-	6.35 *70.57*	7.92 *87.71*	11.13 *122.38*	14.27 *155.80*	19.05 *205.74*	23.83 *254.55*	29.36 *309.62*	34.93 *363.56*	39.67 *408.26*	45.24 *459.37*
500	20	508	9.53 *117.15*	12.7 *155.12*	-	6.35 *78.55*	Std.W.T. *117.15*	XS *155.12*	15.09 *183.42*	20.62 *247.83*	26.19 *311.17*	32.54 *381.53*	38.1 *441.49*	44.45 *508.11*	50.01 *564.81*
550	22	559	9.53 *129.13*	12.7 *171.09*	-	6.35 *86.54*	Std.W.T. *129.13*	XS *171.09*	-	22.23 *294.25*	28.58 *373.83*	34.93 *451.42*	41.28 *527.05*	47.63 *600.63*	53.98 *672.26*
600	24	610	9.53 *141.12*	12.7 *187.06*	-	6.35 *94.53*	Std.W.T. *141.12*	14.27 *209.64*	17.48 *255.41*	24.61 *355.26*	30.96 *442.08*	38.89 *547.71*	46.02 *640.03*	52.37 *720.15*	59.54 *808.22*
650	26	660	9.53 *152.87*	12.7 *202.72*	-	7.92 *127.36*	XS *202.72*	-	-	-	-	-	-	-	-
700	28	711	9.53 *164.85*	12.7 *218.69*	-	7.92 *137.32*	XS *218.69*	15.88 *271.21*	-	-	-	-	-	-	-
750	30	762	9.53 *176.84*	12.7 *234.67*	-	7.92 *147.28*	XS *234.67*	15.88 *292.18*	-	-	-	-	-	-	-
800	32	813	9.53 *188.82*	12.7 *250.64*	-	7.92 *157.24*	XS *250.64*	15.88 *312.15*	17.48 *342.91*	-	-	-	-	-	-
850	34	864	9.53 *200.31*	12.7 *266.61*	-	7.92 *167.20*	XS *266.61*	15.88 *332.12*	17.48 *364.90*	-	-	-	-	-	-
900	36	914	9.53 *212.56*	12.7 *282.27*	-	7.92 *176.96*	XS *282.27*	15.88 *351.7*	19.05 *420.42*	-	-	-	-	-	-
1050	42	1067	9.53 *248.52*	12.7 *330.19*	-	-	-	-	-	-	-	-	-	-	-

Problem

A NPS 22 STD Schedule ASTM A 106 Grade B pipe is used to transport natural gas with design pressure of 12 barg. The design temperature of gas is 120°C. Determine the Maximum Allowable Operating Pressure (MAOP) of the gas pipeline considering to ASME B31.8 standard.

Also determine the factor of safety according to this standard.

Note: 1 psi = 6.895 kPa

Pipeline Inspection, Examination, and Testing

Prior to initial operation, a piping installation shall be inspected to ensure that the piping has been constructed in accordance with the design, material, fabrication, assembly, examination, and testing requirements of the Code ASME B31.1.

Examination denotes the functions performed by the manufacturer, fabricator, erector, or a party authorized by the owner that include **nondestructive examinations (NDE)**, such as

- Visual
- Radiography (RT)
- Ultrasonic (UT)
- Eddy current
- Liquid penetrant (PT) and
- Magnetic particle (MT) methods

The degree of examination and the acceptance standards beyond the requirements of this Code shall be a matter of prior agreement between the manufacturer, fabricator, or erector and the owner.

Visual Examination

Visual examinations may be conducted, as necessary, during the fabrication and erection of piping components to provide verification that the design and WPS (Welding Procedure Specification) requirements are being met.

In addition, visual examination shall be performed to verify that all completed welds in pipe and piping components comply with the acceptance standards or with the limitations on imperfections specified in the material specification under which the pipe or component was furnished.

(ASME B31.1) *Acceptance Standards.* The following indications are unacceptable:

(1) cracks — external surface.

(2) undercut on the surface that is greater than 1⁄32 in. (1.0 mm) deep, or encroaches on the minimum required section thickness.

(3) undercut on the surface of longitudinal butt welds.

(4) weld reinforcement greater than specified in Table 127.4.2-1.

(5) lack of fusion on surface.

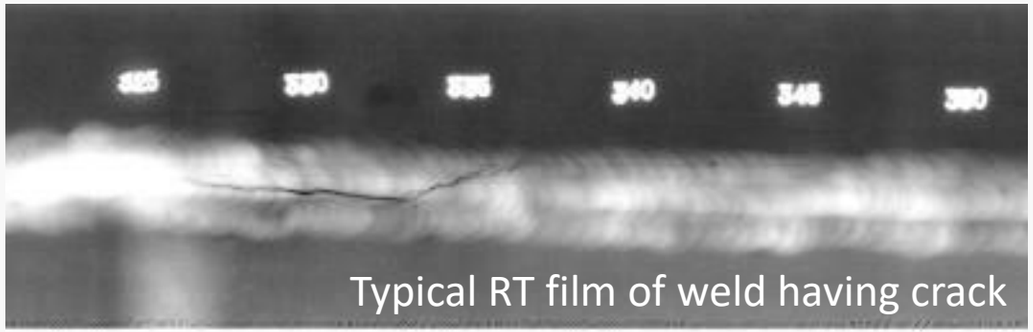
(6) incomplete penetration

(7) surface porosity

Radiography

Radiographic Testing (RT) of weld testing makes use of X-rays, produced by an X-ray tube, or gamma rays, produced by a radioactive isotope. The basic principle of radiographic inspection of welds is the same as that for medical radiography.

- Radiographic testing is a NDE approach for finding porosity, cracks, inclusions and voids in the inside of weldments.
- Surface and subsurface defects can be uncovered.



Typical RT film of weld having crack

(ASME B31.1) *Acceptance Standards.* Welds that are shown by radiography to have any of the following types of discontinuities are unacceptable:

(1) any type of crack or zone of incomplete fusion or penetration

(2) any other elongated indication that has a length greater than

(-a) 1⁄4 in. (6.0 mm) for *t* up to 3⁄4 in. (19.0 mm), inclusive

(-b) 1⁄3*t* for *t* from 3⁄4 in. (19.0 mm) to 21⁄4 in. (57.0 mm), inclusive

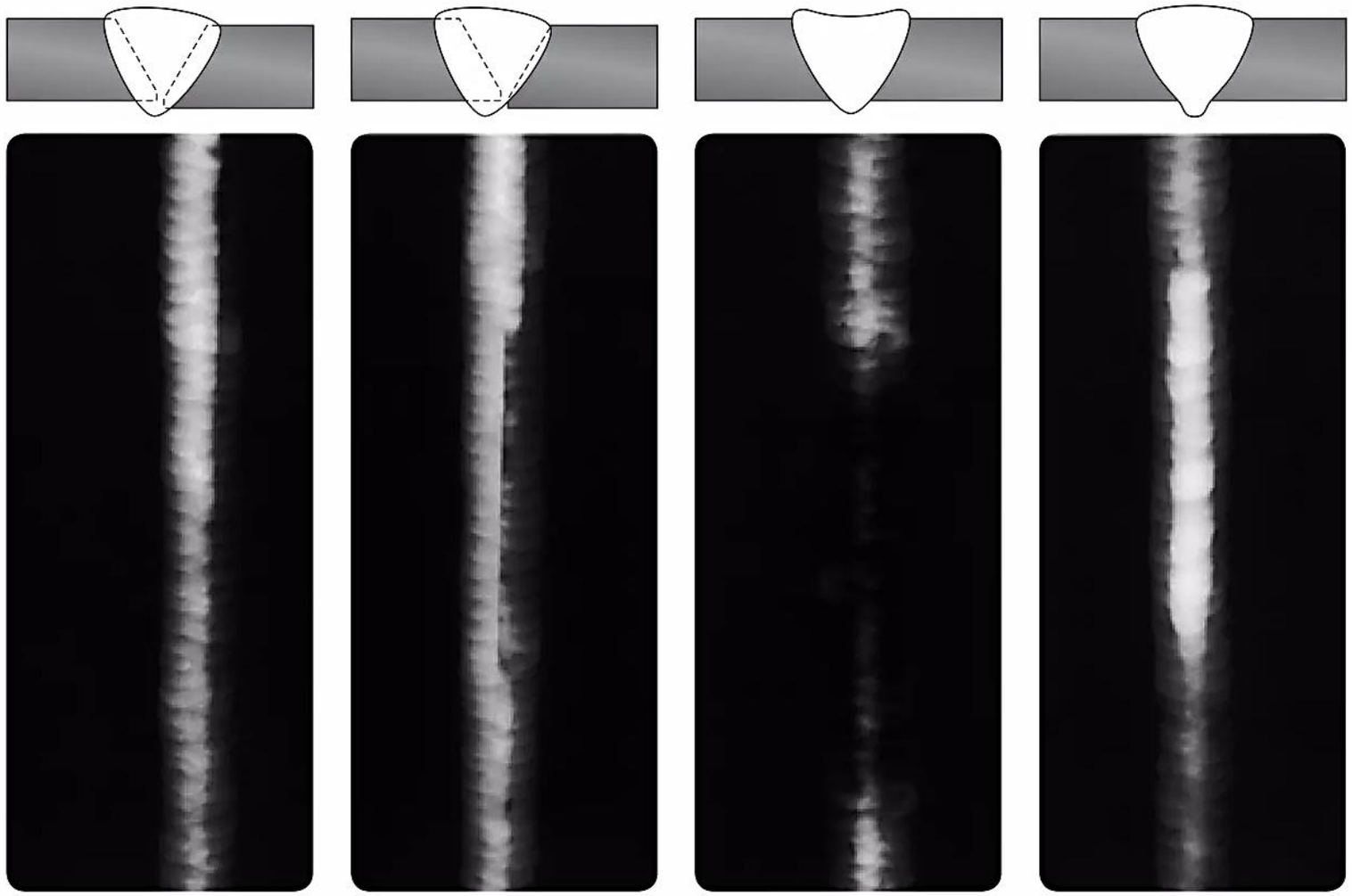
(-c) 3⁄4 in. (19.0 mm) for *t* over 21⁄4 in. (57.0 mm)

where *t* is the thickness of the thinner portion of the weld

Radiography cont.

Reference Radiographs

The following selection of radiographs illustrates the wide variety of possibilities for detection of discontinuities.



Offset or mismatch (Hi-Lo).

An abrupt change in film density across the width of the weld image.

Offset or mismatch with Lack of Penetration (LOP).
An abrupt density change across the width of the weld image with a straight longitudinal darker density line at the centre of the width of the weld image along the edge of the density change.

External concavity or insufficient fill.

The weld density is darker than the density of the pieces welded and extending across the full width of the weld.

Excessive penetration.

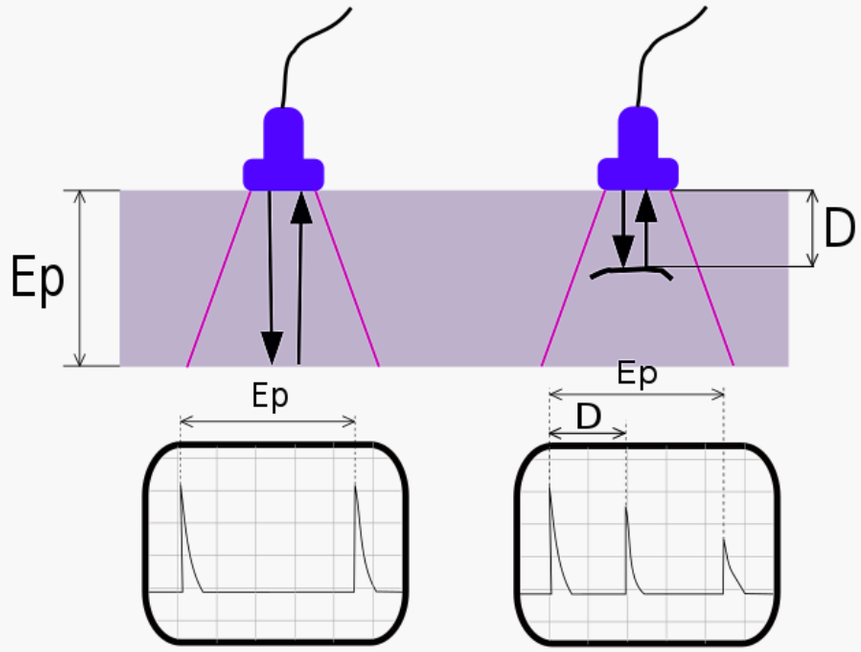
A lighter density in the centre of the width of the weld image, either extended along the weld or in isolated circular drops.

Ultrasonic Examination

Ultrasonic testing (UT) is a family of non-destructive testing techniques based on **the propagation of ultrasonic waves in the object or material tested**.

In most common UT applications, very short ultrasonic pulse waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials.

A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipework corrosion and erosion. Ultrasonic testing is extensively used to detect flaws in welds.



Ultrasonic Examination cont.

(ASME B31.1) ***Acceptance Standards.*** Welds that are shown by ultrasonic examination to have discontinuities that produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location so that they may evaluate each discontinuity for acceptance in accordance with (1) and (2).

(1) Discontinuities evaluated as being cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

(2) Other discontinuities are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(-a) 1⁄4 in. (6.0 mm) for *t* up to 3⁄4 in. (19.0 mm).

(-b) ⅓*t* for *t* from 3⁄4 in. (19.0 mm) to 21⁄4 in. (57.0 mm).

(-c) 3⁄4 in. (19.0 mm) for *t* over 21⁄4 in. (57.0 mm)

where *t* is the thickness of the weld being examined.

PRESSURE TESTS (Hydro Test)

The **pressure testing / Hydrostatic testing / Hydro test** of piping systems to ensure leak tightness shall be acceptable for the determination of any leaks in piping subassemblies.

Test Medium.

Water shall normally be used as the test medium unless otherwise specified by the owner.

Test water shall be clean and shall be of such quality as to minimize corrosion of the materials in the piping system.


Booster pump


Chart recorder

PRESSURE TESTS (Hydro Test) cont.

(ASME B31.1) 137.4.5 Required Hydrostatic Test Pressure. The hydrostatic test pressure at any point in the piping system **shall not be less than 1.5 times the design pressure**, but shall not exceed the maximum allowable test pressure of any nonisolated components, such as vessels, pumps, or valves, etc.

The pressure shall be continuously maintained for **a minimum time of 10 min** and may then be **reduced to the design pressure and held for such time** as may be necessary to conduct the examinations for leakage.

Examinations for leakage shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of weeping or leaking.

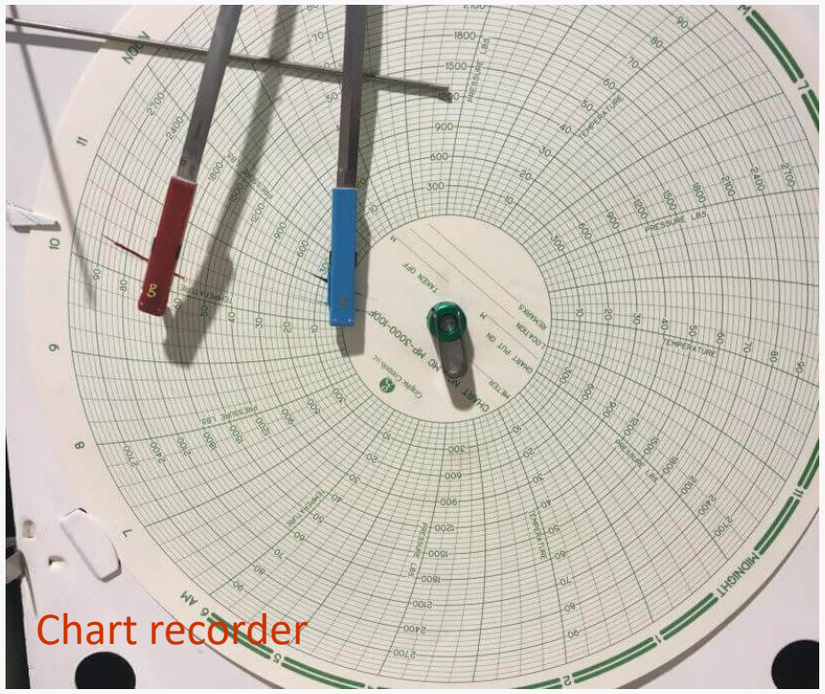


Chart recorder

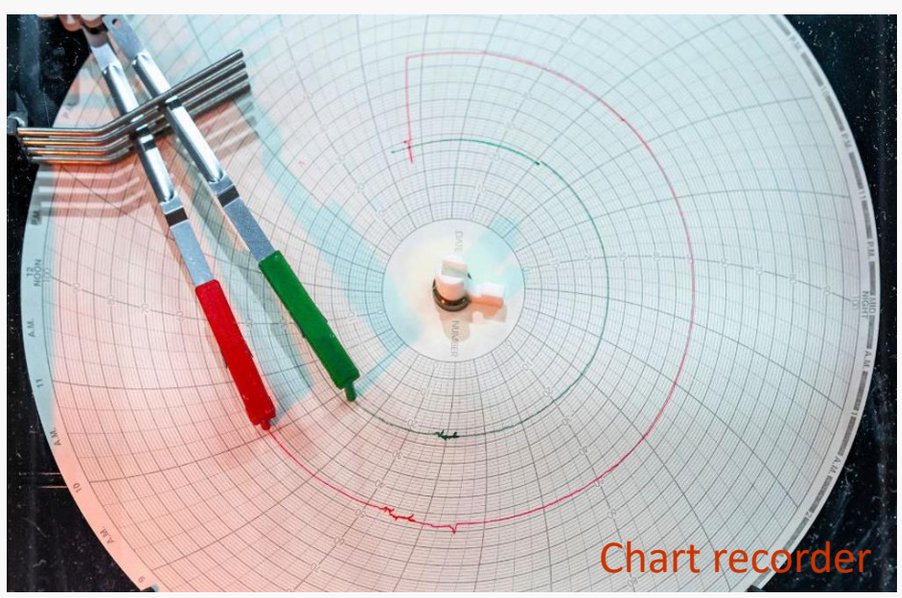


Chart recorder

Gas pipeline Pigging

Pipeline pigging is a concept in pipeline maintenance that involves the use of electro-mechanical devices known as pigs, which clean pipelines and are capable of checking pipeline conditions.

Pigs sweep the line by scraping piping surfaces and pushing debris ahead. They can perform many functions as they travel along a pipeline:

- Clearing the line
- Breaking up clogs
- Inspecting the interior
- Pipeline cleaning

Blowdown valves and piping systems are installed around the mainline valve in a gas transmission piping system in order to evacuate gas from sections of pipeline in the event of an emergency or for maintenance purposes.

The objective of the blowdown assembly is to remove gas from the pipeline once the pipe section is isolated by closing the mainline block valves in a reasonable period of time. The pipe size required to blow down a section of pipe will depend on the gas gravity, pipe diameter, length of pipe section, pressure in the pipeline, and blowdown time. AGA recommends the following equation to estimate the blowdown time:

$$T = \frac{0.0588 P_1^{\frac{1}{3}} G^{\frac{1}{2}} D^2 L F_c}{d^2} \quad \text{(USCS units)} \qquad (6.9)$$

where

T = blowdown time, min
P_1 = initial pressure, psia
G = gas gravity (air = 1.00)
D = pipe inside diameter, in.
L = length of pipe section, mi
d = inside diameter of blowdown pipe, in.
F_c = choke factor (as follows)

Choke factor list

Ideal nozzle = 1.0
Through gate = 1.6
Regular gate = 1.8
Regular lube plug = 2.0
Venturi lube plug = 3.2

BLOWDOWN CALCULATIONS cont.

In SI units,

$$T = \frac{0.0192 P_1^{\frac{1}{3}} G^{\frac{1}{2}} D^2 L F_c}{d^2} \quad \text{(SI units)} \qquad (6.10)$$

where

P_1 = initial pressure, kPa
D = pipe inside diameter, mm
L = length of pipe section, km
d = pipe inside diameter of blowdown, mm

Other symbols are as defined before.

Problem

Example 4:

Calculate the blowdown time required for an NPS 6, 0.250 in. wall thickness blowdown assembly on an NPS 24 pipe, 0.500 in. wall thickness, considering a 5 mi pipe section starting at a pressure of 1000 psia. The gas gravity is 0.6 and choke factor = 1.8.

Ans: 58 min. approx