POLYETHYLENE PIPE LINE NETWORK FOR DOMESTIC DISTRIBUTION OF NATURAL GAS

A project report submitted in partial fulfillment of the requirement for the degree of

MASTER OF TECHNOLOGY

in

GAS ENGINEERING

(Academic Session: 2004-2006)

By

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Date: June 12th 2006

Signature

(Dr.R.P.Badoni)

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Project at a glance

Natural gas is the 21st century fuel for the world. For the last few years this sector is able to gain so much concentration from user point of view. Among the various users of natural gas, domestic user is an integrated part.Since; it is non toxic, non corrosive, clean fuel natural gas is extensively used for domestic purpose world wide. Now in India, emphasis is given on domestic distribution of natural gas which is going to eliminate the use of LPG for domestic purpose. Domestic distribution of natural gas is purely polyethylene based and households are connected safely with polyethylene pipe lines.

The project entitled "Polyethylene Pipe Line Network for Domestic Distribution of Natural Gas" gives idea about the design and construction part of polyethylene pipe lines. This thesis work also put light on the polyethylene pipe line hydraulics which is comparatively a newer research topic in pipe line industry.

Assam Gas Company Limited is one of the pioneer companies in India which is in the business of domestic distribution of natural gas. The company is going to start a new domestic gas grid in Jorhat.Gas from Oil India source at Duliajan is fed to the network by a MS pipeline of 12inch and 8inch diameter. This thesis work is prepared on the basis of this gas grid which gives a general idea about various aspects of any polyethylene pipe line network for domestic natural gas distribution system. This report also gives information about inspection, test, safety of PE pipe line network and packaging and handling of PE pipes as well.

GAS PIPE LINE HYDRAULICS

Pressure Drop Due To Friction

The Bernoulli's equation essentially states the principle of conservation of energy. In a flowing fluid (gas or liquid) the total energy of the fluid remains constant. The various components of the fluid energy are transformed from one form to another, but no energy is lost as the fluid flows in a pipeline.

Average pipeline pressure

The gas compressibility factor Z used in the General Flow equation is based upon the flowing temperature and the average pipe pressure. The average pressure may be approximated as the arithmetic average of the upstream and downstream pressures P_1 and P_2. However, a more accurate average pipe pressure is usually calculated as follows

$$P_{avg}=(2/3)[(P_1+P_2)-(P_1P_2/P_1+P_2)]$$

Velocity of gas in pipe flow

The velocity of gas flow in a pipeline under steady state flow can be calculated by considering the volume flow rate and pipe diameter. In a liquid pipeline, under steady flow, the average flow velocity remains constant throughout the pipeline, as long as the inside diameter does not change. However, in a gas pipeline, due to compressibility effects, pressure and temperature variation, the average gas velocity will vary along the pipeline, even if the pipe inside diameter remains the same. The average velocity in a gas pipeline at any location along the pipeline is a function of the flow rate, gas compressibility factor, pipe diameter, pressure and temperature, as indicated in the equation below.

$$V=.002122(P_b/T_b)(ZT/P)(Q_b/D^2)$$

Where

V = Average gas velocity, ft/s

Q_b = gas flow rate, standard ft^3/day (SCFD)

D = inside diameter of pipe, in.

P_b = base pressure, psia

T_b = base temperature, ^0R

P = gas pressure, psia.

T = gas temperature, ^0R

Z = gas compressibility factor at pipeline conditions, dimensionless

It can be seen from the velocity equation that the higher the pressure, the lower the velocity and vice versa.

The corresponding equation for the velocity in SI units is as follows

$$V=14.7349(P_b/T_b)(ZT/P)(Q_b/D^2)$$

Where

V = gas velocity, m/s

Q_b = gas flow rate, standard m^3/day

D = inside diameter of pipe, mm

P_b = base pressure, kPa

T_b = base temperature, K

P = gas pressure, kPa.

T = gas temperature, K

Z = gas compressibility factor at pipeline conditions, dimensionless

In the SI version of the equation, the pressures may be in any one consistent set of units, such as kPa, MPa or Bar.

Erosional velocity

The erosional velocity represents the upper limit of gas velocity in a pipeline. As the gas velocity increases, vibration and noise result. Higher velocities also cause erosion of the pipe wall over a long time period. The erosional velocity V_{max} may be calculated approximately as follows

$$V_{max}=100\sqrt{(ZRT/29GP)}$$

Where

Z = gas compressibility factor, dimensionless

R = gas constant = 10.73 ft^3 psia/lb-moleR

T = gas temperature, ^0R

G = gas gravity (air = 1.00)

P = gas pressure, psia

Weymouth Equation

The Weymouth equation is used for calculating flows and pressures in high pressure gas gathering systems. It does not use a friction factor or a transmission factor directly, but uses a pipeline efficiency factor. However, we can calculate the transmission factor by comparing the Weymouth equation with the General Flow equation.

The Weymouth equation, in USCS units, is as follows

$$Q=433.5E(T_b/P_b)[(P_1^2-e^S P_2^2)/GT_f L_g Z]^{0.5}D^{2.667}$$

Where E is the pipeline efficiency, expressed as a decimal value less than or equal to 1.0.

All other terms have been defined previously under the General Flow equation.

Comparing the Weymouth equation with General Flow equation, the Weymouth transmission factor in USCS units may be calculated from the following equation.

$$F = 11.18(D)^{1/6}$$

In SI units, the Weymouth equation is expressed as follows

$$Q=3.7435*10^{-3}E\,(T_b/P_b)[(P_1^2-e^S P_2^2)/GT_f L_g Z]^{0.5}D^{2.667}$$

$$F=6.521(D)^{1/6}$$

Panhandle Equations

The Panhandle A and the Panhandle B Equations have been used by many natural gas pipeline companies, including a pipeline efficiency factor, instead of considering the pipe roughness. These equations have been successfully used for Reynolds numbers in the range of 4 million to 40 million. The more common version of

Panhandle A equation is as follows

$$Q=435.87E\,(T_b/P_b)^{1.0788}[(P_1^2-e^S P_2^2)/G^{0.8539}T_f L_g Z]^{0.5394}D^{2.6182}$$

Where E is the pipeline efficiency, a decimal value less than 1.0 and all other symbols have been defined before under General Flow equation.

In SI Units, the Panhandle A equation is stated as follows

$$Q=4.5965*10^{-3}E\,(T_b/P_b)^{1.0788}[(P_1^2-e^S P_2^2)/G^{0.8539}T_f L_g Z]^{0.5394}D^{2.6182}$$

Panhandle B Equation

The Panhandle B Equation sometimes called the revised Panhandle equation is used by many gas transmission companies. It is found to be fairly accurate in turbulent flow for Reynolds numbers between 4 million and 40 million. It is expressed as follows, in USCS units

$$Q=737E\ (T_b/P_b)^{1.02}[(P_1^2-e^SP_2^2)/G^{0.961}T_fL_gZ]^{0.51}D^{2..53}$$

. Where all symbols are the same as defined for the Panhandle A equation

The corresponding equation in SI units is as follows

$$Q=1.002*10^{-2}E\ (T_b/P_b)^{1.02}[(P_1^2-e^SP_2^2)/G^{0.961}T_fL_gZ]^{0.51}D^{2..53}$$

Where all symbols are the same as defined for the Panhandle A equation

It can be seen that the outlet pressure calculated using the Weymouth equation is the smallest value. Hence we conclude that for the same flow rate, Weymouth gives a higher pressure drop compared to Panhandle A and Panhandle B equation. Therefore, Weymouth is considered to be more conservative than the other two flow equations.

The IGT Equation

This is another flow equation for natural gas pipelines, proposed by the Institute of Gas Technology. It is frequently used in gas distribution piping systems.

In USCS units, the IGT equation is as follows.

$$Q=136.9E\ (T_b/P_b)[(P_1^2-e^sP_2^2)/G^{0.8}T_fL_g\mu^{0.2}]^{0.555}D^{2.667}$$

Where μ. is the gas viscosity in lb/ft-s and all other symbols have been defined previously.

In SI units the IGT equation is as follows

$$Q=1.2822*10^{-3}E(T_b/P_b)[(P_1^2-e^sP_2^2)/G^{0.8}T_fL_g\mu^{0.2}]^{0.555}D^{2.667}$$

Where μ is the gas viscosity in Poise and all other symbols have been defined before.

Pressures and Piping System

We calculated flow rates, for short pipe segments, from given upstream and downstream pressures using the General Flow equation as well as Panhandle A, B and Weymouth equation. In a long pipeline the pressures along the pipeline may be calculated considering the pipeline sub-divided into short segments and by calculating the pressure drop in each segment. If we do not do this and consider the pipeline as one long segment, the results will be inaccurate due to the nature of the relationship between pressures and flow rates. To accurately calculate the pressures in a long gas pipeline, we have to use some sort of a computer program, because subdividing the pipeline into segments and calculating the pressures in each segment will become a laborious and time consuming process. Furthermore, if we consider heat transfer effects, the calculations will be even more complex. When pipes of different diameters are connected together end to end, they are referred to as series pipes. If the flow rate is the same throughout the system, we can simplify calculations by converting the entire system into one long piece of pipe with the some same uniform diameter, using the equivalent length concept. We calculate the equivalent length of each pipe segment (for the same pressure drop) based on a fixed base diameter. For example a pipe of diameter D1 and length L1 will be converted to an equivalent length Le1 of some base diameter D. This will be based on the same pressure drop in both pipes. Similarly the remaining pipe segments, such as the pipe diameter D2 and length L2 will be converted to a corresponding equivalent length Le2 of diameter D. Continuing the process we have the entire piping system reduced to the following total equivalent length of the same diameter D.

Total equivalent length = Le1 + Le2 + Le3 +...

The base diameter D may be one of the segment diameters. For example, we may pick the base diameter to be D1. Therefore the equivalent length becomes

Total equivalent length = L1 + Le2 + Le3 +...

From the General Flow equation, we see that the pressure drop versus the pipe diameter relationship is such that $(P_1^2-P_2^2)$ is inversely proportional to the fifth power of the diameter and directly proportional to the pipe length. Therefore, we can state the following

$\Delta P_{sq}=CL/D^5$

Where

$\Delta P_{sq} = (P_1^2 - P_2^2)$ for pipe segment.

P1, P2 = Upstream and downstream pressures of pipe segment, psia.

C = A constant

L = pipe segment length

D = pipe segment inside diameter

Therefore for the equivalent length calculations, we can state that for the second segment

$Le_2=L_2(D_1/D_2)^5$

And for the third pipe segment the equivalent length is

$Le_3=L_3(D_1/D_3)^5$

Therefore the total equivalent length Le for all pipe segments in terms of diameter D1 can be stated as

$Le=L_1+ L_2(D_1/D_2)^5+ L_3(D_1/D_3)^5+\ldots\ldots$

We are thus able to reduce the series pipe system to one of fixed diameter of an equivalent length. The analysis then would be easy since all pipe sizes will be the same. However, if the flow rates are different in each section, there is really no benefit in calculating the equivalent length, since we have to consider each segment separately and apply the General Flow equation for each flow rate. Therefore the equivalent length approach is useful only if the flow rate is the same throughout the series piping system. Pipes may also be connected in parallel .This is also called a looped system. We will next discuss how the pressures and flow rates are calculated in parallel piping systems. we have a pipe segment AB connected to two other pipes (BCE and BDE) in parallel, forming a loop. The two pipes rejoin at E to form a single pipe segment EF. We can replace the two pipe segments BCE and BDE by one pipe segment of some length Le and diameter De. This will be based on the same pressure drop through the equivalent piece of pipe as the individual pipes BCE and BDE. The flow rate Q through AB is split into two flows Q1 and Q2 as shown in the figure, such that Q1 + Q2 = Q. Since B and E are the common junctions for each of the parallel pipes, there is a common pressure drop ΔP for each pipe BCE or BDE. Therefore the flow rate Q1 through pipe BCE results in pressure drop ΔP just as the flow rate Q2 through pipe BDE results in the same pressure drop ΔP. The equivalent pipe of length Le and diameter De must also have the same drop ΔP at the total flow Q, in order to completely replace the two pipe loops. Using this principle, and noting the pressure versus diameter relationship from the General Flow equation, we can calculate the equivalent diameter De based on setting Le equal to the length of one of the loops

BCE or BDE. Another approach to solving the flows and pressures in a looped system is to calculate the flows Q1 and Q2 based on the fact that the flows should total Q and the fact that there is a common pressure drop ΔP across the two parallel segments. Using the General Flow equation, for common ΔP, we can state that

$L_1Q_1^2/D_1^5=L_2Q_2^2/D_2^5$

Where L1 and L2 are the two pipe segment lengths for BCE and BDE and D1 and D2 are the corresponding inside diameters. Simplifying the preceding equation, we get.

$[Q_1/Q_2]=(L_2/L_1)^{0.5}(D_1/D_2)^{2.5}$

Also

$Q=Q_1+Q_2$

Using the two preceding equations, we can solve for the two flows Q1 and Q2. Once we know these flow rates, the pressure drop in each of the pipe loops BCE or BDE can be calculated.

Looping a gas pipeline:

Looping a gas pipeline effectively increases the pipe diameter, and hence results in increased throughput capability. This method of increasing pipeline capacity by looping involves initial capital investment but no increased HP such as that when we install a compressor. Thus we can compare the cost of looping a pipeline with installing additional compressor stations.

Compressor Stations and HP

Compressor stations provide the pressure required to transport the gas in a pipeline from one location to another. Suppose that a 20 mile long pipeline requires 1000 psig pressure at the pipe inlet A to deliver the gas at 100 MMSCFD flow rate to the terminus B at 900 psig. If the gas at A is at 800 psig pressure, it needs to be compressed to 1000 psig using a compressor located at A. The compressor is said to provide a compression ratio of

$(1000+14.7)/(800+14.7)=1.25$ Note that the pressure must be converted to pressures and hence the reason for adding 14.7, the base pressure, to the given pressures. We say that the compressor suction pressure is 814.7 psia and the discharge pressure is 1014.7 psia. Suppose the gas inlet temperature on the compressor suction side is 80 F. Because of the compression process, the gas temperature at the compressor discharge will increase, just like the discharge pressure. If the compression process is adiabatic or isentropic, pressure versus volume will obey the adiabatic compression equation as follows

PV^{γ}=constant

Where γ is the ratio of the specific heats (Cp/Cv) of the gas. This ratio is approximately 1.29 for natural gas.Using the above equation in conjunction with the ideal gas equation, we can write a relationship between the pressure P and the temperature T for the compression process, as follows

$P^{(1-\gamma/\gamma)}T$=constant

If the suction conditions are represented by the subscript 1 and the discharge conditions by the subscript 2, the discharge temperature of the compressed gas can be calculated as follows

$$(T_2/T_1)=[(P_2/P_1)]^{(\gamma-1/\gamma)}$$

Where all temperatures are in ^{O}R and the pressures are in psia.

Taking into account the compressibility of the gas, the temperature ratio above becomes

$$(T_2/T_1)=[(P_2/P_1)]^{(\gamma-1/\gamma)}(Z_1/Z_2)$$

Where Z1 and Z2 are gas compressibility factors at suction and discharge conditions, respectively. When the compression process is polytropic, we use the polytropic coefficient n instead of g and the temperature ratio then becomes

$$(T_2/T_1)=[(P_2/P_1)]^{(\eta-1/\eta)}(Z_1/Z_2)$$

Horsepower required

The compressors compress the natural gas and raise its pressure (and its temperature) to the level required to ensure that the gas will be transported from point A to point B, such that the required outlet pressure can be maintained. The higher the outlet pressure at B, the higher will be the pressure required at A. This will cause the compressors to work harder. The energy input to the gas by the compressors will depend upon the compression ratio and gas flow rate, among other factors. From the energy input to the gas, we can calculate the horsepower (HP) needed. The following equation may be used to calculate the compressor HP.

$$\mathbf{HP=0.0857(\gamma/\gamma-1)\,QT_1\,(Z_1+Z_2)/2(1/\eta_a)[(P_2/P_1)^{(\gamma-1/\gamma)}-1]}$$

Where

HP = compression horsepower

γ = Cp/Cv the ratio of specific heats of gas

Q = gas flow rate, MMSCFD

T_1 = suction temperature of gas, ^{O}R

P_1 =suction pressure of gas, psia

P_2 = discharge pressure of gas, psia

Z_1 = compressibility of gas at suction conditions, dimensionless

Z_2 = compressibility of gas at discharge conditions, dimensionless

η_a = compressor adiabatic (isentropic) efficiency, decimal value

In SI units, the compressor Power required is as follows

$Power=4.0639(\gamma/\gamma-1)\ QT_1\ (Z_1+Z_2)/2(1/\eta_a)[(P_2/P_1)^{(\gamma-1/\gamma)}-1]$

Where

Power = compression Power, kW

Q = gas flow rate, Mm^3/day

T_1 = suction temperature of gas, K

P_1 = suction pressure of gas, kPa

P_2 = discharge pressure of gas, kPa

Other symbols are the same as defined previously. The adiabatic efficiency, also called the isentropic efficiency, is approximately 0.75 to 0.85. Taking into account a mechanical efficiency η_m of the compressor driver, the Brake Horsepower (BHP) required may be calculated as follows

$BHP=HP/\eta_m$

The mechanical efficiency ηm of the driver generally varies from 0.95 to 0.98. By multiplying the two efficiencies, we get the overall efficiency η_o as follows

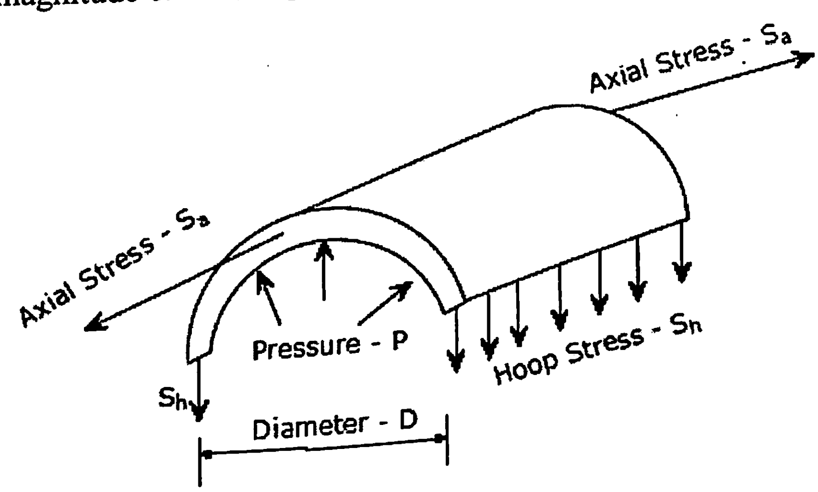
$\eta_o=\eta_a*\eta_m$

The adiabatic efficiency can be calculated, knowing the actual discharge temperature of the gas, suction and discharge pressures and the compressibility factors, using the following equation.

$\eta_a=(T_1/T_2-T_1)[(Z_1/Z_2)(P_2/P_1)^{(\gamma-1/\gamma)}-1]$

Strength of Pipe

Using the flow equations, we calculated the minimum pressure required to transport gas at a certain flow rate and temperature from one point to another. The pipe used for transportation of gas should be able to withstand the necessary internal pressure. The internal pressure in a pipe is limited to what the pipe material and wall thickness can withstand at a certain temperature. As the pipe pressure is increased, the stress in the pipe material increases. Ultimately, at some internal pressure the pipe will rupture. Therefore for each pipe size and wall thickness, depending upon the pipe material, there is a safe internal pressure beyond which it is not advisable to operate the pipeline. This is known as the maximum allowable operating pressure (MAOP), sometimes shortened to maximum operating pressure (MOP). There are two stresses developed in a pipe wall due to internal pressure. The larger of the two is called the hoop stress and acts in the circumferential direction. The second is the axial or longitudinal stress that acts along the axial direction. The axial stress is one-half the magnitude of the hoop stress.



Pipe stress due to internal pressure

The allowable internal pressure can be easily calculated using the Barlow.s equation as follows.

S_h=PD/2t

Where

S_h = allowable hoop stress in pipe, psig

P = allowable internal pressure, psig

D = pipe outside diameter, in.

t = pipe wall thickness, in.

Even though the Barlow.s equation is for calculating the hoop stress in the pipe for a given internal pressure, we can easily re-arrange the equation to solve for the pressure P.

$P=2tS_h/D$

The longitudinal stress, Sa can be calculated from a similar equation as follows

$\mathbf{S_a=PD/4t}$

It must be noted that unlike the General Flow equation or other flow equations, the diameter used here is the outside diameter, not the inside diameter. In practice, to calculate the internal design pressure for a gas pipeline, we modify the Barlow.s equation slightly by introducing some factors that depend upon the pipeline manufacturing method, operating temperature and the class location of the pipeline. The modified equation is as follows.

P=2tSEFET/D

where

P = internal design pressure, psig

D = outside diameter of pipe, in.

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 may be as low as 0.4 depending upon class location and type of construction.

T = temperature deration factor = 1.00 for temperatures below 250OF

For further details on the above internal design pressure equation, refer to the DOT 49 CFR part 192 or ASME B31.8 standard The design factor F depends upon the population density and dwellings in the vicinity of the pipeline. Class locations 1 through 4 are defined by DOT based on the population density.Accordingly the values for F are as shown in Table

Table: Design factor

Class location	Design factor,F
1	.72
2	.60
3	.50
4	.40

Class location Design factor, F

The following definitions for Class locations are taken from the DOT 49 CFR Part 192 code: The class location unit (CLU) is defined as an area that extends 220 yards on either side of the centerline of a one mile section of pipe. Offshore gas pipelines are known as Class 1 locations. For onshore pipelines, any class location unit with 10 or fewer buildings intended for human occupancy is termed Class 1. Class 2 locations are defined as those areas with more than 10 but less than 46 buildings intended for human occupancy. Class 3 locations are defined for areas that have 46 or more buildings intended for human occupancy or an area where the pipeline is within 100 yards of a building or a layground, recreation area, outdoor theatre or other place of public assembly that is occupied by 20 or more people on at least five days a week for ten weeks in any 12 month period. The days and weeks needed not be consecutive. Class 4 locations are defined for areas with multi-story buildings, such as four or more stories above ground. The temperature deration factor T, is equal to 1.00 as long as the temperature of the gas in the pipe does not exceed 250OF. At higher temperatures a value of T less than 1.00 is used as indicated in the table

DESIGN AND ENGINEERING FOR POLYETHYLENE PIPING

Pressure design

A pipeline is defined as "a line of pipes for conveying water, gas, oil, etc." These lines may operate at a positive pressure, negative pressure or atmospheric pressure in the performance of their design parameters. A piping system is acted upon by a multitude of design considerations: corrosion, ground entrained water, stray electromagnetic currents, external loads by soil, water table, and wave and/or current action, thermal changes and the effects of ultraviolet light.

Internal pressure

Polyethylene Pipe for industrial-municipal-mining applications is manufactured to specific dimensions as required in applicable American Society for Testing and Materials (ASTM) standards. Piping outside diameters may meet the IPS, DIPS or Metric systems. Wall thickness is based on the Dimension Ratio (DR) system, a specific ratio of the nominal outside diameter to the minimum specified wall thickness. Use of the DR number in the ISO equation, recognized as an equation depicting the relationship of pipe dimensions, both wall and OD, internal pressure carrying capabilities and tensile stress, in conjunction with a suitable design factor (DF) will give the design engineer confidence the pipe will not fail prematurely due to internal pressurization. To move a material along a pipeline, forces of gravity, or internal pressure, differentials are required. For atmospheric systems (gravity flow), gravitational forces provide the impetus for movement of heavier-than-air mass. To move the same against gravity (pressure flow) additive internal forces are generated, which must be recognized in the design stage in order to provide desired operational life. In some cases a gravity flow system must be treated comparable to the design consideration of a pressure flow system. Calculations for determining the internal pressure rating of Polyethylene Pipes are based on the ISO equation, which is:

$$P = \frac{2HDB*DF}{(DR-1)}$$

Where P = Internal pressure, psi

HDB = Hydrostatic Design Basis, (1600 psi for PE3408)

DR = Pipe dimension ratio (*D/t*)

D = Outside diameter, inches

t = Minimum wall thickness, inches

DF = Design factor (0.5 for water @ 73°F (23°C))

Use of additional factors will provide for a more defined performance characteristic for systems with higher operation temperatures, shorter operational time and system fluid other than water. These additional factors are defined as the following:

- F1 - Factor used where the operational life is less than 50 years.
- F2 - Temperature correction factor for service other than 73oF (23oC).
- F3 - Environmental factor utilized to compensate for the effect of substances other than water.

With the implementation of additional factors, the ISO equation2 now becomes:

$$P = \frac{2HDB*DF*F_1*F2*F3}{(DR-1)}$$

Where P = Internal pressure, psi

HDB = Hydrostatic Design Basis, (1600 psi for PE3408)

DR = Pipe dimension ratio (*D/t*)

D = Outside diameter, inches

t = Minimum wall thickness, inches

DF = Design factor (0.5 for water @ 73°F (23°C))

F_1 = Operational life factor (Figure A-1)

F_2 = Temperature correction factor (Figure A-2)

F_3 = Environmental service factor (Table A-5)

Environmental service factor

Substance	Service factor, F_3
Crude oil	0.50
Wet natural gas	0.50
Federally regulated dry natural gas	0.64

It should be noted the maximum recommended service temperatures, under continuous pressure service, for Polyethylene Pipe is 150°F (66°C). However, for a non-pressure application, temperatures as high as 180°F (82°C) can be considered. In such cases, consult your Polyethylene Pipe supplier for additional design assistance.

Critical Buckling

In the design of a polyethylene piping system, external fluid pressure and/or internal vacuum may be treated comparably. In a non-supported application collapse of the pipe may be calculated from the equation1:

$$P = (2E/1-v^2)\,(t/(D-t))^3 * SF$$

Where P = Critical buckling pressure, psi

E = Modulus of elasticity, psi

D = Outside diameter, inches

t = Wall thickness, inches

v = Poisson's ratio, dimensionless

SF = Safety Factor

Vacuum or external pressure system

A piping system can be subjected to a positive external pressure or vacuum as opposed to the more usual positive internal pressure situation. In most cases this occurs by design, as in a water suction line, but it can also occur in an unexpected manner. For instance, a system that has a high point in the down slope side of the pipeline can result in a flow velocity greater than the velocity on the uphill side. In other applications, there may be both vacuum and external pressure applied to the system. This condition can occur if a pump suction line is buried with significant external load above the top of the pipe. Both of these factors are additive and should be considered in the design of the piping system. In either situation, the effects of external pressure or vacuum conditions must be considered in the design. Pipe buckling can occur in extreme cases, but can be prevented by correctly designing the system. In the event that buckling should occur, it is generally not a catastrophic failure. Buckling occurs as a gradual deflection of the pipe to an out-of-round condition that will progressively worsen to the point of becoming totally flat. Since buckling occurs without cracking or splitting the pipe wall, the pipe can be restored to its original round condition. This can be accomplished by applying an internal pressure for a short period of time. The cause of the buckling should be identified and corrected. In some situations, vacuums and/or external loads occur for a relatively short duration. By estimating the duration of the load and applying the time correction factors, the designer may match the pipe DR (Dimension Ratio) to the particular application. Thinner wall pipe is usually capable of handling short duration loads.

Time correction factor

Time	Time correction factor
Day	2.01
Month	1.40
Year	1.20
2 years	1.12
5 years	1.07
10 years	1.04
50 years	1.00

Pressure drop

A fluid is defined as "a substance which when in static equilibrium cannot sustain tangential or shear forces." Three types of forces that may act on a body are shear, tensile and compressive. Shear and tensile forces on fluids are not addressed in this Guide. Compressive forces, which result in pressure, are considered due to the importance in the design of piping system capabilities. Volumetric flow, Q, can be determined from the continuity equation A • V. Modified for flow in gallons per minute, this is:

$$Q=2.448*V*d^2$$

Where Q = Volumetric flow, gpm

V = Velocity, ft/sec

d = Inside diameter, inches

Frictional pressure loss

The total pressure drop in a system is the sum of pressure losses due to friction, fittings and elevation changes. Pressure loss due to friction in the pipe is calculated using the Hazen-Williams formula1. This applies to systems pumping water and fluids of like viscosities. The Hazen-Williams formula is:

$$\Delta Pf = \frac{453 * Q^{1.85}}{C^{1.85} * d^{4.86}}$$

ΔPf=Pressure loss due to friction, psi per 100 feet

C = Hazen-Williams Flow Factor Coefficient*

Q = Volumetric flow rate, gpm

d = Inside diameter, inches

The Hazen-Williams formula can be used to calculate any one of the following variables: volumetric flow rate (Q), velocity (V), inside pipe diameter (d) or frictional pressure loss (ΔPf).

Elevation pressure loss/gain

The Hazen-Williams formula is used to establish only the pressure losses due to friction in the pipe. If there is a change in elevation, it is necessary to calculate the change in pressure due to elevation changes. The change in pressure may be either a positive change (downhill) or negative (uphill). In a line with an elevation change without a change in pipe diameter, the pressure loss can be calculated as follows:

$$\Delta P_e = \rho(h_2 - h_1)/144$$

ΔPe=Change in pressure due to elevation change, psi

h_2 = High point elevation, feet

h_1 = Low point elevation, feet

ρ = Density of fluid, lbs/ft^3

Pressure loss in fittings

Any calculation of the pressure drop in a piping system cannot be made accurately without consideration of the loss in pressure due to the presence of fittings in the system.

The fluid flow, when encountering a fitting, is subjected to change in direction and the resultant degree of initiation of turbulence, or at least an interruption in the desirable steady flow condition which exists in the straight run of pipe, is an increase in head loss or pumping pressure. Due to the geometry and variance in flow conditions through the fitting, the exact pressure loss cannot be calculated in any practical sense. The pressure loss is calculated by expressing the fitting as an equivalent length of pipe expected to produce the same pressure loss. The values shown in Table have been derived to some extent by experimentation, but are to a greater extent the result of a general industry consensus (PPI Technical Report #14).

Pressure drop in fitting

TYPE OF FITTING	EQUIVALENT LENGTH OF PIPE*, ft
90° Elbow, molded	16D
90° Elbow, mitered	**24D**
60° Elbow	16D
45° Elbow, molded	16D
45° Elbow, mitered	12D
Running Tee	**20D**
Branch Tee	60D
Gate Valve, full open	**8D**
Butterfly Valve 3"-14" (76-356 mm)	40D
114" (356 mm) and larger	**30D**

Total pressure loss

The total pressure required to maintain the flow rate can be calculated by summing pressure losses calculated using the Hazen-Williams for frictional pressure loss in the pipe, for elevation changes and for fitting pressure losses.

$\Delta P_t = \Delta P_f + \Delta P_e + \Delta P_{fitting}$

Effect of temperature

Thermal conductivity

The thermal conductivity of a material is expressed as the rate at which heat is transferred by conduction through a unit cross-sectional area of a material when a temperature gradient exists perpendicular to the area. The units generally used for expressing this value are BTU - in per hour, per square foot, per °F. Polyethylene Pipe, like many thermoplastic materials, has a low coefficient of thermal conductivity. Polyethylene Pipe has an "R" value of 0.3 BTU/in.Poly pipes has a thermal conductivity 2.7BTU - in/ft2/hr/°F

Due to its low value of thermal conductivity, Polyethylene Pipe is a fairly good insulator.

Thermal expansion and contraction

As with all materials, Polyethylene Pipe is subject to expansion/contraction due to changes in temperatures. It is important to consider this property when designing a piping system. The coefficient of thermal expansion/contraction, α, for Polyethylene Pipe is approximately:

1.0×10^{-4} inch per inch per °F ($1.75 \cdot 10^{-4}$ mm/mm/°C)

The amount of expansion/contraction can be calculated by the following formula

$\Delta l = l * \alpha * (T_2 - T_1)$

Δl= Change in length, inches

α= Coefficient of thermal expansion, 1.0×10^{-4} in/in/°F

l= Initial pipe length, inches

T_1= Initial temperature, °F

T_2= Final temperature, °F

Temperature gradients produced through a change in fluid or ambient temperature will create a gradient across the pipe wall. The midwall temperature of the pipe will reflect neither the internal nor the external condition. The effect of the temperature gradient occurs more gradually due to the low thermal conductivity of Polyethylene

Pipe. Polyethylene, which is viscoelastic, undergoes a molecular rearrangement due to the temperature gradient. This restructure dissipates a large portion of the temperature-induced stresses. This behavior is referred to as stress relaxation and is considered beneficial to a pipe system that may experience temperature fluctuations. In certain circumstances, it is necessary to be able to calculate the degree of stress imparted to the pipe due to an environmental or process change. In a system where the pipe is restrained at both ends, a compressive stress is created. Thermally induced forces for polyethylene can be calculated from the following equation

$$F=\sigma*A$$

$$\sigma=E*\alpha*\Delta T$$

Where F = Force, lbs

σ = Stress, psi

A = Pipe wall cross-sectional area, in^2

E = Modulus of elasticity, psi

ΔT = Temperature change, °F

α = Coefficient of thermal expansion, 1.0×10^{-4} in/in/°F

The modulus of elasticity, *E*, for polyethylene is a function of time and temperature. A buried system, by virtue of the continuous contact of the backfill material and the reduction in temperature fluctuations, needs no further special considerations. Pipe to soil friction will restrain the buried pipe in place. Above ground pipeline, however, does not have restraints and the thermal expansion/contraction must be allowed for in the design. The design must incorporate necessary restraints to accommodate adverse effects due to thermal expansion/contraction. This may be accomplished by one of the following methods:

1. The pipeline design contains no restraints allowing the pipeline to move freely.
2. Anchored closely and tightly so that unit changes occur in the elasticity of the material rather than transferring all the forces to one point.
3. Anchoring ends and changes in direction with addition of expansion loops at or near the mid-point of a run. For long continuous pipelines laid above ground, the amount of expansion/contraction can be significant as a result of normal variances in

temperature from day to night. The pipeline should be installed to minimize direct sunlight. As the pipe temperature increases, the movement is generally from side to side. Although this expansion cannot be prevented, placing anchor points at intervals along the line can control it. The formula shown below is used to estimate the distance between the anchor points.

$$L=\sqrt{2*\Delta y^2/\alpha*\Delta T}$$

Where L = Distance between anchor points, inches

Δy = Lateral deflection, inches

α = Coefficient of thermal expansion, 1.0 x 10-4 in/in/°F

ΔT = Temperature change, °F

Chemical resistance

Thermoplastic materials generally are resistant to attack from many chemicals, which make them suitable for use in many process applications. The suitability for use in a particular process piping application is a function of:

1. Material

A. The specific plastic material: ABS, CPVC, PP, PVC, PE, PB, PVDF, PEX, PA11, PK.

B. The specific plastic material and its physical properties as identified by its cell classification according to the appropriate ASTM material specification.

2. Product and Joint System

A. Piping product dimensions, construction, and composition (layers, fillers, etc.).

B. Joining system. Heat fusion and solvent cementing do not introduce different materials into the system. Mechanical joints can introduce gaskets such as elastomers, or other thermoplastic or non-thermoplastic materials used as mechanical fitting components.

C. Other components and appurtenances in the piping system.

3. Use Conditions - Internal and External

A. Chemical or mixtures of chemicals, and their concentrations.

B. Operating temperature — maximum, minimum, and cyclical variations.

C. Operating pressure or applied stress — maximum, minimum and cyclical variations.

D. Life-cycle information — such as material cost, installation cost, desired service life, maintenance, repair and replacement costs, etc.

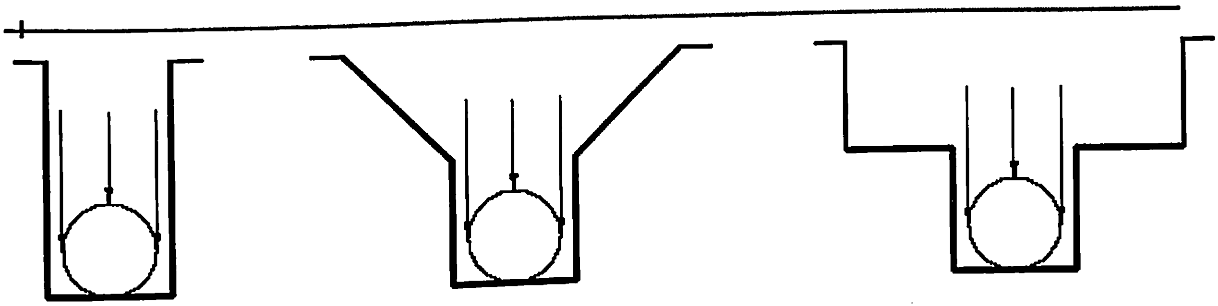
Polyethylene does not rust, rot, pit or corrode as a result of chemical, electrolytic or galvanic action. Chemicals that pose potentially serious problems for polyethylene are strong oxidizing agents or certain hydrocarbons. These chemicals may reduce the pressure rating for the pipe or be unsuitable for transport. Either can be a function of service temperature or chemical concentration. Continuous exposure to hydrocarbons can lead to permeation through the material or elastomeric gaskets used at joints. The degree of permeation is a function of pressure, temperature, the nature of the hydrocarbons and the polymer structure of the piping material. The chemical environment may also be of concern where the purity of the fluid within the pipe must be maintained. Hydrocarbon permeation may affect pressure ratings and hinder future connections. For more detailed information on chemical resistance, The Plastics Pipe Institute (PPI) has prepared a technical report, TR-19 "Thermoplastic Piping for the Transport of Chemicals", as a service to the industry.

Underground installations

The installation of pipes constructed from conventional materials generally requires the joining and laying of the pipe piece by piece in the trench. This will necessitate the trench being of such width it will accommodate one or two installers carrying out the installation with their tools and enough room for them to work. Due to the flexibility and resilience of Polyethylene Pipe, it can be pre-assembled above ground. This not only allows for ample working area, but also provides an opportunity for a thorough inspection of butt-fused joints prior to burial. The trench dimensions are very narrow in comparison to widths used for traditional materials and can be constructed by any one of a number of types of machinery. As with any operation, a large contribution to the success of the job can be made by adequate planning. In many instances it may not be possible to avoid some difficult circumstances that may result in extended installation time. This is particularly true for installation of steel pipe. As an example, in very uneven or hilly terrain, the lightweight of Polyethylene Pipe would be a definite advantage allowing the pipe to be assembled in a more suitable area and then carried or pulled to the job site in longer sections for installation into the trench.

Trenching

As has been previously stated, the trench width should be as narrow as possible. The maximum width should be no more than the diameter of the pipe plus two feet. If possible, the trench can be made as narrow as the pipe itself plus one foot. The importance of the trench width is not so much the cost of the trenching, which is of course is a factor, but more the working efficiency of the finished system. Trenches should be as straight-sided as is practical and flat-bottomed to facilitate the proper consolidation and packing of the filling materials in ground that is coarse grain with many large rocks or protrusions, it may be necessary to over-cut and lays a bed of fine gravel in the base of the trench to allow for stress-free bedding of the pipe. It is not recommended that ordinary sand be used for this purpose, as it is possible to be washed away, leaving the pipe unsupported. The formation of the base of the trench is of great importance. It should be as flat and level as possible or graded to the correct slope where specified. An installation where this is significant would be a gravity flow system. Grading can be accomplished by the use of gravel or finely crushed stone. If the condition of the soil is poor due to standing water in a high water table area, it may be required to establish more stabilization to the base of the trench after having drained the area first. In rocky terrain, the installation should be made such that the pipe is not laid in direct contact with the hard surface. The trench should be cut to a depth of six inches to one foot below the required level and then brought back to grade with soil or fine gravel. Ditches in soil that is loose may require a slope to the top edges of the trench to prevent the collapsing of the sides and filling of the trench In some cases it may be preferable to excavate a trench having a wider top section cut straight down to the intended top position of the pipe. In either case, the backfilling of the trench will not result in higher earth load on the pipe.



Pipe curvature

In the building of long runs of pipe it is often necessary to negotiate bends. The natural flexibility of polyethylene will allow runs of pipe to be pulled around fairly tight radii. Trenches can therefore be excavated to accommodate bends, which are within the capabilities of the pipe. The degree to which a pipe can be cold bent around a radius is dependent upon the diameter to wall thickness ratio, D/t, or the DR ratio. The table below lists minimum recommended bending radius for any size of pipe.

Minimum bending radius

DR ratio	Minimum radius factor, K_{mrf}
32.5	40
26	36
21	32
17	26
15.5	24
11 or lower	20

By multiplying the minimum radius factor, K_{mrf}, by the actual outside diameter, D, of the pipe being installed you can determine the minimum bending radius, r_m, for the pipe being installed. Use the following formula:

$r_m = D\ K_{mrf}$

Pipe laying

If the pipe is to be joined piece by piece at the trench site prior to being lowered into the trench, the transport of the pipe lengths to the work site is of little consideration. In those situations where on-site conditions require that several lengths be butt fused in a remote position from the trench, then there are some other considerations to be taken into account. The effect of pulling a number of joined lengths of pipe across the ground by gripping one end results in the generation of a tensile load in the pipe. The size of pipe will determine the means used to lay the pipe in the trench. For sizes up to 6" (152mm) the pipe can be manhandled fairly readily and laid in the desired position. Single joints of up to 10" (254mm) in diameter can also be laid in the trench manually if they are to be butt fused afterwards. Sizes above 10" (254mm) will require moving and positioning with the use of equipment such as pry bars or perhaps light construction equipment. Larger diameters will need to be placed into the trench with rubber-tired lifting equipment or lifted into position with a cherry picker. In the pipe-laying phase, some accommodations can be made to allow for thermal expansion/contraction. Placement of the pipe in the trench will normally provide for some "snaking". Even straight lengths have a tendency to wave from side to side. Pipe should not be pulled to straighten. Leave the side-to-side path and cut to length for the tie-in. Whenever possible, a final tie-in should be performed after an overnight stay in the trench to allow the pipe to cool down to near normal soil conditions. Connections made to valves, rigid pipes or manholes should be supported. An alternative for some of these situations is the construction of solidified, well tamped bedding below the joint. A concrete pad should be installed under the heavy member to resist settlement and preclude the polyethylene pipe supporting the component. The need for support of this kind is especially critical in unstable soil conditions.

Pulling lengths

The following information may be used to estimate an allowable pulling length for nominal polyethylene pipe applications. The equations shown below result in a pulling length that is based on short-term tensile strength. Use of pull forces greater than calculated may result in pipe damage. Polyethylene Pipe recommends a load cell be used to monitor the applied force. This information is also available in **PolyPipe** Info Brief #6.

The Maximum Pulling Force (*MPF*) in pounds that may be applied to the pipe can be calculated by the following equation

$MPF=f_y f_t T\pi D^2(1/DR-1/DR^2)$

Where MPF = Maximum pulling force, lbs (ATL and MPF are synonymous)

f_y = Tensile yield design (safety) factor, 0.40

f_t = Time under tension design (safety) factor, 0.95*

*The value of 0.95 is adequate for pulls up to 12 hours.

T = Tensile yield strength, psi (See Table F-2 below)

D = Outside diameter of pipe, inches

DR = Dimension ratio (dimensionless)

Once the Maximum Pulling Force is determined, one can calculate the maximum pulling length, MPL, of the HDPE material for the type of installation. Installations can be divided into four categories:

1. On level soil.
2. Through an existing conduit that is empty.
3. Through an existing conduit where the HDPE and the existing conduit are both full of water.
4. Through a bored hole using the horizontal drilling technique.

1. Level soil

MPL=MPF/f*W

Where MPL = Maximum pulling length, feet

MPF = Maximum pulling force, lbs (Equation (34))

f = Coefficient of friction on smooth sandy soil, 0.7 (dimensionless)

W = Weight of pipe, lbs/ft

2. Slip lining empty

For determining the Maximum Pulling Length of HDPE pipe through an existing conduit that is straight, level, and empty, **PolyPipe** recommends using the same procedure for determining the pulling length on a relatively flat surface aboveground.

3. Slip lining wet

For slip lining conduits where the HDPE pipe and existing conduit are both full of water, the maximum allowable pulling length can be estimated by using a coefficient of friction of 0.1.

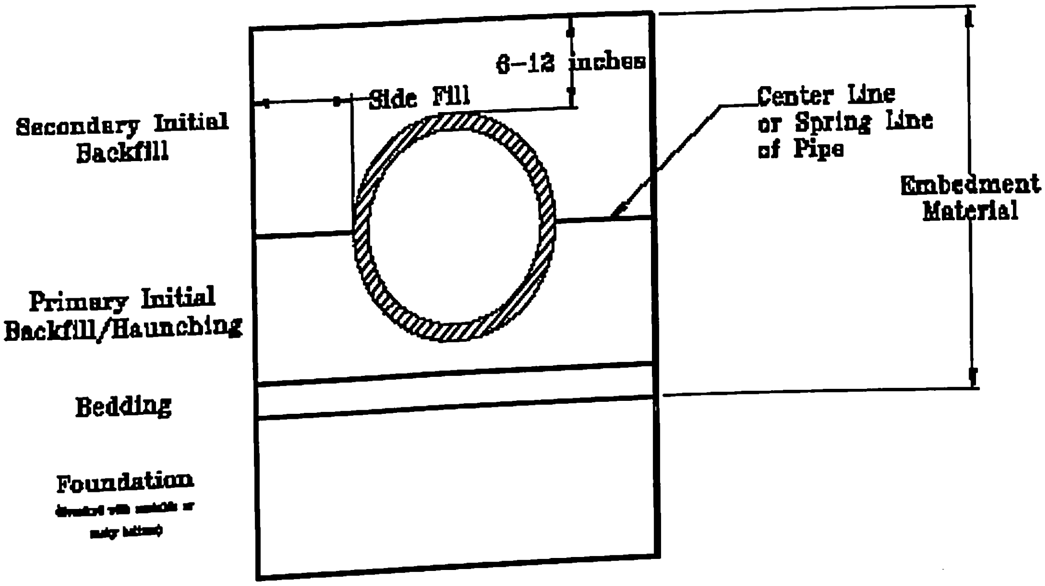
4. Bored holes

Estimating the maximum pulling length for holes as provided by the horizontal directional drilling (HDD) technique is more complex. Before the pipe is pulled into position, a survey of the area should be made to ensure that surface conditions will not cause the pipe to suffer any damage in the form of gouges or deep scarring. A system of rollers constructed from short lengths of pipe can be used to reduce the pulling force required and to keep the pipe off the ground. A pulling head is used to attach to the leading end of the pipe. This can take the form of a simple rubber pad with steel cable wrapped around the pipe or can be more sophisticated in the form of a pulling head. The pipe should never be pulled by attaching to the flange. If flange assemblies are installed, these must be elevated to avoid dragging, both in front and behind.

Backfilling

Not only is backfill utilized to fill the trench, but it also serves a very specific design function. The main purpose of the backfill material is to provide adequate support and protection for the pipe. By ensuring the backfill is solid and continuous, damage can be prevented from surface traffic, falling rock or lifting due to the trench filling with water.The soil used for backfill can be the original soil excavated from the trench or foreign soil that has been transported to the site. Whatever soil is used, it is recommended that the haunching and the initial backfill material be free of any rocks, hard lumps, frozen material or clay. It should also be sufficiently friable to readily flow into the haunches of the pipe. It is important that the initial backfill be consolidated to ensure continuous contact and support of the pipe . This can be achieved by using fill material that is of fine sand or clay based materials. These materials should only be used in dry areas where it is unlikely to be washed out.

Trench configuration and terminology

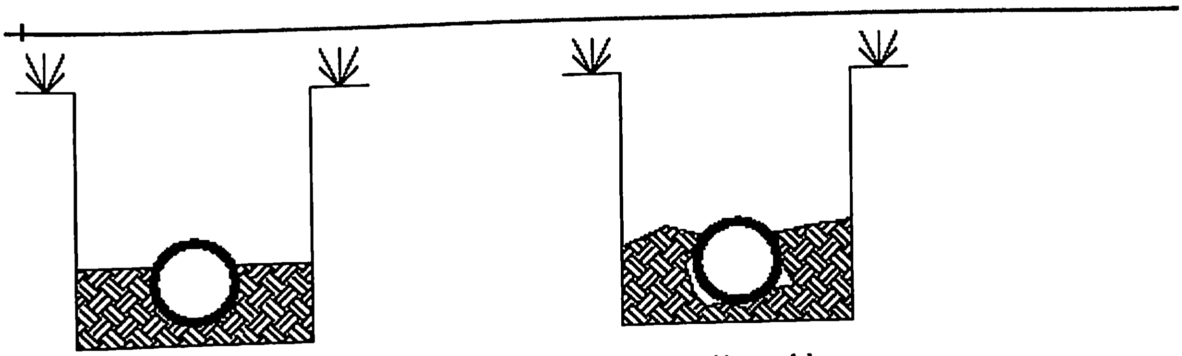


Foundation and Bedding

Use of foundation material may only be required where the base of the trench is required to be brought up to the pipeline level, or when encountering an unstable or rocky trench bottom. As noted earlier, this can be soil or fine gravel.

Haunching

The haunching provides stability to the pipe from the sides and from underneath. The best material is crushed stone, fine gravel or coarse sand, and should be tampered into position with a narrow tamping tool to ensure that the material is well consolidated under the sides of the pipe as well as around it. The haunching material must be poured into the trench gradually so that the tamping operation can be carried out simultaneously with the placement. Applying too much of the material at one time may cause a bridging effect which will result in a cavity being formed below the pipe, which can later result in a loss of support for the pipe.



Correct Haunching   Incorrect Haunching

Initial Backfill

Materials include coarse sand, fine gravel or crushed stone. This section of the backfilling should be carried out the same as with the haunching. The material should be gradually added in 4-6 inch (102-152 mm) lifts and tamped simultaneously. The initial backfill should be brought up to a height of 6-12 inches (152-305 mm) above the top of the pipe, depending upon the size of the pipe.

Final Backfill

As previously mentioned, the final backfill can be the original excavated material or other convenient soil, provided it does not contain excessively large rocks or frozen lumps that may damage the pipe initially or later allow washing away and the loss of consolidation.In areas where a high water table exists, it is necessary to allow for the effect of buoyancy of the pipe and of the backfill material. The result of the fill material being saturated due to the water table will reduce the load imparted on the pipe. In these conditions, the conventional trench configuration will no longer be sufficient to overcome a tendency for the pipe to float. This situation can be addressed by designing for a certain amount of extra cover to ensure the pipe will remain in place. The required depth of cover can be calculated from the equation below:

$$H = \frac{\rho_w * \pi * (D^2 - d^2) - W_p}{48 * \rho_s * D}$$

Where H = Minimum backfill depth, feet

ρ_w = Density of water, lbs/ft^3

W_p = Weight of pipe, lbs/ft

ρ_s= Density of soil, lbs/ft3

D = Outside diameter, inches

d = Inside diameter, inches

Recommended testing procedure

Leak testing

The intent of leak testing is to find unacceptable faults in a piping system. If such faults exist, they may manifest themselves by leakage or rupture. Leakage tests may be performed if required in the Contract Specifications. Testing may be conducted in various ways. Internal pressure testing involves filling the test section with a nonflammable liquid or gas, then pressurizing the medium. Hydrostatic pressure testing with water is the preferred and recommended method. Other test procedures may involve paired internal or end plugs to pressure test individual joints or sections, or an initial service test. Joints may be exposed to allow inspection for leakage. Liquids such as water are preferred as the test medium because less energy is released if the test section fails catastrophically. During a pressure test, energy (internal pressure) is applied to stress the test section. If the test medium is a compressible gas, then the gas is compressed and absorbs energy while applying stress to the pipeline. If a catastrophic failure occurs, both the pipeline stress energy and the gas compression energy are suddenly released. However, with an incompressible liquid such as water as the test medium, the energy release is only the energy required to stress the pipeline.

Pressure testing precautions

The piping section under test and any closures in the test section should be restrained or otherwise restricted against sudden uncontrolled movement in the event of rupture. Expansion joints and expansion compensators should be temporarily restrained, isolated or removed during the pressure test. Testing may be conducted on the system, or in sections. The limiting test section size is determined by test equipment capability. If the pressurizing equipment is too small, it may not be possible to complete the test within allowable testing time limits. If so, higher capacity test equipment, or a smaller test section may be necessary. If possible, test medium and test section temperatures should be less than 100°F (38°C). At temperatures above

100°F (38°C), reduced test pressure is required. Before applying test pressure, time may be required for the test medium and the test section to temperature equalize. Contact the pipe manufacturer for technical assistance with elevated temperature pressure testing.

Test Pressure

Valves or other devices may limit test pressure, or lower pressure rated components. Such components may not be able to withstand the required test pressure, and should be either removed from, or isolated from the section being tested to avoid possible damage to, or failure of these devices. Isolated equipment should be vented.

- For continuous pressure systems where test pressure limiting components or devices have been isolated, or removed, or are not present in the test section, the maximum allowable test pressure is 1.5 times the system design pressure at the lowest elevation in the section under test.
- If the test pressure limiting device or component cannot be removed or isolated, then the limiting section or system test pressure is the maximum allowable test pressure for that device or component.
- For non-pressure, low pressure, or gravity flow systems, consult the piping manufacturer for the maximum allowable test pressure.

Test Duration

For any test pressure from 1.0 to 1.5 times the system design pressure, the total test time including initial pressurization, initial expansion, and time at test pressure, must not exceed eight (8) hours. If the pressure test is not completed due to leakage, equipment failure, etc., the test section should be de-pressurized, and allowed to "relax" for at least eight (8) hours before bringing the test section up to test pressure again.

Pre-Test Inspection

Test equipment and the pipeline should be examined before pressure is applied to ensure that connections are tight, necessary restraints are in-place and secure, and components that should be isolated or disconnected are isolated or disconnected. All low pressure filling lines and other items not subject to the test pressure should be disconnected or isolated.

Hydrostatic testing

Hydrostatic pressure testing is preferred and is strongly recommended. The preferred testing medium is clean water. The test section should be completely filled with the test medium, taking care to bleed off any trapped air. Venting at high points may be required to purge air pockets while the test section is filling. Venting may be provided by loosening flanges, or by using equipment vents. Re-tighten any loosened flanges before applying test pressure.

Over head or intermittently supported pipe lines

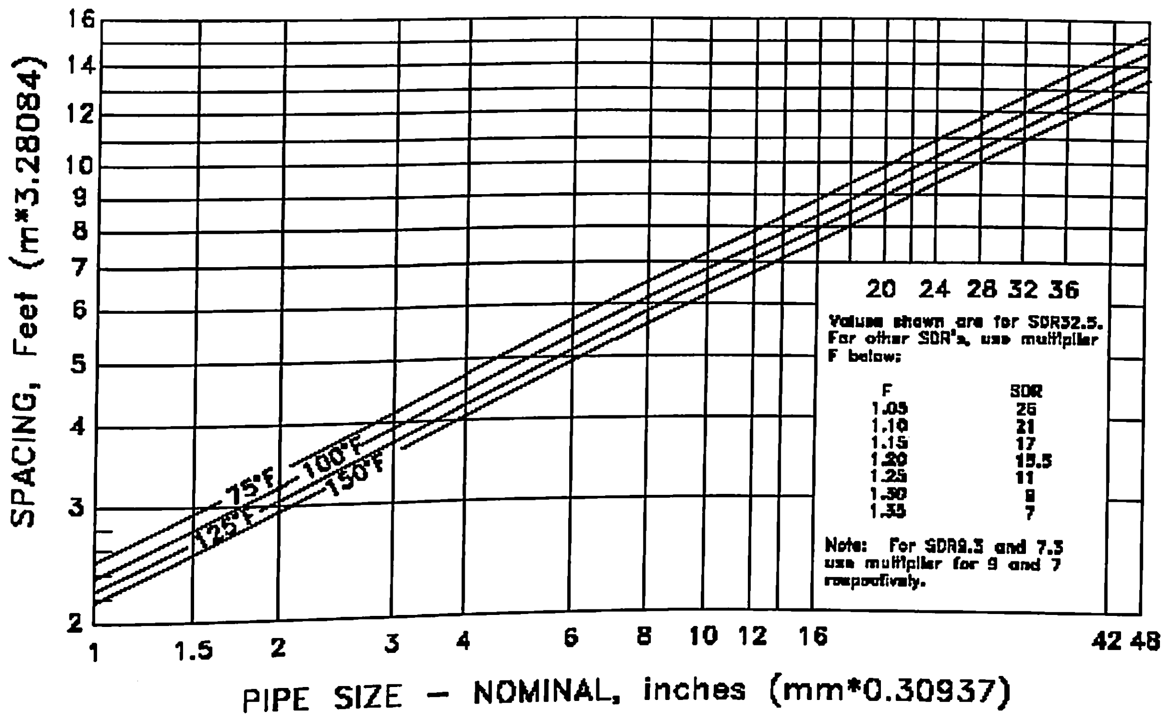
Items of consideration in the installation of intermittently supported pipelines are:

1. Supported spacing
2. Type of support
3. Temperature influence
4. Pipeline weight and sag
5. Installation

Sag

The amount of sag in mid-span depends upon the weight of the pipe per foot, including effluent. However, in situations where a dry gas is being carried, the indicated span can be doubled. When condensation occurs in the pipeline, the liquid accumulates in the sag, unless the pipe is sloped; therefore, accelerating the sag due to the increased weight. If less deflection is desired, new support spacing can be determined by multiplying the spacing by the following correction factors:

1. 0.67 for 0.05 inch (1.3 mm) deflection
2. 0.80 for 0.10 inch (2.5 mm) deflection
3. 0.88 for 0.15 inch (3.8 mm) deflection
4. 0.95 for 0.20 inch (5.1 mm) deflection



Temperature

An increase in temperature decreases the beam strength of the pipeline resulting in an increase in the amount of sag.

Note: A pipeline operating at temperatures above 150°F (65°C) should have continuous support.For this reason, the pipe temperature at the time of installation becomes very important and final tie-ins should be made as near as possible to or above the operating temperature. If a 100 ft. (30.5m) pipeline is installed and tied-in at 60°F (16°C) and operated at 120°F (49°C), as much as a 7 inch (178 mm) increase in length may occur that will manifest itself as additional sag.

Support

Polyethylene is a relatively soft material and requires rather wide, padded surfaces for supports. A pipeline full of water is approximately three (3) times the weight of an empty line or a line conveying gaseous materials. Support for lines flowing full of water should be at least as wide in the longitudinal pipeline direction as one-half the pipe outside diameter. The support should cradle the pipe for approximately 135 degrees, i.e., assuming the open pipe end to be the face of a clock; the support should be at least from 4:00 to 8:00. Suspended piping should have 180 degrees of support, and if held tightly in a clamp type device, the support would be 360 degrees. Where metal supports or bands are utilized, a resilient padding such as neoprene or rubber must be used to protect the pipe from damage by the supports.

Spacing

For determination on support spacing, the following formula11 can be used to estimate the distance between anchor or support points:

$$\Delta y = \frac{0.0651\pi[\rho_p(D^2-d^2)+\rho_f d^2]L^4}{E(D^4-d^4)}$$

Where Δy = Sag of pipe at the lowest point, feet

ρ_p = Density of pipe, lbs/ft^3 (0.955 for HDPE)

ρ_f= Fluid density, lbs/ft^3

E= Modulus of elasticity, lbs/in^2

L = Distance between supports, feet

D = Outside diameter, inches

d = Inside diameter, inches

Natural gas flow

Natural gas distribution piping shall be designed and installed in accordance with all applicable federal, state and local codes. Current law limits the design pressure rating to 125 psig for plastic pipe used in distribution systems or Class 3 or 4 locations. Please refer to the Code of Federal Regulations (CFR), Parts 186 – 199 for additional information. The inside surface of Polyethylene Pipe is extremely smooth and has a very low coefficient of friction. HDPE's flow resistance is considerably less than that of steel pipe. There is minimal drag on the pipe wall and due to polyethylene's exceptional resistance to corrosion there is little deterioration of the piping surface due to the presence of aggressive media, both inside and outside of the pipe. Polyethylene pipe will maintain these advantages for its entire service life, up to 50 years or more. Due to the physical properties of polyethylene and the extremely smooth bore surface, it would appear only natural to assume that polyethylene pipe would have significantly higher flow capacity. While this would be true in water service systems, where the flow is fully turbulent, it is not entirely true in gas service systems, where the flow is partially turbulent. The initial flow capacities for polyethylene and steel are similar; however, as the pipe ages, the steel pipe can begin to corrode. Once this happens, the flow capacity for the steel pipe begins to decrease dramatically. Therefore, for comparison purposes of performance over the service lives of the two pipes, polyethylene would provide for a longer life. Steel and polyethylene pipe have similar flow capacities. It has been found that flow formulas developed for sizing of steel pipe are applicable for sizing of polyethylene pipe. However, consideration must be given to differences in inside diameter.

Typical maximum flow rates experienced in 60 PSI natural gas distribution system

Nominal inside pipe diameter Inches	Maximum flow rates, Mcfh(thousand cubic feet per hour)
2	17.4
3	43.5
4	81.1
6	163
10	556

Any of the accepted gas flow equations used with steel pipe, such as Mueller, Pole, Weymouth, Spitzglass, or the IGT Distribution Equation, can be used for calculations of polyethylene pipe flow capacities. It should be noted that no direct formulas provide the proper modifier to account for the extremely low coefficient of friction, which is characteristic of polyethylene. The IGT Distribution Equation shown below, is thought to be representative of polyethylene for most distribution design situations.

$$Q = \left(0.6643 * \frac{T_b}{P_b}\right) \frac{[(P_1^2 - P_2^2)]^{5/9}}{TL} \frac{d^{8/3}}{(SG^{4/9} \mu^{1/9})}$$

Where Q = Volumetric flow rate, MSCFH

T_b Base temperature, °R (Rankine)

P_b = Base pressure, psia

P_1 = Upstream pressure, psia

P_2 =Down stream pressure,psia

L = Length of pipe section, feet

T = Average fluid temperature, ^{o}R (Rankine)

μ =Viscosity, lb/ft-sec

d = Inside diameter, inches

SG = Specific gravity, dimensionless

In order to supply our customers with the best possible tools upon which to base a design decision, the formulae that follow represent a sampling of other acceptable equations that can be utilized for the determination of gas flow capacity. These include the Mueller, Weymouth, and Spitzglass1 equations. They are as follows:

Mueller Equation:

$$Q=\frac{2826*d^{2.725}}{SG^{0.425}}\left[\frac{(P_1^2-P_2^2)}{L}\right]0.575$$

Weymouth Equation:

$$Q=\frac{2034*d^{2.667}}{SG^{0.5}}\left[\frac{(P_1^2-P_2^2)}{L}\right]^{0.5}$$

Spitzglass Equation:

$$Q=\frac{3410}{SG^{0.5}}\left[\frac{(P_1^2-P_2^2)}{L}\right]^{0.5}[d5/(1+3.6/d+0.03d)]0.5$$

Pipe curvature

In the construction of long distance runs of piping it is often necessary to negotiate bends and/or curves. The natural flexibility of polyethylene piping, as mentioned previously, allows runs of piping to be routed around obstacles in a fairly tight radius. Therefore, with proper planning, trenches can be excavated in such a manner to accommodate bends and/or curves that are within the capabilities of the pipe.

Installation

Prior to installation, an inspection should be completed of the pipe. Surface damage can occur during construction handling and the installation process. Significant damage may impair the performance capabilities of the pipeline. The following guidelines, as taken from the PPI Engineering Handbook, may be used to assess surface damage significance.

For pressure applications, surface damage or butt fusion misalignment should not exceed 10% of the minimum wall thickness required for the pipeline's operating pressure. Deep cuts, abrasions or grooves cannot be field repaired by hot gas or extrusion welding. Excessive damage may require removal and replacement of the damaged section. Misaligned butt fusions should be cut out and redone. If damage is not significant, the shape of the damage may be a consideration. Sharp notches and cuts should be dressed smooth so the notch is blunt. Blunt scrapes or gouges should not require attention. Minor surface abrasion from sliding on the ground or insertion into a casing should not be of concern.

Handling and storage

After the piping system has been designed and specified, the piping system components must be obtained. Typically, project management and purchasing personnel work closely together so that the necessary components are available when they are needed for the upcoming construction work.

Unloading instructions

Before unloading the shipment, there must be adequate, level space to unload the shipment. The truck should be on level ground with the parking brake set and the wheels chocked. Unloading equipment must be capable of safely lifting and moving pipe, fittings, fabrications or other components.

Handling equipment

Appropriate unloading and handling equipment of adequate capacity must be used to unload the truck. Safe handling and operating procedures must be observed. Pipe must not be rolled or pushed off the truck. Pipe, fittings, fabrications, tanks, manholes, and other components must not be pushed or dumped off the truck, or dropped. Although polyethylene-piping components are lightweight compared to similar components made of metal, concrete, clay, or other materials, larger components can be heavy. Lifting and handling equipment must have adequate rated capacity to lift and move components from the truck to temporary storage. Equipment such as a forklift, a crane, a side boom tractor, or an extension boom crane is used for unloading. When using a forklift, or forklift attachments on equipment such as articulated loaders or bucket loaders, lifting capacity must be adequate at the load center on the forks. Forklift equipment is rated for a maximum lifting capacity at a distance from the back of the forks. If the weight-center of the load is farther out on the forks, lifting capacity is reduced. Before lifting or transporting the load, forks should be spread as wide apart as practical, forks should extend completely under the load, and the load should be as far back on the forks as possible. Lifting equipment such as cranes, extension boom cranes, and side boom tractors, should be hooked to wide web choker slings that are secured around the load or to lifting lugs on the component. Only wide web slings should be used. Wire rope slings and chains can damage components, and should not be used. Spreader bars should be used when lifting pipe or components longer than 20 feet. Large fabrications, manholes and tanks should be unloaded using a wide web choker sling and lifting equipment such as an extension boom crane, crane, or lifting boom. The choker sling is fitted around the manhole riser or near the top of the tank. Do not use stub outs, outlets, or fittings as lifting points, and avoid placing slings where they will bear against outlets or fittings. Larger diameter manholes and tanks are typically fitted with lifting lugs.

Pre-Installation Storage

The size and complexity of the project and the components, will determine pre-installation storage requirements. For some projects, several storage or staging sites along the right-of-way may be appropriate, while a single storage location may be suitable for another job. The site and its layout should provide protection against physical damage to components. General requirements are for the area to be of sufficient size to accommodate piping components, to allow room for handling equipment to get around them, and to have a relatively smooth, level surface free of stones, debris, or other material that could damage pipe or components, or interfere with handling. Pipe may be placed on 4-inch wide wooden Dunn age, evenly spaced at intervals of 4 feet or less. Coiled pipe is best stored as received in silo packs. Individual coils may be removed from the top of the silo pack without disturbing the stability of the remaining coils in the silo package. Pipe received in bulk packs or strip load packs should be stored in the same package. If the storage site is flat and level, bulk packs or strip load packs may be stacked evenly upon each other to an overall height of about 6 feet. For less flat or less level terrain, limit stacking height to about 4 feet. Before removing individual pipe lengths from bulk packs or strip load packs, the pack must be removed from the storage stack, and placed on the ground. Individual pipes may be stacked in rows. Pipes should be laid straight, not crossing over or entangled with each other. The base row must be blocked to prevent sideways movement or shifting . The interior of stored pipe should be kept free of debris and other foreign matter.

Exposure to UV and Weather

Polyethylene pipe products are protected against deterioration from exposure to ultraviolet light and weathering effects. Color and black products are compounded with antioxidants, thermal stabilizers and UV stabilizers. Color products use sacrificial UV stabilizers that absorb UV energy and are eventually depleted. In general, non-black products should not remain in unprotected outdoor storage for more than two years; however, some manufacturers may allow longer unprotected outside storage. Black products contain at least 2% carbon black to protect the material from UV deterioration. Black products with and without stripes are generally suitable for unlimited outdoor storage and for service on the surface or above grade.

Cold Weather Handling

Temperatures near or below freezing will affect polyethylene pipe by reducing flexibility and increasing vulnerability to impact damage. Care should be taken not to drop pipe, or fabricated structures, and to keep handling equipment and other things from hitting pipe. Ice, snow, and rain are not harmful to the material, but may make storage areas more troublesome for handling equipment and personnel. Unsure footing and traction require greater care and caution to prevent damage or injury. Walking on pipe can be dangerous. Inclement weather can make pipe surfaces especially slippery.

POLYETHYLENE PIPES FOR PRESSURE APPLICATIONS

Scope and application

Application

The maximum allowable operating pressure for gas pipes was changed from 1000kPa to 1050kPa to reflect practice within the gas industry and a more accurate conversion from 50psi. This change shall be immediate. Where aromatic constituents in excess of a train level are present, the reference to ISO 4437 is now quoted directly rather than AS/NZS4131.

Definitions

Co-extruded "jacket" pipes

This definition was introduced to define a continuous, coloured outer layer that is extruded as part of the pipe wall to aid identification. In principle the process is no different to applying stripes that have been in the Standard since its inception. A test has been added to Section 7 to ensure the layer is adhered correctly to the inner pipe. Correct adhesion is not only necessary to resist internal pressure but it is necessary to ensure proper jointing with mechanical and electro fusion fittings.

Lower prediction limit of the predicted hydrostatic strength (σLPL)

The definition was changed to align with ISO. (Refers to section 3.6 in AS/NZS 4130:2001)

Maximum allowable operating pressure (MAOP)

The definition was changed to align with ISO. (Refers to section 3.7 in AS/NZS 4130:2001)

Minimum required strength (MRS)

The definition was changed to align with ISO. (Refers to section 3.8 in AS/NZS 4130:2001)

Notation

The design factor F has been replaced with the overall service (design) coefficient C. A definition was added for Tmax. These are for clarification purposes only.

Overall service (design) coefficient

The heading and text changed from "Design Factor" in accordance with the adoption of the overall service (design) coefficient but the usage is unchanged.

Classification

Table

The following corrections were made to the Table. It now conforms to the dimension specified in ISO4427.

Value	Previous	Current
SDR 17, 40mm OD	Minimum wall thickness 2.2	Minimum wall thickness 2.4
SDR 7.4, 16mm OD	Minimum wall thickness 2.3	Minimum wall thickness 2.2
SDR 7.4, 16mm OD	Minimum wall thickness 2.7	Minimum wall thickness 2.6
SDR 9, 16mm	Not included	included
SDR 11, 16mm	Not included	included

Note number 2 referring to "rural applications" was deleted as this is a specification Standard not an application Standard. Use and application guides can be found in other Standards or codes. The corresponding grey highlighting within the table was also removed. All changes shall be immediate.

Composition

Striping and jacket compounds

General

Striping and jacket compounds no longer need to comply with AS/NZS 4131 as this was determined to be a requirement that in many cases was impractical. The striping and jacket compounds must however comply with the properties that affect the overall performance of the pipe. i.e.

1. The base resin must come from a material that complies with AS/NZS 4130. eg. The striping or jacket compound could be made from the natural base resin that was used to produce a black material that complies with AS/NZS 4131.
2. The MRS classification of the base resin for the striping and jacket compound must be greater than or equal to the pipe material. eg. PE80 or PE100 for PE80 Pipe or PE100 for PE100 pipe.
3. The compound must comply with the thermal stability test detailed in section 7.3.2.
4. The compound must comply with the dispersion test detailed in section 7.3.3.
5. The compounds must either contain 0.2% of hindered amine light stabilizers (HALS) or meet the requirement for the weathering resistance test specified in section 7.3.4.
6. The minimum thickness of the jacket must be 0.2mm. All changes shall be immediate.

Thermal stability of striping compounds

The test method has been changed to ISO 11357-6.

Weathering resistance

The test method reference is now AS/NZS 1462.26 but the test is precisely the same as the one previously specified in Appendix F of AS/NZS 4131:2001. Retesting or the evaluation of new test data is not required as a result of this change.

Cohesive resistance

This is new type test. It is expected that the type test be conducted before claiming jacketed pipe conforms to the standard.

Color

General

The color lilac has been specified to signify recycled water. This is in line with International designations and industry practice in Australia and New Zealand.

Stripes and jackets

General

The description for stripes has been changed from "solid" to "opaque". Opaque is a better description of the blending of the colours that occurs between the pipe and stripe materials at a homogenous join. Solid inferred sharp, well-defined edges and that could lead to a poor bond and premature failure.

Yellow, Blue, Lilac

The color is now defined by RAL numbers rather than by reference to AS2700 or Z7702. Colors that complied with the previous specification will comply with the new RAL specifications. The changes shall be immediate.

General requirements

Diameter and wall thickness

The measurement method is now specified in AS/NZS 1462.1 but the method is essentially the same as the one previously specified in Appendix D of AS/NZS 4130:2001. The only applicable differences are:

1. Measurements no longer need to be taken within 24 hours of manufacture.
2. The conditioning time varies for various wall thicknesses.
3. The wall thickness must be measured at 6 places equally spaced around the pipe circumference.

Retesting or the evaluation of new test data is not required as a result of this change.

Effect on Water

A scaling factor of 1 has been added to clarify what has been the practice since the introduction of AS/NZS4020. Retesting or the evaluation of new test data is not required as a result of this change.

Thermal Stability

The test method reference is now ISO11357.6. This is an update to the previous test method specified, ie ISO/TR 10837, and it now accounts for advances in Differential Scanning Calorimeter (DSC) instrumentation and practices. The major changes are:

1. A DSC must be used. A Differential Thermal Analyser can no longer be used.
2. The grades and purity of Oxygen and Nitrogen are now clearly defined and in practice are more pure than previously used.
3. The sample mass range is broader.
4. The test now consists of a minimum of two samples rather than five.
5. It now includes a method for determining the onset of oxidation when the "knee" is not well defined.

However, some ISO member countries have highlighted difficulties with changeover and therefore compliance with either Standard is deemed acceptable until a resolution is issued by the ISO Committee.

Slow crack growth resistance

The test method reference is now AS/NZS 1462.24 but the test is precisely the same as the one previously specified in ISO 13479. Retesting or the evaluation of new test data is not required as a result of this change. . The previous Standard adopted the cautious approach of adapting PE100 grades for both 165 and 500 hours slow crack resistance tests. It had since been established that a core group of materials conform to the 500 hours test and the committee felt it was prudent to adopt the higher performance. The latest ISO draft incorporates 500 hours.

Deleted Clause

The requirement for the squeeze-off test was deleted on the basis that pipes manufactured to the Standard have always passed the requirement. In addition, squeezing off pipe to prevent flow is only used while emergency repairs are undertaken and it is recommended hat the pipe affected by the squeeze-off be replaced or reinforced as soon as practicable. Therefore a test is unnecessary.

Marking

The marking requirements have been defined in terms of "not initiating cracks" and "legibility maintained for the life of the pipe". A test to confirm that the marking meets these requirements is not available but it is accepted that standard ink jet printing will suffice.

DESIGN FOR DYNAMIC STRESSES POLYETHYLENE PRESSURE PIPES

Introduction

Polyethylene pressure pipes are designed on the basis of a burst regression line for pipes subjected to constant internal pressure. From this long term testing and analysis, nominal working pressure classes are allocated to pipes as a first indication of the duty for which they are suitable. However, there are many other factors which must be considered, including the effects of dynamic loading. Whilst most gravity pressure lines operate substantially under constant pressure, pumped lines frequently do not and it is essential that the effects of this type of loading be considered in the pipeline design phase to avoid premature failure. This note is intended to assist in the selection of pipe class for polyethylene pipes in applications involving transient and cyclic operating pressures. Pressure fluctuations in pumped mains result from events such as pump start-up and shutdown or valves opening and closing. The approach adopted for pipe design and class selection when considering these events depends on the anticipated frequency of the pressure fluctuation as follows:

♦ for random, isolated surge events, for example, those which result from emergency shutdowns, the designer must ensure that the maximum and minimum pressures experienced by the system are within acceptable limits; and

♦ for frequent, repetitive pressure variations, the designer must consider the potential for fatigue and design accordingly.

Definitions

For the purposes of this note, surge is defined as a rapid, very short term pressure variation caused by an accidental, unplanned event such as an emergency shutdown resulting from a power failure. Surge events are characterized by high pressure rise rates with no time spent at the peak pressure. The maximum duration of a surge event is about 5 minutes. Fatigue is associated with a large number of repetitive events. The key factors to consider are the size and frequency of the repeated event. For large pressure cycles, a lower number of events can be tolerated in the pipe lifetime. For smaller pressure changes, a greater number of events is acceptable. The gradual diurnal pressure changes hitch occur in most distribution pipelines as a result of demand variation will not cause fatigue. The only design consideration required for this type of pressure fluctuation is that the maximum pressure should not exceed the pressure rating of the pipe.

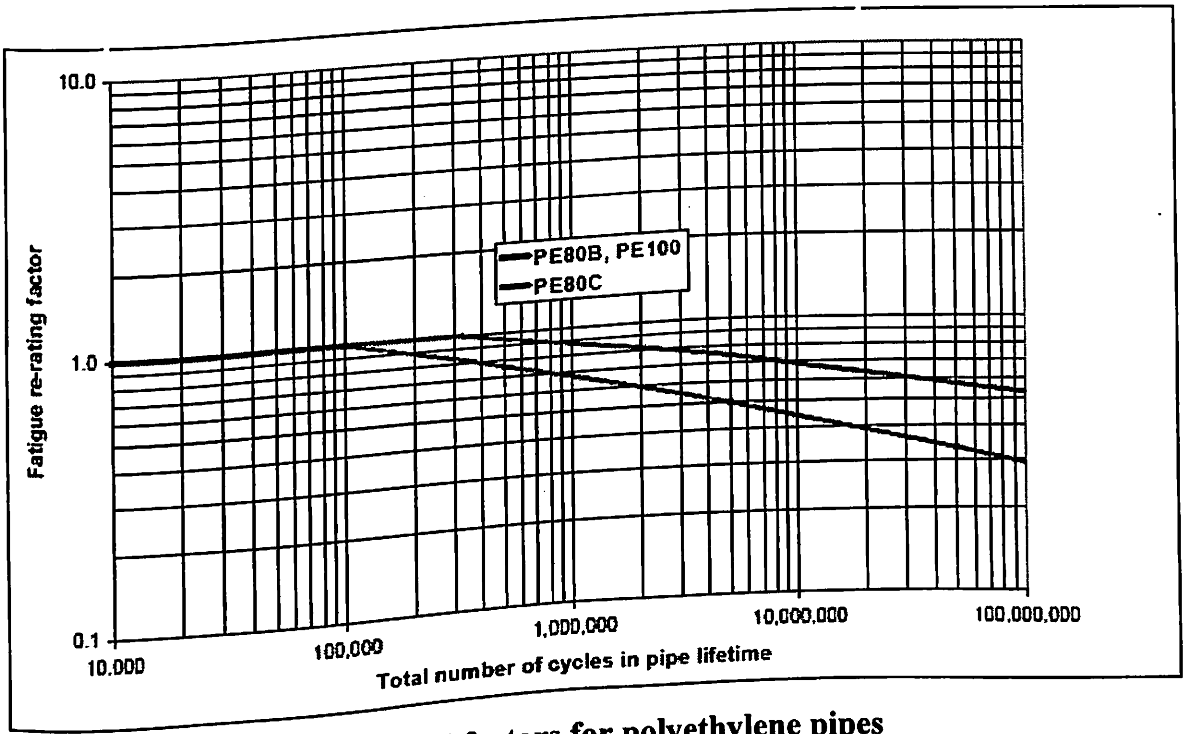
Surge design

It has long been recognized that polyethylene pipes are capable of handling short-term stresses far greater than the long-term loads upon which they are designed. However, this characteristic feature has, to date, not been utilized in design in Australia. Previous design recommendations have advised that the peak pressure should not exceed the nominal working pressure of the pipe. Recently, studies in the UK (1) have examined the response of plastics pipes to short-term over-pressurization. This work has culminated in the publication of a design recommendation (2) allowing significant over-pressurisation of plastics pipes during rapid surge events. However, while these results highlight the capabilities of plastics pipes in this respect, they do not discuss the effect of over-pressurisation on the pipe where it is restrained by tapping bands or flange connections. The effect on other pipeline components is also not considered. Field tests of installed pipelines are conducted to verify the pipeline design and construction. These tests are generally carried out at a pressure of 1.25 times the maximum system operating pressure. Since the test pressure is generally the highest pressure a pipeline will experience, the field test serves to demonstrate that all system components, including items such as anchor blocks which are formed in-situ, will be satisfactory for the operating conditions. The demonstrated ability of polyethylene pipes to accommodate short-term surge pressures can be utilised to advantage by allowing some over-pressurization. However, it is recommended that the peak design pressure is limited to the field test pressure of that pipeline in order to ensure that the pipeline as a whole is capable of performing under these conditions. Where the generation of negative pressures is anticipated, the possibility of transverse buckling should be considered. This topic is well covered in other technical literature.

Fatigue design

Many materials will fail at a lower stress when subjected to cyclic or repetitive loads than hen under static loads. This type of failure is known as fatigue. For thermoplastics pipe aterials, fatigue is only relevant where a large number of stress cycles are anticipated. The important factors to consider are the magnitude of the stress fluctuation and the loading frequency. Where large stress fluctuations are predicted, fatigue design may be required where the total number of cycles in the operational lifetime of the pipe exceeds 100,000. For smaller stress cycles, a larger number of cycles can be tolerated. The fatigue response of thermoplastics pipe materials has been extensively investigated (3-9). The results of laboratory studies can be used to establish a relationship between stress range, defined here as the difference between the maximum and minimum stress (see Fig 2), and the number of cycles to failure. From these relationships it is possible to derive load factors that can be applied to the operating pressures, to enable selection of an appropriate class of pipe. This type of experimental data inevitably has a degree of scatter and it has been Australian practice, after Joseph (3), to adopt the lower bound for design purposes. This approach is retained here because it ensures the design has a positive safety factor and recognises that pipelines may sustain minor surface damage during installation, which could promote fatigue crack initiation. Note that for fatigue loading situations, the maximum pressure reached in the repetitive cycle should not exceed the static pressure rating of the pipe. Table gives the recommended fatigue load factors for thermoplastics pipes.

Total cycles	Approx.no of cycles per day For 100y life time	Fatigue load factor PE80B PE100	Fatigue load factor PE80C
36,500	1	1.00	1.00
100,000	3	1.00	1.00
300,000	8	1.00	0.82
500,000	14	0.95	0.76
1,000,000	27	0.88	0.67
5,000,000	137	0.74	0.50
10,000,000	274	0.68	0.44
50,000,000	1370	0.57	0.33



Fatigue load factors for polyethylene pipes

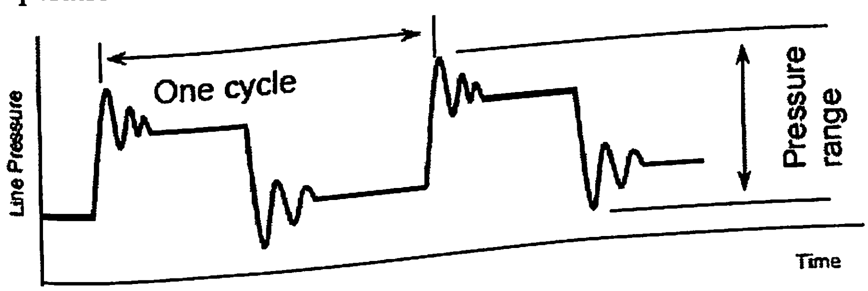
Procedure

To select the appropriate pipe class for fatigue loading, the following procedure should be adopted:

1. Estimate the likely pressure range, ΔP, ie. The maximum pressure minus the minimum pressure.
2. Estimate the frequency or the number of cycles per day which are expected to occur.
3. Determine the required service life and calculate the total number of cycles this will occur in the pipe lifetime
4. Using Table 1 or Figure 1, look up the fatigue load factor for the appropriate pipeline material and number of cycles
5. Divide the pressure range by the fatigue load factor to obtain an equivalent operating pressure
6. Use the equivalent operating pressure to determine the class of pipe required.

Definition of Pressure Range

For simplicity, the pressure range is defined as the maximum pressure minus the minimum pressure, including all transients, experienced by the system during normal operations.



Pressure cycle

Effect of Temperature

Few data have been established concerning the relationships between fatigue performance and temperature. It might be expected that higher temperatures could actually inhibit fatigue crack growth by blunting of the crack tip through the reduced yield strength. Normal temperature de-rating principles should apply in class selection for maximum operating pressure. Fatigue should then be considered separately and the highest pressure class selected. That is select the highest class arrived via:

a) Static design including temperature derating; or

b) Dynamic design as covered herein.

Safety Factors

The fatigue design guidelines presented in Table 1 are based on the lower bound of laboratory test data. They are therefore considered conservative and no additional safety factor need be applied in general. However, where the magnitude or frequency of dynamic stresses cannot be estimated in design with any reasonable degree of accuracy, appropriate caution should obviously be applied. This judgement is in the hands of the designer. Whilst it is always possible to predict the steady operating conditions with good accuracy, it will occasionally be the case, in complex systems, that is impossible to predict the extent of surge pressures. In such circumstances, relatively low cost surge mitigation techniques, for example solid state soft-start motor controllers, should be considered. It is of course recommended that actual operating conditions for all systems should be measured, as a matter of routine, when the system is commissioned. Should surge pressure amplitudes in the event exceed expected levels, it is relatively easy matter to retrofit control equipment to ensure that they are kept in check.

Design Hints

To reduce the effect of dynamic fatigue in an installation, the designer can:

♦ Limit the number of cycles by:

♦ Increasing well capacity for a sewer pumping station;

♦ Matching pump performance to tank size to eliminate short demand cycles for an automatic pressure unit; or

♦ Using double-acting float valves or limiting starts on the pump by the use of a time clock when filling a reservoir.

♦ Reduce the dynamic range by:

♦ Eliminating excessive water hammer; or

♦ Using a larger bore pipe to reduce friction losses.

PACKAGING, HANDLING AND STORAGE OF POLYETHYLENE PIPES

Polyethylene pipes and fittings are light in weight and easy to handle, and have considerable resilience, flexibility and resistance to impact. However PE pipes and fittings can be scored by sharp edges and can be distorted under load, particularly at higher temperatures.

General

Pipes and fittings should not be dropped, indented, crushed or impacted. Pipes and fittings must not be stored or transported where they are exposed to heat sources likely to exceed 70°C. While PE is very resistant to low temperatures, as the temperature drops below freezing the impact resistance will slowly drop, and therefore care must be taken to avoid damage by impact. Care should be taken in handling pipes and fittings in wet or frosty conditions as they may become slippery. Do not place pipes and fittings in contact with lubricating or hydraulic oils, petrol, solvents or other aggressive materials. Scores or scratches to a depth of 10% or more of the wall thickness are sufficient to cause rejection for any pressure application Polyethylene is combustible and may be subject to fire regulations, the requirements of the local Authorities must be observed. In the event of a fire there are no restrictions on the type of fire extinguisher which can be used.

Lifting and Handling

PE pipes and fittings should not be subjected to rough handling during loading and unloading operations. Only webbing slings should be used to lift PE pipes by crane. Under no circumstances should chains, wire ropes and hooks be used on PE pipe Lifting of individual pipes or packs up to 6 m in length can be handled by a fork lift. To prevent drooping of long packs or individual pipes and subsequent scuffing of pipe ends. Two lifting points or spreader bars should be used for pipes or pipe packs exceeding 6 meters in length.

Drums

The same stored energy is found in drums as with coils, except that the pipe is under more control when it is restrained on a drum. It is therefore only necessary to restrain the end of the pipe to make sure it is under control, and to see that the drum is restrained so that it cannot turn freely, and allow the pipe to unravel. Drums are very heavy and must not be manhandled, but must always be handled with the appropriate equipment. Drums must be stored on flat, stable ground to make sure they will not topple over, and should be controlled by the use of chocks to ensure they do not roll out of position. When lifting drums from the vehicle, they should be lifted by use of a strap placed under the plate carrying the pipe, and not through the outer rim of the drum, as this will bend the rim inwards and damage both the drum and the pipe. If lifted by a fork, the tines should be fitted inside the drum under the cross members, making sure the length of the tine is sufficient to fit through the drum to support both sides. Under no circumstances should a drum be allowed to drop from the back of a vehicle on to the ground, or even on to a stack of tyres or other buffer system. When lifting steel drums, care must be taken to make sure they do not come in contact with overhead wires.

Storage and Transport

Pipes of other colour than black should be protected from elevated temperatures and direct sunlight during storage and transport, particularly if they are to be stored for more than 6 months. Pipes stacked for storage or transport should be continuously and evenly supported to minimise distortion. Alternatively horizontal supports of at least 75mm bearing width, spaced not further apart then 1.5 metre centre-to-centre, should be placed beneath the pipes. If stacks are rectangular, vertical supports at twice that spacing should be provided at the sides. Timber framed packs should be stacked with the frames close together and alternating evenly. Packs with widely differing frame spacing should not be stacked. Do not align the bearers vertically as the stacks are likely to be unstable. In such load bearing stacks the maximum free height should be such that the pipe is not permanently deformed, having regard to sideways stability. For larger diameter pipes it may be necessary to brace the ends of the pipe with internal supports to prevent end distortion. Sharp sections bearing against the pipes should be avoided as these can cause indentations in, or scoring of, the pipe wall Pipes with end treatments such as belling, forming, flanging or pre-assembled fittings should be stacked so that the ends are free from loading; if necessary they should be protected from damage. Pipes cut and squared for butt fusion should be given special attention to ensure that they are always handled, particularly in transit, in a manner that keeps the pipe ends free from damage. If different classes of pipe are kept in the same stacks then the heaviest class should always be at the bottom. Pipes may be nested inside each other for transport or storage provided distortion does not occur. When being transported pipes should not be restrained in a manner likely to result in damage to them. Electro fusion Fittings should be stored under cover in dry conditions. They should be kept in their packaging until ready for use. Coiled pipe can be stored and transported by being laid flat on a continuous surface such as pallets but shall be stored and only to such a height that the bottom convolutions does not become distorted. Pipe coils can also be stored and transported in a near vertical position, although this may be governed by the availability of a support which will safely hold leaning coils, provided that the bottom outside coils are not damaged or flattened in transport Where drums are available they should be used to transport pipe; their radiused bearing surface is designed to protect the pipe from indentations. In the storage and issuing of pipe and fittings the principle of 'first in, first out' should be observed.

INSPECTION, TEST AND SAFETY

Considerations

Once a polyethylene piping system has been selected and designed for an application, the design is implemented by securing the pipe, fittings and other necessary appurtenances, installing the system, and placing it in service. Piping installation involves setting various parts, people, and machines in motion to obtain, assemble, install, inspect and test the piping system. Whenever machinery, piping parts, and personnel are engaged in piping system construction, safety must be a primary consideration. Generally, piping system installation begins with obtaining the pipe, fittings, and other goods required for the system. Assembly and installation follow, then system testing and finally, release for operation. Throughout the installation process, various inspections and tests are performed to ensure installed system quality, and that the system when completed is capable of functioning according to its design specifications. In the selection, design, and installation of polyethylene piping systems, professional engineering services, and qualified installers should be used.

Scope

Introduction

Polyethylene piping products are integrated pipe and fitting systems for a broad range of commercial, municipal, utility and industrial applications. They may be buried, laid on the surface, supported above grade, installed underwater, or floated on the surface of lakes or rivers. Polyethylene piping products are manufactured from 1/4" (6 mm) diameter through 120" (3050 mm) diameter under applicable industry standards (ASTM, AWWA, etc.) for pressure, non-pressure and low pressure applications. As well, polyethylene fittings, custom fabrications, special structures and appurtenances are available for full pressure rated, reduced pressure rated, or non-pressure rated applications. Conventionally extruded polyethylene pipes have homogeneous walls and smooth interior and exterior surfaces. Profile pipes are manufactured by extruding a profile over a mandrel. These pipes have smooth interiors, and may have smooth or profiled exteriors. Profile pipes are primarily applied to non-pressure or low pressure applications. Fittings, fabricated structures, tanks, and manholes are constructed for pressure, low pressure and non-pressure applications. Smaller size fittings are usually injection molded. Larger fittings, fabricated structures, tanks, and manholes are fabricated in manufacturer's facilities. Thermal joining techniques used for fabrication usually limit the design pressure capacity of the structure. Complex structures are generally not suitable for field fabrication. After the piping system has been designed and specified, the piping system components must be obtained. Typically, project management and purchasing personnel work closely together so that the necessary components are available when they are needed for the upcoming construction work.

Receiving Inspection

Few things are more frustrating and time consuming than not having what you need, when you need it. Before piping system installation begins, an important initial step is a receiving inspection of incoming products. Construction costs can be minimized, and schedules maintained by checking Inspections, Tests and Safety Considerations

Load Inspection

There is no substitute for visually inspecting an incoming shipment to verify that the paperwork accurately describes the load. Products are usually identified by markings on each individual product. These markings should be checked against the Order Acknowledgment and the Packing List. The number of packages and their descriptions should be checked against the Bill of Lading.

This is the time to inspect for damage which may occur anytime products are handled. Obvious damage such as cuts, abrasions, scrapes, gouges, tears, and punctures should be carefully inspected. When pipe installation involves saddle fusion joining, diesel smoke on the pipe's outside surface may be a concern because it may reduce the quality of saddle fusion joints. Smoke damage is effectively prevented by covering at least the first third of the load with tarpaulins. If smoke tarps are required, they should be in place covering the load when it arrives.

Exposure to UV and Weather

Polyethylene pipe products are protected against deterioration from exposure to ultraviolet light and weathering effects. Color and black products are compounded with antioxidants, thermal stabilizers, and UV stabilizers. Color products use sacrificial UV stabilizers that absorb UV energy, and are eventually depleted. In general, non-black products should not remain in unprotected outdoor storage for more than 2 years, however, some manufacturers may allow longer unprotected outside storage. Black products contain at least 2% carbon black to protect the material from UV deterioration. Black products with and without stripes are generally suitable for unlimited outdoor storage and for service on the surface or above grade

Cold Weather Handling

Temperatures near or below freezing will affect polyethylene pipe by reducing flexibility and increasing vulnerability to impact damage. Care should be taken not to drop pipe, or fabricated structures, and to keep handling equipment and other things from hitting pipe. Ice, snow, and rain are not harmful to the material, but may make storage areas more troublesome for handling equipment and personnel. Unsure footing and traction require greater care and caution to prevent damage or injury. Walking on pipe can be dangerous. Inclement weather can make pipe surfaces especially slippery.

General Considerations during Installation

Cleaning

Before joining, and before any special surface preparation, surfaces must be clean and dry. General dust and light soil may be removed by wiping the surfaces with clean, dry, lint free cloths. Heavier soil may be washed or scrubbed off with soap and water solutions, followed by thorough rinsing with clear water, and drying with dry, clean, lint-free cloths.

The manufacturer's instructions for use, and the material safety data sheet (MSDS) for the chemical should be consulted for information on risks to persons and for safe handling and use procedures. Some solvents may leave a residue on the pipe, or may be incompatible with the material. See PPI Technical Report TR-19, Thermoplastics

Piping for the Transport of Chemicals for additional information on chemical compatibility of polyethylene materials

Field Handling

Polyethylene pipe is tough, lightweight, and flexible. Installation does not usually require high capacity lifting equipment. See Handling and Storage for information on handling.

Pipe up to about 8" (219 mm) diameter and weighing roughly 6 lbs per foot (20 kg per m) or less can usually be handled or placed in the trench manually. Heavier, larger diameter pipe will require appropriate handling equipment to lift, move and lower the pipe. Pipe must not be dumped, dropped, pushed, or rolled into a trench.

Coiled lengths and long strings of heat fused polyethylene pipe may be cold bent in the field. Field bending usually involves sweeping or pulling the pipe string into the desired bend radius, then installing permanent restraint such as embedment around a buried pipe, to maintain the bend. These paragraphs have attempted to convey the primary safety and handling considerations associated with joining and connecting polyethylene pipe. For a more thorough discussion on the joining methods used with polyethylene pipe, the reader is referred to PPI's Handbook of Polyethylene Pipe, Polyethylene Joining Procedures chapter. Inspections and tests begin before construction. Jobsite conditions dictate how piping may be installed and what equipment is appropriate for construction. Soil test borings and test excavations may be useful to determine soil bearing stress and whether or not native soils are suitable as backfill materials. In slipline rehabilitation applications, the deteriorated pipeline should be inspected by remote TV camera to locate structurally deteriorated areas, obstructions, offset and separated joints, undocumented bends, and service connections. In some cases, a test pull, drawing a short section of slip liner through the line, may be conducted to ensure that the line is free of obstructions. The installer should carefully review contract specifications and plans. It is important that the specifications and plans fit the job. Different piping materials require different construction practices and procedures. These differences should be accurately reflected in the contract documents. Good plans and specifications help protect all parties from unnecessary claims and liabilities. Good documents also set minimum installation quality requirements, and the testing and inspection requirements that apply during the job. All incoming materials should be inspected to be sure that sufficient quantities of the correct products for the job are at hand, and that they arrived in good condition, ready for installation.

During Construction

Tests and inspections performed during construction include butt fusion joint quality tests, soil compaction and density tests, pipe deflection tests, pressure tests, and other relevant inspections. Fusion joint qualification and inspection guidelines for butt, socket and saddle fusions should be obtained from the pipe or fitting manufacturer.

Pre-Construction

Inspection and Testing

Cold fusion is a poor quality joint that should be removed and re-done. If not repaired, joint failure can occur. When butt fusion is between pipe and molded fittings, the fitting-side bead may exhibit shape irregularities which are caused by the fitting manufacturing process. A slightly irregular fitting-side bead may not indicate an improper joint, provided that the pipe-side bead is properly shaped, and the v-groove between the beads is correct. Contact the pipe or fitting manufacturer if assistance is required. Fusion joining may be destructively tested to confirm joint integrity, operator procedure, and fusion machine set-up. A field-performed destructive test is a bent strap test. The bent strap test specimen is prepared by making a trial butt fusion, usually the first fusion of the day, and allowing it to cool to ambient temperature. A test strap that is at least 6" or 15 pipe wall thicknesses long on each side of the fusion, and about 1" or 1-1/2 wall thicknesses wide is cut out of the trial fusion pipe. (See Figure 6) The strap is then bent so that the ends of the strap touch. Any disbandment at the fusion is unacceptable, and indicates poor fusion quality. If failure occurs, fusion procedures and/or machine set-up should be changed, and a new trial fusion and bent strap test specimen should be prepared and tested. Field fusion should not proceed until a test joint has passed the bent strap test.

High-speed, tensile-impact testing, a destructive test of a tensile coupon cut from the pipe joint, can provide a quantitative joint strength assessment. Tensile impact strength of the joint may be compared to that of the base pipe.

Soil Tests

During buried pipe installation, work should be checked throughout the construction period by an inspector who is thoroughly familiar with the jobsite, contract specifications, materials, and installation procedures. Inspections should reasonably ensure that significant factors such as trench depth, grade, pipe foundation (if required), quality and compaction of embedment backfill, and safety are in compliance with contract specifications and other requirements. To evaluate soil stability, density and compaction, appropriate ASTM tests may be required in the contract specifications.

Pipe Surface Damage

Surface damage may occur during construction handling and installation. Significant damage may impair the future performance of the pipeline. The following guidelines may be used to assess surface damage significance. For polyethylene pressure pipelines, damage or butt fusion misalignment should not exceed 10% of the minimum wall thickness required for the pipeline's operating pressure. (Ref. 5) Deep cuts, abrasions or grooves cannot be field repaired by hot gas or extrusion welding. Excessive damage may require removal and replacement of the damaged pipe section, or reinforcement with a full encirclement repair clamp. Misaligned butt fusions should be cut out and redone. If damage is not excessive, the shape of the damage may be a consideration. Sharp notches and cuts should be dressed smooth so the notch is blunted. Blunt scrapes or gouges should not require attention. Minor surface abrasion from sliding on the ground or insertion into a casing should not be of concern.

Deflection Tests

Buried flexible pipes rely on properly installed backfill to sustain earth loads and other loads. Proper installation requires using the backfill materials specified by the designer, and installing the pipe as specified by the designer. Large diameter extruded profile pipes, and larger diameter, high DR conventionally extruded pipes are inherently flexible. Pipe deflection can be used to monitor the installation quality. Improperly embedded pipe can develop significant deflection in a short time, thus alerting the installer and the inspector to investigate the problem. Inspection should be performed as the job progresses, so errors in the installation procedure can be identified and corrected. Initial deflection checks of extruded profile pipe may be performed after embedment materials have been placed and compacted

Leak Testing

The intent of leak testing is to find unacceptable faults in a piping system. If such faults exist, they may manifest themselves by leakage or rupture. Leakage tests may be performed if required in the Contract Specifications. Testing may be conducted in various ways. Internal pressure testing involves filling the test section with a nonflammable liquid or gas, then pressurizing the medium. Hydrostatic pressure testing with water is the preferred and recommended method. Other test procedures may involve paired internal or end plugs to pressure test individual joints or sections, or an initial service test. Joints may be exposed to allow inspection for leakage. Liquids such as water are preferred as the test medium because less energy is released if the test section fails catastrophically. During a pressure test, energy (internal pressure) is applied to stress the test section. If the test medium is a compressible gas, then the gas is compressed and absorbs energy while applying stress to the pipeline. If a catastrophic failure occurs, both the pipeline stress energy and the gas compression energy are suddenly released. However, with an incompressible liquid such as water as the test medium, the energy release is only the energy required to stress the pipeline.

Post Installation

Pressure Testing Precautions

The piping section under test and any closures in the test section should be restrained or otherwise restricted against sudden uncontrolled movement in the event of rupture. Expansion joints and expansion compensators should be temporarily restrained, isolated or removed during the pressure test. Testing may be conducted on the system, or in sections. The limiting test section size is determined by test equipment capability. If the pressurizing equipment is too small, it may not be possible to complete the test within allowable testing time limits. If so, higher capacity test equipment, or a smaller test section may be necessary. If possible, test medium and test section temperatures should be less than 1000F (380C). At temperatures above 1000F (380C), reduced test pressure is required. Before applying test pressure, time may be required for the test medium and the test section to temperature equalize. Contact the pipe manufacturer for technical assistance with elevated temperature pressure testing.

References

The following reference publications provide pressure testing information:

ASME B31.1 Power Piping, Section 137, Pressure Tests. (Ref. 6) PPI TR-31 Underground Installation of Polyolefin Piping, Section 7, System Testing. (Ref 1) ASTM F 1417, Standard Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air. (Ref. 7) Uni-Bell PVC Pipe Association Standard, Uni-b-6-90 Recommended Practice for Low-Pressure Air Testing of Installed Sewer Pipe. The piping manufacturer should be consulted before using pressure testing procedures other than those presented here. Other pressure testing procedures may or may not be applicable depending upon piping products and/or piping applications.

Test Pressure

Test pressure may be limited by valves, or other devices, or lower pressure rated components. Such components may not be able to withstand the required test pressure, and should be either removed from, or isolated from the section being tested to avoid possible damage to, or failure of these devices. Isolated equipment should be vented.

Test Duration

For any test pressure from 1.0 to 1.5 times the system design pressure, the total test time including initial pressurization, initial expansion, and time at test pressure, must not exceed eight (8) hours. If the pressure test is not completed due to leakage, equipment failure, etc., the test section should be de-pressurized, and allowed to "relax" for at least eight (8) hours before bringing the test section up to test pressure again.

Pre-Test Inspection

Test equipment and the pipeline should be examined before pressure is applied to ensure that connections are tight, necessary restraints are inplace and secure, and components that should be isolated or disconnected are isolated or disconnected. All low pressure filling lines and other items not subject to the test pressure should be disconnected or isolated.

Hydrostatic testing

Hydrostatic pressure testing is preferred and is strongly recommended. The preferred testing medium is clean water. The test section should be completely filled with the test medium, taking care to bleed off any trapped air. Venting at high points may be required to purge air pockets while the test section is filling. Venting may be provided by loosening flanges, or by using equipment vents. Re-tighten any loosened flanges before applying test pressure.

Monitored Make-up Water Test

The test procedure consists of initial expansion, and test phases. During the initial expansion phase, the test section is pressurized to the test pressure, and sufficient make-up water is added each hour for three (3) hours to return to test pressure After the initial expansion phase, about four (4) hours after pressurization, the test phase begins. The test phase may be one (1), two (2), or three (3) hours, after which a measured amount of make-up water is added to return to test pressure.

Non-monitored Make-Up Water Test

The test procedure consists of initial expansion, and test phases. For the initial expansion phase, make-up water is added as required to maintain the test pressure for four (4) hours. For the test phase, the test pressure is reduced by 10 psi. If the pressure remains steady (within 5% of the target value) for an hour, no leakage is indicated.

Pneumatic Testing

Pneumatic testing should not be used unless the Owner and the responsible Project Engineer specify pneumatic testing or approve its use as an alternative to hydrostatic testing. Pneumatic testing (testing with a gas under pressure) should not be considered unless one of the following conditions exists:

1.when the piping system is so designed that it cannot be filled with a liquid; or

2.where the piping system service cannot tolerate traces of liquid testing medium. The testing medium should be non-flammable and non-toxic. The test pressure should not exceed the maximum allowable test pressure for any non-isolated component in the test section. Leaks may be detected using mild soap solutions (strong detergent solutions should be avoided), or other non-deleterious leak detecting fluids applied to the joint. Bubbles indicate leakage. After leak testing, all soap solutions or leak detecting fluids should be rinsed off the system with clean water.

High Pressure Procedure

For continuous pressure rated pipe systems, the pressure in the test section should be gradually increased to not more than one-half of the test pressure, then increased in small increments until the required test pressure is reached. Test pressure should be maintained for ten (10) to sixty (60) minutes, then reduced to the design pressure rating, and maintained for such time as required to examine the system for leaks.

Low Pressure Procedure

For components rated for low pressure service the specified rated test pressure should be maintained for ten (10) minutes to one (1) hour, but not more than one (1) hour. Test pressure ratings must not be exceeded. Leakage inspections may be performed during this time. If the test pressure remains steady (within 5% of the target value) for the one (1) hour test time, no leakage is indicated. Pressure testing of gravity-flow sewer lines should be conducted in accordance with ASTM F 1417, Standard Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air. (Ref. 7)

Initial Service Testing

An initial service test may be acceptable when other types of tests are not practical, or where leak tightness can be demonstrated by normal service, or when initial service tests of other equipment are performed. An initial service test may apply to systems where isolation or temporary closures are impractical, or where checking out pumps and other equipment affords the opportunity to examine the system for leakage prior to full scale operations.

Test Procedure

The piping system should be gradually brought up to normal operating pressure, and held at operating pressure for at least ten (10) minutes. During this time, joints and connections should be examined for visual evidence of leakage.

Non-Testable Systems

Some systems may not be suitable for pressure testing. These systems may contain non-isolatable components, or temporary closures may not be practical. Such systems should be carefully inspected during and after installation. Inspections such as visual examination of joint appearance, mechanical checks of bolt or joint tightness, and other relevant examinations should be performed.

Disinfecting Water Mains

Applicable procedures for disinfecting new and repaired potable water mains are presented in standards such as ANSI/AWWA C651, Disinfecting Water Mains. (Ref. 8) ANSI/AWWA C651 uses liquid chlorine, sodium hypochlorite, or calcium hypochlorite to chemically disinfect the main. Disinfecting solutions containing chlorine should not exceed 12% active chlorine, because greater concentration can chemically attack and degrade polyethylene.

Considerations for Post Start-Up and Operation

Cleaning

Pipelines operating at low flow rates (around 2 ft/sec or less) may allow solids to settle in the pipe invert. Polyethylene has a smooth, non-wetting surface that resists the adherence of sedimentation deposits. If the pipeline is occasionally subject to higher flow rates, much of the sedimentation will be flushed from the system during these peak flows. If cleaning is required, sedimentation deposits can usually be flushed from the system with high pressure water. Water-jet cleaning is available from commercial services. It usually employs high pressure water sprays from a nozzle that is drawn through the pipe system with a cable. Pressure piping systems may be cleaned with the water-jet process, or may be pigged. Pigging involves forcing a resilient plastic plug (soft pig) through the pipeline. Usually, hydrostatic or pneumatic pressure is applied behind the pig to move it down the pipeline. Pigging should employ a pig launcher and a pig catcher. A pig launcher is a wye or a removable spool. In the wye, the pig is fitted into the branch, then the branch behind the pig is pressurized to move the pig into the pipeline and downstream. In the removable pipe spool, the pig is loaded into the spool, the spool is installed into the pipeline, and then the pig is forced downstream. Commercial pigging services are available if line pigging is required.

Repairs

Repair situations may arise if a polyethylene pipe has been damaged. Damage may occur during shipping and handling, during installation, or after installation. Damage may include scrapes or abrasions, breaks, punctures, kinks, or emergency squeeze-off. Permanent repair usually involves removing and replacing the damaged pipe or fitting. In some cases, temporary repairs may restore sufficient serviceability and allow time to schedule permanent repairs in the near future.

Damage Assessment

Damaged pipe or fittings should be inspected and evaluated. Pipe, fittings, fabrications or structures with excessive damage should not be installed. Damage that occurs after installation may require that the damaged pipe or component be removed and replaced. Improper butt fusions must be cut-out and re-done from the beginning. Poorly joined socket or electrofusion fittings must be removed and replaced. Poorly joined saddle fittings must be removed by cutting out the main pipe section, or, if the main is undamaged, made unusable by cutting the branch outlet or chimney off the saddle fitting, and installing a new saddle fitting on a new section of main. Kinked pipe must be removed and replaced. Squeeze-off damaged pipe must be removed and replaced.

Permanent Repairs

For buried large diameter polyethylene pipe that has been poorly backfilled, excessive deflection may be correctable using point excavation to remove backfill, then reinstalling embedment materials in accordance with recommended procedures. Where replacement is required, any joining method appropriate to the product and service requirements is generally acceptable. Butt and socket fusion joining procedures require that one of the components move longitudinally. However, constrained installations, such as buried pipes, may not allow such movement. Permanent repair of constrained pipe typically employs techniques that do not require longitudinal movement of one or both pipe ends. Techniques include deflecting one pipe end to the side, using a mechanical or electrofusion coupling, or installing a flanged spool. See Figure 9. Typical methods for joining repair pipe sections include flanges, electrofusion couplings, and fully restrained mechanical couplings. To repair using a flanged spool, cut out, remove and discard the damaged pipe section. Install flanges on the two pipe ends. Measure the distance between the flange sealing surfaces, and prepare a flanged pipe spool of the same length. Install the flanged spool. Repair using an electrofusion coupling or a fully restrained mechanical coupling is limited to pipe sizes for which such couplings are available. Mechanical or electrofusion coupling repairs are made by deflecting one pipe end to the side for the coupling body to be slipped on. The pipe ends are then realigned and the coupling joint fitted up. To allow lateral deflection, a length of about 10 times the pipe outside diameter is needed. Replacement using Electrofusion or Fully Restrained Mechanical Coupling

Temporary Repair

Until permanent repairs can be effected, temporary repairs may be needed to seal leaks or punctures, to restore pressure capacity, or to reinforce damaged areas. Temporary repair methods include but are not limited to mechanical repair couplings and welded patches. A successful piping system installation is dependent on a number of factors. Obviously, a sound design and the specification and selection of the appropriate quality materials are paramount to the long term performance of any engineered installation. The handling, inspection, testing, and safety considerations that surround the placement and use of these engineered products is of equal importance. In this chapter, we have attempted to provide fundamental guidelines regarding the receipt, inspection, handling, storage, testing, and repair of polyethylene piping products. While this chapter cannot address all of the product applications, test and inspection procedures, or construction practices, it does point out the need to exercise responsible care in planning out these aspects of any job site. It is the responsibility of the contractor, installer, site engineer, or other users of these materials to establish appropriate safety and health practices specific to the job site and in accordance with the local prevailing codes that will result in a safe and effective installation.

PROJECT AT GLANCE

SOURCE AND QUANTITY OF GAS REQUIREMENT

SOURCE

Gas will be made available from OIL and ONGCL from Duliajan and Khoraghat respectively.

REQUIREMENT OF GAS

Domestic, Jorhat (phase i)

No of EDC	NG consumed by each EDC in a day Scmd	Total consumption
4095	2	8190

TECHNICAL DETAILS

No of roads

1 to 100m	101 to 500m	501m and above
21	19	10

H.D.P.E pipe requirement

32 mm OD (Meters)	50 mm OD (Meters)	63 mm OD (Meters)	75mm OD (Meters)	90mm OD (Meters)	180 mm OD (Meters)
32000	9400	6500	8600	1700	4500

Valve requirement

32mm to 90mm OD	110mm to 180mm OD
50	3

Pressure reducing station

Capacity	Use
4000scm/hr	To reduce working pressure to 4 kg/sqcmg while gas is in flowing to the PE network

Technical details

H.D.P.E pipe requirement

Length details	Diameter 7-8inch	Diameter 2-3inch	Diameter 1-2inch	Length k.m
Baghchung to Lichubari Tiniali	7.08			1
Lichubari Tiniali to Bongalpukhuri Tiniali	7.08	2		2
Bongalpukhuri Tiniali to Railgate	7.08			
Lichubari Tiniali to Sadar		2 2.5		1.4
Sadar Road to Bongalpukhuri Tiniali		2.04	1.55	2
By lanes			1.5	16.86

Natural gas requirement

Area details	Total no of e.d.c	Gas required per day Cubic foot per day	Gas required per month Cubic meter per month
Along Na ali	2675	5350	160500
Along Club road	1180	2360	70800
Along Sadar road	240	480	14400

Pressure details

Pressure points	In psia	In kg/sq.cmg
Baghchung	56.92	4
Lichubari tiniali	54.49	3.83
Bongalpukhuri tiniali	50.43	3.54
Rail gate	48.51	3.4
Sadar	54.40	3.82

Technical calculations

Using Weymouth equation

$$q_h = \frac{18.062\, T_b\, [(P_1^2 - P_2^2)\, D^{16/3}]^{1/2}}{P_b\, [\gamma_g T L z]^{1/2}}$$

q_h=gas flow rate, cfh at P_b and T_b

T_b=base temperature, °R

P_b=base pressure, psia

P_1=inlet pressure, psia

P_2=outlet pressure, psia

D=inside diameter, inch

γ_g=gas specific gravity

T=average flowing temperature, °R

L=length of pipe, miles

z=gas deviation factor at average flowing temperature and average pressure

Assume data

T_b=520°R

P_b=14.73psia

γ_g=0.64

T=528°R

z=0.979

Pressure calculations

Used formula

$$P_1^2 - P_2^2 = \frac{(q_h * P_b)^2 \gamma g T L z}{(18.062 * T_b)^2 D^{16/3}}$$

Pressure points

Baghchung

Initial pressure=**4k.g/cm²g** or **56.92 psia**

Lichubari tiniali

qh=134750cfh

L=0.625miles

D=7.08inch

P_1=56.92psia

$$P_2^2 = 56.92^2 - \frac{(134750*14.73)^2*0.64*528*0.625*0.979}{(18.062*520)^2\ 7.08^{16/3}}$$

P_2=54.49psia

=**3.83kg/cm²g**

Bangalpukhuri tiniali

qh=119523.25cfh

L=1.25miles

D=7.08inch

P_1=54.49psia

$$P_2^2 = 54.49^2 - \frac{(119523.25*14.73)^2*0.64*528*1.25*0.979}{(18.062*520)^2\ 7.08^{16/3}}$$

P_2=50.43psia

$=\underline{3.54 kg/cm^2 g}$

Na Ali rail gate

qh=112677.95cfh

L=0.625miles

D=7.08inch

P_1=50.43psia

$$P_2^2 = 50.43^2 - \frac{(112677.95*14.73)^2*0.64*528*0.625*0.979}{(18.062*520)^2\ 7.08^{16/3}}$$

P_2=48.51psia

$=\underline{3.4 kg/cm^2 g}$

Sadar

qh=1293.6cfh

L=0.875miles

D=2.5inch

P_1=54.49psia

$$P_2^2 = 54.49^2 - \frac{(1293.6*14.73)^2*0.64*528*0.875*0.979}{(18.062*520)^2\ 2.52^{16/3}}$$

P_2=54.40psia

$=\underline{3.82 kg/cm^2 g}$

Diameter calculation

Used formula

$$D^{16/3} = \frac{(q_h * P_b)^2 \gamma_g * T * LZ}{(18.062 * T_b)^2 (P_1^2 - P_2^2)}$$

Sadar road

q_h=1293.6cfh

L=0.875miles

P_1=54.49psia

P_2=54.40psia

$$D^{16/3} = \frac{(1293.6*14.73)^2 *0.64*528*0.875*0.979}{(18.062*520)^2 *(54.49^2-54.40^2)}$$

D=2.45inch

Club road (left)

q_h=2075.15cfh

L=1.25miles

P_1=54.40psia

P_2=50.43psia

$$D_{16/3} = \frac{(2075.15*14.73)^2 *0.64*528*1.25*0.979}{(18.062*520)^2 *(54.40^2-50.43^2)}$$

D=1.55inch

Club road (right)

All values are similar to above except qh=4285.05cfh

$$D^{16/3} = \frac{(4285.05*14.73)^2 *0.64*528*1.25*0.979}{(18.062*520)^2 *(54.40^2-50.43^2)}$$

D=2.04inch

Na Ali

Main pipeline of diameter **7.08inch** and length **4k.m** is proposed. Along with this line there will be another line of diameter **2inch** and length **3k.m** to feed consumers on the left side of na ali.

GAS SUPPLY TO JORHAT DOMESTIC GAS GRID

TITLE:INTEREST
CALCULATION

TOTAL PROJECT COST:RS 723(APPROXIMATELY)

LOAN FROM BANK:RS 516(APPROXIMATELY)

INTEREST RATE PER ANNUM:8%

REPAYMANT:7 YEARS

PERIOD	CAPITAL	INTEREST	REPAYMENT	TOTAL INTEREST
1	516	20.64	36.85	39.81
2	479.15	19.17	36.85	
3	442.3	17.69	36.85	33.9
4	405.45	16.21	36.85	
5	368.6	14.74	36.85	28.01
6	331.75	13.27	36.85	
7	294.9	11.79	36.85	22.11
8	258.05	10.32	36.85	
9	221.2	8.84	36.85	16.21
10	184.35	7.37	36.85	
11	147.5	5.9	36.85	10.32
12	110.65	4.42	36.85	
13	73.8	2.95	36.85	4.42
14	36.85	1.47	36.85	
TOTAL		154.78	515.9	154.78

ALL AMOUNTS ARE IN LAKHS OF RUPEES

NAME OF THE PROJECT: GAS SUPPLY TO JORHAT DOMESTIC GAS GRID

TITLE: CASH FLOW STATEMENT

TOTAL PROJECT COST: RS 723 LAKHS

SERIAL NO	REVENUE	EXPENSES	SURPLUS	TAX 38.5%	DEPRECIATION AND INTEREST	CFAT	P.V
1	259.92	256.14	3.06	1.17	220.56	222.45	185.3
2	434.06	208.38	225.68	86.88	169.46	308.26	214.0
3	455.76	172.28	283.48	109.13	129.68	304.03	175.9
4	478.55	144.99	333.56	128.42	98.36	303.5	146.3
5	502.47	124.46	378.01	145.53	73.39	305.87	122.9
6	532.61	109.15	423.46	163.03	53.2	313.63	105.0
7	564.57	97.9	466.67	179.66	36.58	323.59	90.
8	598.44	91.34	507.1	195.23	24.12	335.99	78.1
9	640.33	91.81	548.52	211.18	18.09	355.43	68.8
10	685.15	94.42	590.73	227.43	13.56	376.87	60.8
11	746.81	98.89	647.92	249.44	10.17	408.65	54.9
12	806.56	105	701.56	270.1	7.63	439.09	49.2
13	871.08	112.61	758.47	292.01	5.72	472.18	44.1
14	940.77	121.64	819.13	315.36	4.29	508.06	39.5
15	1025.44	132.07	893.37	343.94	3.21	552.67	35.8
TOTAL				2918.51	868.02	5530.27	1471.6

PAYBACK PERIOD=3 YEARS (7 YEARS FOR TOTAL AMOUNT AND 3 YEARS FOR LOAN AMOUN

IRR=20%

ALL AMOUNTS ARE IN LAKHS OF RUPEES

References

The following references are used for the various Figures and Formulae in preparing the report.

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- www.plasticpipe.org