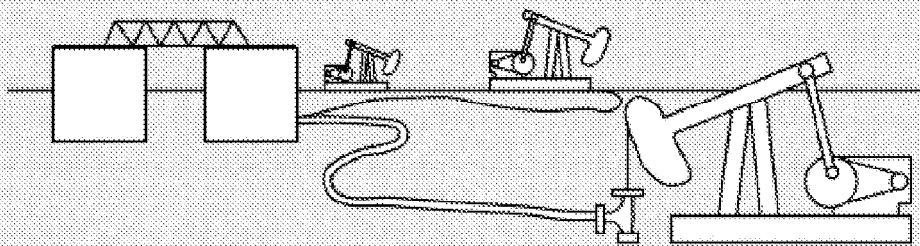


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Above Ground Applications for Polyethylene Pipe



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Above-Ground Applications for Polyethylene Pipe

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Foreword

Above-Ground Applications for Polyethylene Pipe is one of the chapters being prepared for inclusion in the Plastics Pipe Institute's *PPI Handbook of Polyethylene Piping*, which will be issued as a complete volume in the future. Other topics to be addressed in the handbook will include design of polyethylene piping systems, joining procedures, engineering properties, relevant codes and standards, and a variety of related information.

PPI is a division of The Society of the Plastics Industry, Inc. (SPI), and the major U.S. trade association representing all segments of the plastics industry.

The *Municipal and Industrial (M&I) Division of PPI* are producing the *PPI Handbook of Polyethylene Piping*. M&I membership consist of major North American manufacturers of polyethylene (PE) pipe and fittings, PE piping materials, machinery, and equipment used for joining and installing PE piping, related test laboratories, and professional organizations.

PPI maintains additional groups that address other applications such as gas distribution. PPI provides technical and promotional support for the effective use and continued application of thermoplastics pipe and related products, consistent with the best public interest. PPI membership also includes producers of polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), polybutylene (PB), and crosslinked PE (PEX) piping products and materials.

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April, 1998

ABOVE-GROUND APPLICATIONS FOR POLYETHYLENE PIPE

Introduction

A significant portion applications require that a pipe be laid out, or “strung out”, across the prevailing terrain. It may simply be placed on the surface, or it may be suspended or “cradled” in support structures. These types of installations may be warranted by any one of several factors. One is the economic considerations of a temporary piping system. Another is the ease of inspection and maintenance. Still another is simply that prevailing local conditions prevent burial of the pipe.

Polyethylene pipe provides unique joint integrity, toughness, flexibility, and low weight. These factors combine to make its use practical for many “above-ground” applications, so PE pipe is utilized extensively. This resilient material has been used for temporary water lines, various types of bypass lines, dredge lines, mine tailings, and fines-disposal piping. Polyethylene pipe is used for slurry transport in many industries such as those that work with kaolins and phosphates. The ease of installation and continued toughness of polyethylene pipe often make it practical for oil and gas collection. The economics and continued successful performance of this unique piping material is evident despite the extreme climatic conditions that exist in these diverse applications.

This chapter presents design criteria and prevailing engineering methods that are used for above-ground installation of polyethylene pipe. The effects of temperature extremes, chemical exposure, ultraviolet radiation, and mechanical impact are discussed in detail. Engineering design methodology for both “on-grade” and suspended or cradled polyethylene pipe installations are presented and illustrated with typical sample calculations. All equations in the design methodology were obtained from published design references. These references are listed so the designer can verify the applicability of the methodology to his particular project. Additional installation considerations are also discussed.

Design Criteria

The design criteria that can influence the behavior of polyethylene pipe installed above ground include:

- Temperature,
- Chemical exposure,
- Ultraviolet radiation,
- Potential mechanical impact or loading.

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Temperature

The diversity of applications for which polyethylene pipes are used in above-ground applications reflects the usable temperature range for this material. Above-grade installations are exposed to demanding fluctuations in temperature extremes as contrasted to a buried installation where system temperatures can be relatively stable. Irradiation by sunlight, seasonal changes, and day-to-night transitions can impose a significant effect on any piping material installed above the ground.

As a general rule, polyethylene pipe can be used safely at temperatures as low as -75°F (-60°C) and as high as 150°F (65°C). However, polyethylene is a thermoplastic material and, as such, these extremes do impact on the engineering properties of the piping. Additional information is available from individual pipe manufacturers.

Pressure Capability

The pressure capability of a polyethylene pipe is predicated on the long-term hydrostatic strength (LTHS) of the polymer used in its manufacture. This strength is then classified into one of a series of hydrostatic design bases (HDB's) in accordance with ASTM D2837^[1]. This information is, in turn, used by the Hydrostatic Stress Board of the Plastics Pipe Institute to establish a recommended hydrostatic design stress (HDS) for pipe made from a specific material ^[2]. The hydrostatic design basis of a PE3408 piping material is 1600 psi at 73.4°F (23°C). This yields a hydrostatic design stress (HDS) of 800 psi at the same temperature. The HDS is used in Equation 8.1 to determine the pressure capability for a specific wall thickness or pipe series used to transport a specific medium, such as water or natural gas ^[3].

$$P = \frac{2(\text{HDS})}{(\text{DR} - 1)} = \frac{2(\text{HDS})}{((\text{OD}/t) - 1)} \quad (\text{Eq. 1})$$

Pressure Capability, P

where P = Pressure capability in psi

HDS = Recommended hydrostatic design stress in psi
= HDB x f

DR = Ratio of OD to wall thickness (OD/t)

OD = Outside diameter of pipe in inches

t = Minimum wall thickness in inches

and where HDB = Hydrostatic design basis of material

= 1600 psi for PE 3408 at 73.4°F (23°C)

= 1250 psi for PE 2406 at 73.4°F (23°C)

f = Service design factor

= 0.50 for water

= 0.32 for natural gas

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As the temperature to which the polyethylene pipe is exposed increases above the reference temperature of 73.4°F (23°C), the LTHS decreases. Correspondingly, the HDS and the Pressure rating of a specific DR is reduced as the service temperature increases. On the other hand, if the service temperature is lowered below 73.4°F (23°C), the LTHS and HDS increase. In other words, the pressure capability of a polyethylene pipe with the same DR increases as the service temperature decreases. Temperature has a similar effect on material stiffness. As the temperature increases, the modulus of elasticity decreases.

Table 1 Pressure Capability Design Factors

Service Temperature °F (°C)	Apparent Modulus of Elasticity (E_s) psi	Apparent Long-Term Modulus of Elasticity (E_L) psi	Pressure Design Factor
140 (60)	50,000	12,000	0.50
130 (55)	57,000	13,000	0.50
120 (49)	65,000	15,000	0.70
110 (44)	80,000	18,000	0.75
100 (38)	100,000	23,000	0.80
90 (32)	103,000	24,000	0.90
80 (27)	108,000	25,000	0.95
73.4 (23)	130,000	30,000	1.00
60 (16)	130,000	30,000	1.15
50 (10)	165,000	38,000	1.30
40 (4)	170,000	39,000	1.40
30 (-1)	200,000	46,000	1.60

The temperature effects on elasticity and pressure ratings for polyethylene pipe are illustrated in Table 8.1. This table lists design factors that are applied to the standard pressure ratings at 73.4°F (23°C) to derive an estimation of the true long-term pressure capability of a polyethylene pipe at a specific service temperature. The manner by which these factors are utilized will be discussed within the design methodology section of this chapter.

The values listed in Table 1 represent a generalization of the temperature effect on the HDB of all PE3408 piping materials. Information regarding the temperature-responsive nature of a specific polyethylene pipe is available from the respective pipe manufacturer.

Low Temperature Extremes

Generally speaking, the limitation of extremely low environmental temperature is the potential for embrittlement of the material. Note, however, that most polyethylene

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piping materials are tested at extremely low temperatures with no indication of embrittlement.

The effect of low temperature on polyethylene pipe is unique. As shown in Table 8.1, the modulus of elasticity increases as temperatures are lowered. In effect, the pipe becomes stiffer but retains its ductile qualities. The actual low temperature embrittlement of most polyethylene is below -180°F (-118°). In actual practice, polyethylene pipe has been used in temperatures as low as -75°F (-60°C)^[4,5]. Obviously, service conditions at these extremes may warrant insulation to prevent heat loss and freezing of the material being conveyed.

Expansion and Contraction

The coefficient of linear expansion for unrestrained polyethylene pipe is approximately ten times that of metal or concrete. The end result is that large changes in the length of unrestrained polyethylene piping may occur due to temperature fluctuations. While the potential for expansion (or contraction) is large when compared with that of metal, concrete, or vitrified clay pipe, note that the modulus of elasticity for polyethylene is substantially lower than that of these alternative piping materials^[19]. This implies that the degree of movement associated with a specific temperature change may be higher for the polyethylene, but the stress associated with restraint of this movement is significantly less. The end result is that the means of restraint required to control this movement potential is often less elaborate or expensive. The stresses imposed by contraction or expansion of a polyethylene piping system are usually on an order of 5% to 10% of those encountered with rigid piping materials.

Chemical Resistance

Unlike many piping materials, polyethylene pipe will not rust, rot, pit, or corrode as a result of chemical, electrolytic, or galvanic action. The only chemical environments that pose potentially serious problems for polyethylene pipe are strong oxidizing agents or certain hydrocarbons. Concentrated sulphuric and nitric acids are strong oxidizers, while diesel and fuel oils typify these hydrocarbons.

Environments that contain these harsh chemicals may affect the performance characteristics of an above-ground system made from polyethylene pipe. The continued exposure of polyethylene to strong oxidizing agents may lead to crack formation or crazing of the pipe surface. Occasional or intermittent exposure to these agents will not, however, significantly affect the long-term performance of a polyethylene pipe.

Hydrocarbon exposures normally cause only temporary effects on polyethylene. The result of the exposure is, for the most part, evident only as long as the exposure is maintained. Exposure to certain hydrocarbons tends to reduce the pressure capability of the polyethylene. It is also evidenced by a reduction in tensile strength and an increase in physical dimensions (swelling) due to adsorption of the hydrocarbon by the polyethylene structure. Continued exposure can lead to permeation of the polyethylene pipe wall and eventual leaching of the material being conveyed. The de-

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degree of permeation is a function of pressure, temperature, the nature of the hydrocarbons, and the polymer structure of the piping material. Each of these parameters should be considered before using polyethylene pipe to transport hydrocarbons in an above-ground installation.

Various references are available concerning the effects of chemical exposure on polyethylene pipe. PPI Technical Report No. 19 contains further information regarding resistance of polyethylene pipe to various chemical environments ^[6].

Ultraviolet Exposure

When polyethylene pipe is utilized outdoors in above-ground applications, it will be subjected to extended periods of direct sunlight. The ultraviolet component in sunlight can produce a deleterious effect on the polyethylene unless the material is sufficiently protected. Weathering studies ^[18] have shown that pipe produced with a minimum 2.0% concentration of finely divided and evenly dispersed carbon black is protected from the harmful effects of UV radiation for indefinite periods of time. Polyethylene pipe that is protected in this manner is the principal material selected for above-ground installations.

Black pipe (containing 2.0% minimum carbon black) is normally recommended for above-ground use. Consult the manufacturer's recommendations for any non-black pipe that is either used or stored above ground.

Mechanical Impact or Loading

Any piping material that is installed in an exposed location is subject to the rigors of the surrounding environment. It can be damaged by the movement of vehicles or other equipment, and such damage generally results in gouging, deflecting, or flattening of the pipe surfaces.

If an above-ground installation must be located in a region of high traffic or excessive mechanical abuse (along a roadway, etc.), the pipe requires extra protection. It may be protected by building a berm or by encasing the pipe where damage is most likely. Other devices may be used, as appropriate to the situation. Design criteria for the installation of buried flexible thermoplastic pipe should be used for those areas where the above-ground polyethylene system must pass under a roadway or other access, and where an underground installation of a portion of the system is necessary ^[7,8].

In general, in an installation in which any section of polyethylene pipe has been gouged in excess of 10% of the minimum wall thickness, the gouged portion should be removed. When the polyethylene pipe has been excessively or repeatedly deflected or flattened, it may exhibit stress-whitening, crazing, cracking, or other visible damage, and any such regions should be removed and replaced with new pipe material.