ME 423: FLUIDS ENGINEERING

Gas Pipeline Hydraulics

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Pipe Analysis

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PIPE WALL THICKNESS

In preceding chapters, we calculated the pressure needed to transport a given volume of gas through a pipeline. The internal pressure in a pipe causes the **pipe wall to be stressed**, and if allowed to **reach the yield strength of the pipe material, it could cause permanent deformation of the pipe and ultimate failure**. Obviously, the pipe should have sufficient strength to handle the internal pressure safely.

In addition to the internal pressure due to gas flowing through the pipe, the **pipe might also be subjected to external pressure.** External pressure can result from the weight of the soil above the pipe in a buried pipeline and also by the loads transmitted from vehicular traffic in areas where the pipeline is located below roads, highways, and railroads.

In most cases involving buried pipelines transporting gas and other compressible fluids, the effect of the internal pressure is more than that of external loads. Therefore, the necessary **minimum wall thickness will be dictated by the internal pressure in a gas pipeline.**

Stresses in thin-walled pipe due to internal pressure

$$S_h = \frac{PD}{2t}$$

$$S_a = \frac{PD}{4t}$$

where

S_h = hoop or circumferential stress in pipe material, psi

S_a = axial or longitudinal stress in pipe material, psi

P = internal pressure, psi

D = pipe outside diameter, in.

t = pipe wall thickness, in.

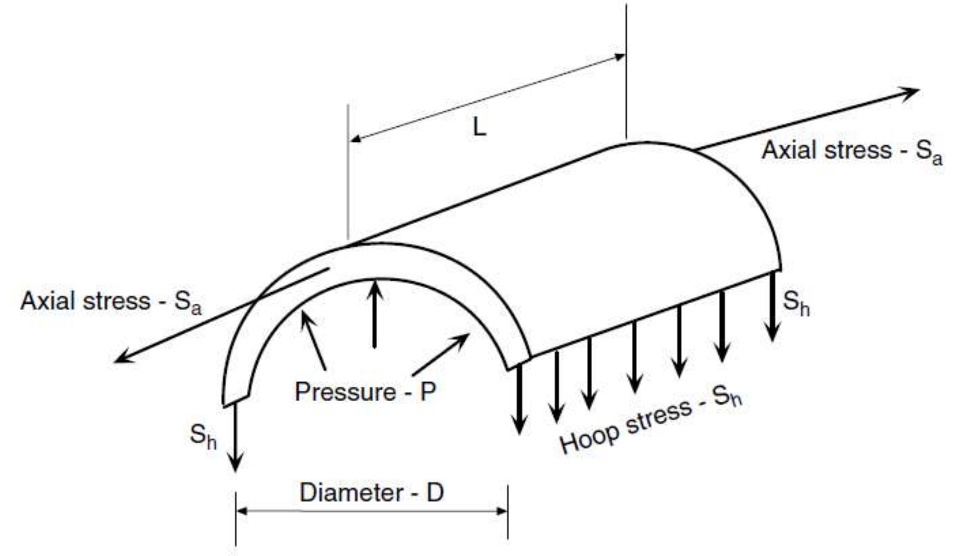

Figure 6.1 Stresses in pipe subject to internal pressure.

The hoop stress S_h is the larger of the two stresses and, hence, will govern the minimum wall thickness required for a given internal pressure.

Pipe Material

SMYS: Specified Minimum Yield Strength

Table 6.1 Pipe Material and Yield Strength

Pipe Material API 5LX Grade	Specified Minimum Yield Strength (SMYS), psi
X42	42,000
X46	46,000
X52	52,000
X56	56,000
X60	60,000
X65	65,000
X70	70,000
X80	80,000
X90	90,000

API Spec 5L is an International Standard that specifies requirements for the manufacture of two **product specification levels** (PSL 1 and PSL 2) of seamless and welded steel pipes for use in pipeline transportation systems in the petroleum and natural gas industries.

INTERNAL DESIGN PRESSURE EQUATION

The following form of Barlow's equation is used in design codes for petroleum transportation systems to calculate the **allowable internal pressure in a pipeline** based upon given diameter, wall thickness, and pipe material:

$$P = \frac{2tSEFT}{D}$$

The internal design pressure calculated from this equation is known as the **maximum allowable operating pressure (MAOP)** of the pipeline. This term has been shortened to **maximum operating pressure (MOP)** in recent years.

where

P = internal pipe design pressure, psig

D = pipe outside diameter, in. (*flow & pressure required calculation were based on inside diameter*)

t = pipe wall thickness, in.

S = specified minimum yield strength (SMYS) of pipe material, psig

E = seam joint factor, 1.0 for seamless and submerged arc welded (SAW) pipes.

F = design factor, usually 0.72 for cross-country gas pipelines, but can be as low as 0.4, depending on class location and type of construction

T = temperature deration factor = 1.00 for temperatures below 250°F

Seam joint factor E

The **seam joint factor E** varies with the type of pipe material and welding employed.

Seam joint factors are given in Table 6.2 for the most commonly used pipe and joint types.

Table 6.2 Pipe Seam Joint Factors

Specification	Pipe Class	Seam Joint Factor (E)
ASTM A53	Seamless	1
	Electric Resistance Welded	1
	Furnace Lap Welded	0.8
	Furnace Butt Welded	0.6
ASTM A106	Seamless	1
ASTM A134	Electric Fusion Arc Welded	0.8
ASTM A135	Electric Resistance Welded	1
ASTM A139	Electric Fusion Welded	0.8
ASTM A211	Spiral Welded Pipe	0.8
ASTM A333	Seamless	1
ASTM A333	Welded	1
ASTM A381	Double Submerged Arc Welded	1
ASTM A671	Electric-Fusion-Welded	1
ASTM A672	Electric-Fusion-Welded	1
ASTM A691	Electric-Fusion-Welded	1
API 5L	Seamless	1
	Electric Resistance Welded	1
	Electric Flash Welded	1
	Submerged Arc Welded	1
	Furnace Lap Welded	0.8
	Furnace Butt Welded	0.6
API 5LX	Seamless	1
	Electric Resistance Welded	1
	Electric Flash Welded	1
	Submerged Arc Welded	1
API 5LS	Electric Resistance Welded	1
	Submerged Arc Welded	1

Class Location F

Class 1
Offshore gas pipelines are Class 1 locations. For onshore pipelines, any class location unit that has 10 or fewer buildings intended for human occupancy is termed Class 1.

Class 2
This is any class location unit that has more than 10 but fewer than 46 buildings intended for human occupancy.

Class 3
This is any class location unit that has 46 or more buildings intended for human occupancy or an area where the pipeline is within 100 yards of a building or a playground, recreation area, outdoor theatre, or other place of public assembly that is occupied by 20 or more people at least 5 days a week for 10 weeks in any 12-month period. The days and weeks need not be consecutive.

Class 4
This is any class location unit where buildings with four or more stories above ground exist.

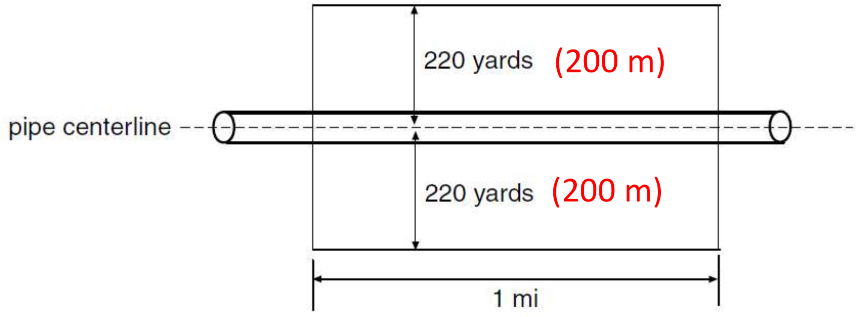

Figure 6.2 Class location unit.

Table 6.3 Design Factors for Steel Pipe

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

Temperature Deration Factor T

Table 6.4 Temperature Deration Factors

Temperature		
°F	°C	Deration Factor *T*
250 or less	121 or less	1.000
300	149	0.967
350	177	0.033
400	204	0.900
450	232	0.867

Problem

Example 2

A gas pipeline is constructed of API 5L X65 steel, NPS 16, 0.250 in. wall thickness. **Calculate the MAOP** of this pipeline for class 1 through class 4 locations. Use a temperature deration factor of 1.00.

Class 1: 1462.5 psig
Class 2: 1218.8 psig
Class 3: 1015.6 psig
Class 4: 812.5 psig

HYDROSTATIC TEST PRESSURE

When a pipeline is designed to operate at a certain MOP, it must be tested to ensure that it is structurally sound and can withstand safely the internal pressure before being put into service.

Generally, gas pipelines are **hydrotested with water** by filling the test section of the pipe with water and pumping the pressure up to a value higher than the MAOP and **holding it at this test pressure for a period of 4 to 8 hours.**

The magnitude of the **test pressure is specified by design code, and it is usually 125%** of the operating pressure. Thus, a pipeline designed to operate continuously at 1000 psig will be hydrotested to a minimum pressure of 1250 psig.

Problem

Example 3

A gas pipeline, NPS 20, 0.500 in. wall thickness, is constructed of API 5L X52 pipe.
(a) Calculate the design pressures for class 1 through class 4 locations.
(b) What is the required minimum hydrotest pressures for each of these class locations?

Assume joint factor = 1.00 and temperature deration factor = 1.00.

Design Pressure:
Class 1: 1872 psig
Class 2: 1560 psig
Class 3: 1300 psig
Class 4: 1040 psig

Hydrotest Pressure:
1.25 x Design pressure