high density polyethylene pipe

Sclairpipe®

Systems Design

KWH
PIPE

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The accuracy or applicability of all information contained herein is intended as a guide and is not guaranteed. Hence, KWH Pipe assumes no obligation or liability for this information. All tables and statements may be considered as recommendations but not as warranty. Users of our products should perform their own tests to determine the suitability of each such product for their particular purposes. KWH Pipe's liability for defective products is limited to the replacement, without charge, of any product found to be defective. Under no circumstances shall it be responsible for any damages beyond the price of the products, and in no event shall it be liable for consequential damages.

Rules for Choice of Pipe Weight

PRESSURE CLASS DESIGNATION

SCLAIRPIPE® high density polyethylene (HDPE) pipe pressure class ratings are designated by a Dimension Ratio (DR) number. This is a common "rating" system specified by ASTM, AWWA and CSA for polyethylene pipes. The DR number is also used for pressure classification of other non-metallic piping materials such as PVC, ABS and polypropylene.

A dimension ratio is defined as the ratio of outside pipe diameter to minimum allowable wall thickness. The relationship of a pipe's dimension ratio to a pipe's standard pressure rating is described in the modified ISO formula as detailed below:

$$P = \frac{(2)(HDS)(t)}{D_o - t}$$

where: P = maximum operating pressure at 73.4°F under steady state conditions
HDS = Hydrostatic Design Stress at 73.4°F
t = minimum pipe wall thickness
D_o = pipe outside diameter
and: $DR = D_o/t$

By substituting the above relationship into the modified ISO formula, it reduces to:

$$P = \frac{2\,(HDS)}{DR - 1}$$

This simplified relationship shows the pipe pressure rating, P, as a function of the pipe DR number and the hydrostatic design stress of the resin used to extrude the pipe.

The HDS is derived from the extrapolation of a series of hydrostatic pressure tests used to define the pipe's time-to-failure envelope. Circumferential wall stress (hoop stress) is developed by pressurizing a number of pipe samples and recording the time to failure. This data is analyzed according to the method described in ASTM D2837 to extrapolate and pinpoint the pipe compounds Long-Term Hydrostatic Strength (LTHS). The LTHS is then used to categorize the pipe's Hydrostatic Design Basis (HDB) based on the respective range that it fits into. Once the HDB is assigned to the pipe's hydrostatic capabilities, it is reduced by a design factor of 0.50 to determine the Hydrostatic Design Stress (HDS). This allows an appropriate safety margin and permits operation with the reasonable expectation that the pipe will have indefinite life (i.e. 50 years or more).

DESIGN CRITERIA

For each pipe DR number, there is a corresponding maximum allowable continuous operating pressure at 73.4°F when used in water service. This pressure rating varies when different pipe design hoop stress values (HDS) are substituted into the pipe design equation. Typically, HDPE pipes are made from materials qualified as PE 3408 which means the compound has a HDS of 800 psi.

This pipe design methodology has been checked against long term pipe strain. Strain in polyethylene pipe has been found to govern the life of the pipe system. Operation at the design stress level should induce no greater than 3% strain over 50 years of continuous service at 73.4°F. This is consistent with other investigations where the long term strain design limit of 3% to 4%, incorporating a 0.5 design factor, has been designated.

SUMMARY OF RULES FOR PIPE SELECTION

As described previously, a specific DR and material hydrostatic design stress, HDS, produces the same continuous standard maximum operating pressure for 50 years life at 73.4°F incorporating a 2:1 safety factor, regardless of the nominal pipe size (NPS).

In design, it is this "pressure" rating which can be factored to provide a "service" rating depending on the conditions of service. Service factors can vary from 1.0 (or more) to 0.25 (or less) and will depend on the relationship between the pipes' operating conditions, the pipes' intended use and expected lifetime.

Certain operating conditions may not necessarily utilize a design service factor such a buckling and pipe deflection in buried pipe applications. Here, design performance limits have been defined for each pipe DR rating. How service factors and design performance limits are defined, are discussed in the appropriate sections of this manual.

Installation of 24 inch SCLAIRPIPE for a twin sewage siphon line in Victoria, B.C. The pipe is completely resistant to seawater and its smooth surface discourages the adherence of algae and other marine growths.

SCLAIRPIPE used in a tailing applications at a molybdenum mine in Arizona. Inclusion of 2% finely dispersed carbon black ensures that the pipe is resistant to ultraviolet light degradation enabling it to be installed at grade. Anchoring of the pipeline is achieved simply by dumping a load of tails on the pipe at regular intervals.

Internal Pipe Pressure

Pressure performance requirements for SCLAIRPIPE at 73.4°F are as follows:

ASTM F714	The pipe shall not fail, when tested by the methods detailed in ASTM D1599, in 60 to 70 seconds at a pressure less than 3.63 times the standard pressure rating.
ASTM F714	The pipe shall not fail, when tested in accordance with ASTM D1598, in 1,000 hours at a pressure equal to 2 times the pipe standard pressure rating.
ASTM D2837	The pipe shall withstand a pressure equivalent to 1.97 times the pipe's standard pressure rating for a period of 11.4 years (100,000 hours).

It should be noted that the above requirements are test requirements under laboratory conditions and therefore must be adjusted by a design factor to be used for pipe pressure rating purposes. Although a basic design factor of 0.5 is used for determining long-term (50 years) operating limits, shorter term phenomena may be related to the "safe strain limit" which laboratory investigations demonstrate to be approximately 3% to 4%. The following maximum stress levels are therefore recommended for protection against varying terms of pressure exposure for Sclairpipe produced from a PE3408 material:

Duration of Surge or Pressure Phenomena	Maximum Allowable Hoop Stress at 73.4°F
Instantaneous (up to 60 sec.)	1600 psi
Up to 1 hour	1465 psi
1 hour to 1,000 hours	1070 psi
Sustained pressure, 50 years	800 psi

The above recommendations are based on the assumption that the pipe will not be subjected to other imposed stresses. They refer to phenomena which cease within the time limits given and the pipe then returns to a "normal" operating pressure. These phenomena may be repeated with reasonable expectation that the service life expectancy of the piping will not be significantly affected.

Regular pressure cycling, outside of hydraulic transient situations, should not be accommodated in this way. When such cycling is expected as a regular condition of operation, the highest pressure anticipated for the majority of the operating time should be considered as the operating pressure and treated as though it would persist continuously for the design life of the system.

SHOCK LOADS

Hydraulic shock loads (sometimes called "water hammer") can be difficult to calculate in complex systems, however, their presence and cause can be predicted. For further information reference should be made to the "Waterhammer and Hydraulic Transients" section of this manual.

It is often more economical to eliminate the cause rather than attempt to accommodate stresses by increasing the standard pressure rating of the selected pipe. It is known that under some conditions, a lighter weight pipe will be more resistant to damage under these conditions than a heavier weight pipe and that rigid materials and structures will increase the magnitude of the stresses. Overpressure is not likely to be a limiting factor in design. Negative pressures, resulting from column separation and pressure shocks resulting from the collapse of the separation, are more likely to be limiting factors in design.

EXTERNAL LOADS

Performance limits with regard to earthloading design and external hydraulic loading follow the recommendations given in "Earthloading - Design of Underground Piping Systems" and "Vacuum and External Hydraulic Overpressure" sections of this manual. Strength requirements under these conditions are functions of the cube of the Dimension Ratio (DR).

ENVIRONMENTAL CONDITIONS

Temperature is the most important environmental consideration. For operation at temperatures in excess of 73.4°F, a thermal service factor should be applied to the pressure rating as described in "Design Considerations Related to Environment" section of this manual.

Corrosive conditions are normally not a consideration with SCLAIRPIPE, but they do occur in industrial processing uses associated with strong oxidizing chemicals (see section on "Chemical Resistance and Permeability"). Oxidation, which results from exposure to certain aggressive chemicals is usually manifested by embrittlement of the surface and a significant reduction in the long-term stress resistance of the material.

The polyethylene material used in the manufacture of SCLAIRPIPE has a high resistance to environmental stress cracking. However, when the pipe is stressed in the presence of certain surface active chemicals, e.g. wetting agents, environmental stress cracking can take place with a detrimental effect to the products projected long-term life.

When chemical resistance is in doubt, exposure tests are recommended. Generally these tests follow the procedures described in ASTM D543. Changes in tensile properties can be measured on ring tensile specimens in accordance with the procedures described in ASTM D2513, paragraph 8.6. Significant variation between control specimens and those exposed to the chemical is generally accepted as evidence of corrosive degradation and decisions as to use of SCLAIRPIPE in this application shall be made accordingly.

Direct assistance of KWH technical personnel is recommended where further explanation and assistance is required.

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Flow Rates and Frictional Losses

INTRODUCTION

SCLAIRPIPE high density polyethylene pipe has a mirror smooth interior surface which offers practically no resistance to flow due to roughness. The surface is hydrophobic, i.e. not subject to a wetting action that can increase the drag effect at the pipe wall. This surface is retained throughout the product service life because of the lack of corrosive action. For these reasons, frictional losses are lower in SCLAIRPIPE than in most other piping systems.

The flow loss in pipes under pressure is commonly calculated from the Hazen Williams formula:

$$V = 1.318\ C\ R^{o\ .63}\ S^{o\ .54}$$

in combination with the general flow formula:

$$Q = AV$$

giving:

$$Q = 16.55\ C\ R^{2\ .63}\ S^{o\ .54}$$

where:

Q = volume of discharge (ft.^{3} per sec.)
C = a cold water flow resistance factor representing the roughness of the interior surface of the pipe
R = hydraulic radius of pipe (ft.)
S = frictional head loss (ft. per lineal feet of pipe)
V = mean velocity of flow (ft. per sec.)
A = cross-sectional area of pipe (ft.^{2})

For pipelines consisting of continuously extruded SCLAIRPIPE, a Hazen Williams C-factor of 150 to 155 is generally used in the above formula for water flowing in the pipe. This value recognizes the essentially frictionless nature of SCLAIRPIPE, and represents about the highest permissible C-factor based on Moody's work on "frictionless" pipe. When standard pipe lengths are joined by butt fusion into continuous lines, the resulting fusion beads have a minor effect on the overall friction factor and the use of a "C" value of 150 is recommended. These values have been substantiated by test work conducted by the National Research Council in Ottawa. The testing was done using a 200 foot length of butt-fused 4 inch SCLAIRPIPE. Tests were first done with fusion beads in the line and secondly with the fusion beads reamed out.

Head losses in flowing systems are normally composed of two components, the retardant to flow in the pipe due to friction at the walls and the retardant to flow due to elevation changes and directional changes at elbows, tees or valves. For directional changes, the standard method of relating head losses to equivalent footage of pipe should be used and the C-factor of 150 (for fusion-joined systems) should be applied to the total equivalent footage of pipe.

Over the life of the pipe, there will be no corrosion or solution effect and the interior surface will be changed only through deposit of scale or algae, neither of which adhere tightly to polyethylene and hence, will have a very small effect on flow.

Experimental testing for flow coefficients in forced sewage systems has been conducted by an independent engineering consultant. Tests were done on two separate sewage forcemains, approximately 1000 and 1800 feet in length, both constructed of 6 inch SCLAIRPIPE. The lines, carrying typical municipal sewage, had both been operating for more than five years. Based on these tests, a long-term "C" value of 130 is recommended for forced sewage applications.

Where uneven grades may cause air entrapment or where the nature of the fluid is such that deposition of solids may occur to a significant extent, the use of a lower C-factor may be justified. Elimination of the problem through the use of bleedoffs, venting valves, flush-out ports and other familiar appurtenances is as practical with SCLAIRPIPE as with conventional piping materials, and is usually less expensive that the use of overdesign as a means of correction.

Published flow loss tables are available for all sizes of SCLAIRPIPE from your local SCLAIRPIPE representative, to simplify the procedure of selecting an appropriately sized pipeline for your application.

Waterhammer and Hydraulic Transients

CAUSES OF WATERHAMMER AND HYDRAULIC TRANSIENTS

Any sudden reduction in the velocity of a moving water column in a pipe causes all or part of its energy to be expended in the form of a shock or pressure wave moving within the pipe at a defined velocity. The wave velocity is that of an acoustic wave in an elastic medium, the elasticity of the medium being a compromise between that of the liquid and that of the pipe. Reflection of the wave at the pipe discharge and causes movement of a negative pressure wave back up the pipe. Each successive reversal, together with energy losses incurred as the wave courses through the pipe, causes dampening or a reduction in the intensity of the shock until the waves "die out". Energy losses arise from the wave compressing the liquid itself, from stretching of the pipe walls and from frictional resistance to wave propagation. A positive pressure wave from waterhammer is additive to the normal hydrostatic pressure and, depending on the conditions under which it was imposed, can create very high instantaneous pressures in the system.

Hydraulic transients can be created in several ways and may result in either positive or negative pressures. The most common occurrence is the too rapid closure of a valve in a line or the sudden shutdown of a pump. On the upstream side of the valve, the energy of the moving fluid column compresses the fluid against the closed valve, bringing it to rest and stretching the pipe walls. A higher than normal hydrostatic pressure is created at the valve and as such successive layer of fluid, so to speak, is compressed against the valve, the high pressure moves upstream as a wave. On the downstream side of the closed valve, the inertia of the fluid column causes it to separate from the valve, creating a very rapid loss in pressure to a valve below atmospheric and causing some liquid to vaporize. The resulting pressure condition at this point becomes that of the fluid's vapour pressure at the existing temperature. This negative pressure wave propagates downstream and assists in bringing the water column to rest. These two examples represent only the first steps in the creation of pressure waves; a more thorough discussion of the events following can be obtained from the literature.

INDUCED OVERPRESSURE AND SHOCKWAVE VELOCITY IN SCLAIRPIPE

In one of the simplest systems with no appurtenances (pumps, surge tanks, etc.) other than a valve that is suddenly closed, the excess pressure that can be developed in SCLAIRPIPE polyethylene pipe can be calculated from the following equation:

$$Ps = \frac{a \quad \Delta V}{2.31 \ g}$$

where:

Ps = excess pressure due to waterhammer, (psi)

ΔV = change in velocity causing waterhammer, (ft/s)

g = acceleration due to gravity, (32.2 ft/s^2)

a = velocity of wave travel in elastic pipe, (ft/s)

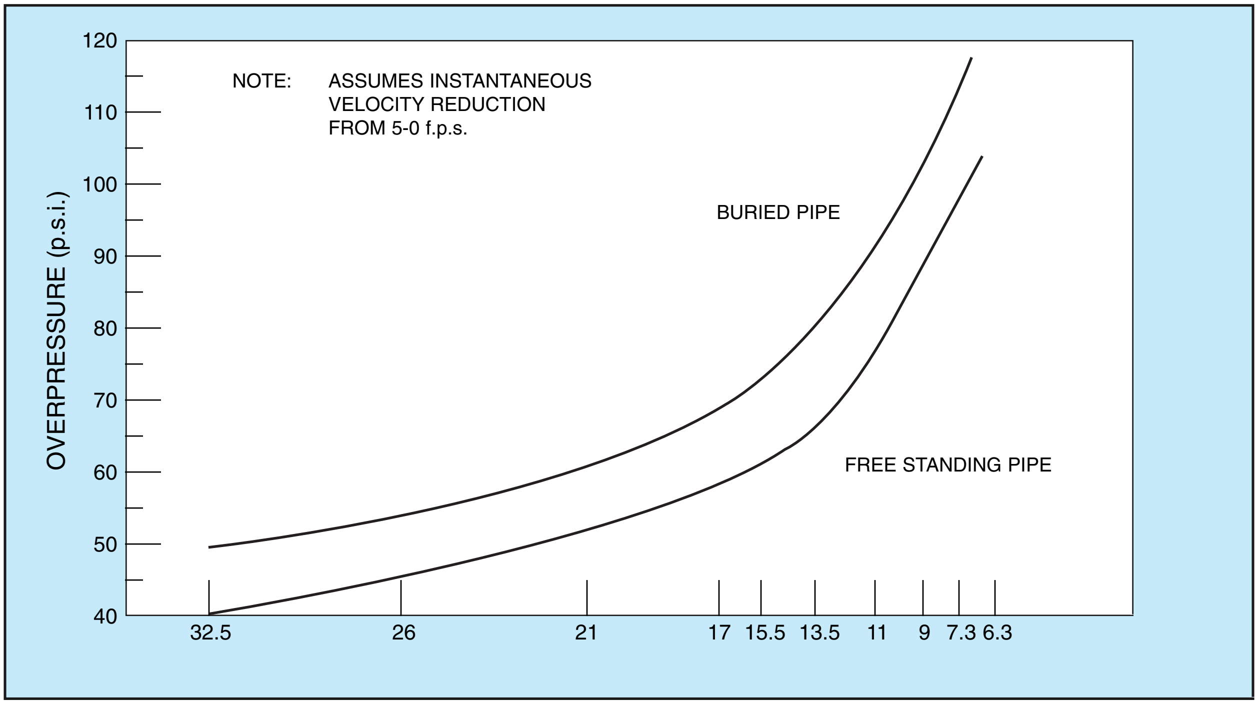

Figure 1: Induced Overpressure in SCLAIRPIPE

The value of "a" depends on the method of anchoring. The usual installation condition for polyethylene pipe is that in which it is anchored against movement throughout its length, as it occurs when it is buried underground. The other installation condition is that in which the pipeline is not anchored against movement, as it occurs in free-standing pipe.

The equations for determining "a" are:

$$a = \frac{5{,}660}{\left[1 + \frac{K\,(DR-2)}{E}\right]^{1/2}} \quad \text{(Buried Pipe)}$$

$$a = \frac{4720}{\left[1 + \frac{K\,(DR-2)}{E}\right]^{1/2}} \quad \text{(Free-Standing Pipe)}$$

where:

K = bulk modules of elasticity of liquid, in psi (approx. 300,000 psi for water)

DR = dimension ratio $= \frac{\text{outside diameter}}{\text{min. wall thickness}}$

E = instantaneous modules of elasticity in tension for pipe material (150,000 psi)

Comparative calculations show that, under similar conditions, wave velocities and the resulting overpressures in buried SCLAIRPIPE are in the order of 1/5 of those experienced in steel pipe. (See Fig. 1). The lower overpressures in SCLAIRPIPE are advantageous, however, due to the slower wave velocities, valve or pump operating procedures may require modification. The time "period" of the wave is defined as twice the length of the line under consideration divided by the wave velocity. To avoid reinforcement of the pressure waves, it is necessary to make changes in fluid column velocity over a time interval that allows successive pressure waves to dampen out. The changes should be made over an interval representing some 6 to 8 times the pipe "period". For example, if the pipe period is calculated to be 4 seconds, valve openings and closings should be restricted to a minimum interval of about 25 seconds. When pumps are involved, a valve at the pump discharge should be in the closed position for pump startup and should be closed prior to pump shutdown; it should also be ensured that the valve operating interval exceeds the minimum time interval.

The addition of appurtenances on the pipeline complicates calculation of the "period" and analysis of the waterhammer situation. Graphical solutions are available, however, a full analysis of the phenomenon of hydraulic transients is very complicated for most systems.

The design of SCLAIRPIPE provides for a shockwave overpressuring of two times the pressure rating of the pipe. If the analysis indicates that this design limit (2 times recommended operating pressure for the pipe) will be exceeded, the system should be designed so as to reduce or eliminate the causes of overpressuring. It is generally recommended that the possibilities of waterhammer and its effect be investigated for pumped lines or gravity flow lines operating at velocities in excess of five feet per second.

28 inch series 60 SCLAIRPIPE was used to replace a woodstave line at a mine site in Noranda, Quebec. This 10,000 foot water supply line had a design pressure of 50 psig and was installed in 1978.

SCLAIRPIPE was the material of choice for a 20 mile brine line running from a potash mine in Sussex, N.B. to the Bay of Fundy. The line was installed without surge protection devices although it included sections operating in excess of 200 psig.

Earthloading - Design of Underground Piping Systems

INTRODUCTION

This section defines the performance limits for SCLAIRPIPE polyethylene pipe in the following three burial environments - in varying soils and soil compaction levels, in firm soils where the buried pipe is subjected to external hydrostatic pressure and in firm and loose soils with the buried pipe subjected to internal vacuum or net external hydrostatic pressure. In all cases, the pipe is considered to be empty with no resistance to deflection contributed by internal pressure.

Flexible conduits react to earthloads or external hydrostatic loads very differently than rigid pipes do. The natural ring stiffness of the flexible pipe contributes only a small portion of the total resistance to deflection; most of the resistance arises from the soil stiffness. When the buried pipe deflects slightly in the vertical axis, the accompanying outward movement of the pipe side walls mobilizes the support available due to the stiffness of the surrounding soil envelope. Figure 2 provides an illustration of this mobilization process. The pipe is supported against further movement and exhibits load-bearing capabilities far greater than unsupported pipe. The amount of support which is available in the embedment soil is a direct consequence of the installation procedure. The stiffer the embedment materials are; the less deflection occurs and the more stable the pipe-soil system is.

DESIGN CRITERIA

When selecting the most appropriate wall thickness or DR for Sclairpipe to resist anticipated burial conditions or when confirming the adequacy of a selection which was made based on pressure class requirements three design criterion are considered separately; vertical deflection, wall buckling and wall compression or crushing. The amount of deflection which can be expected under specific burial conditions may be estimated using the form of the Iowa pipe deflection formula presented below. The estimated vertical deflection as a percentage of the mean pipe diameter is then compared to the safe design limits presented in Table 1. In order to verify the adequacy of the pipe-soil system against wall buckling or collapse the *safe allowable buckling load* (q_a) is determined using the equation presented and compared to the anticipated applied loads. Compressive stress in the pipe walls may also be estimated and compared to the safe compressive strength of HDPE which is conservatively estimated as 800 psi.

DEFLECTION

$$\Delta y = \frac{(D_l W_C + W_L)\, K_X\, r^3}{EI + 0.061E'r^3} \qquad (1.0)$$

Where; Δy = predicted vertical pipe deflection in inches.

D_l = the deflection lag factor to compensate for the time-consolidation rate of the soil, dimensionless. Normally estimated as 1.5.

W_C = vertical soil load on the pipe per unit length, in pounds per linear inch. W_C is estimated by multiplying the appropriate value from Table 2 by the outside diameter (in inches) of the pipe.

W_L = live load on the pipe per unit length, in pounds per linear inch. W_L is estimated by multiplying the appropriate value from Figure 3 by the outside diameter (in inches) of the pipe.

K_X = deflection coefficient, dimensionless, Use 0.083 for most installations.

r = mean pipe radius in inches.

$r = (O.D. - t_{min})/2$

t_{min} = minimum wall thickness of pipe in inches.

E = Apparent modulus of elasticity of the pipe material in psi. A long-term apparent modulus of 30,000 psi may be used in most situations.

I = the moment of inertia of the pipe wall for ring bending in inches^4/inch.

$I = t_{min}^3/12$

E' = modulus of soil reaction, in psi. The appropriate value for E' should be selection from Table 3.

Table 1
SAFE DESIGN LIMITS

Dimension Ratio	Allowable Vertical Ring Deflection as a % of Diameter
32.5	8.6
26	6.5
21	5.0
17	4.0
11	3.3
9	2.6

WALL BUCKLING

The safe allowable buckling load for the soil-pipe structure (q_a) is estimated as follows;

$$q_a = (DF)\,(32\, R_w\, B'\, E'\, EI/D_{avg}^3)^{0.5} \qquad (2.0)$$

Where: q_a = safe allowable buckling load in psi.

DF = design factor, 0.40

R_w = water buoyancy factor, calculated as follows;

$R_w = 1 - 0.33(h_w/h);\ 0 \leq h_w \leq h$

Where: h_w = height of ground water surface above top of pipe in inches.

h = height of ground surface above top of pipe in inches.

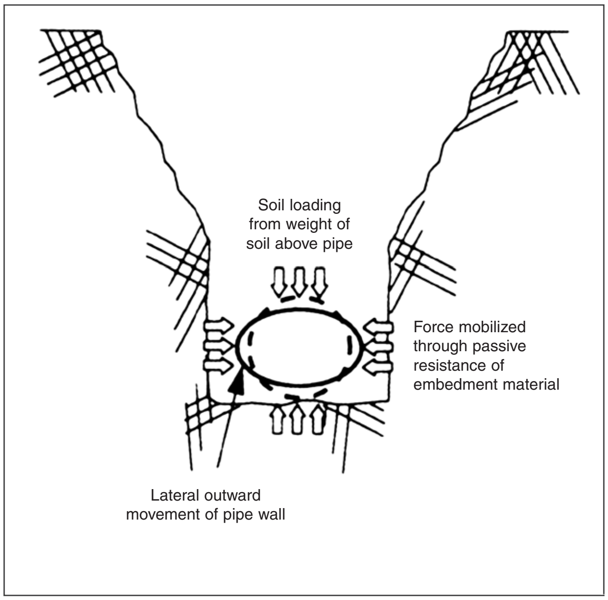

Figure 2: Mobilization of Enveloping Soil through Pipe Deformation

Table 2

Vertical Soil Load in lbs./in²				
Depth to Top of Pipe in ft.	Soil Density 90 lbs.ft³	Soil Density 100 lbs.ft³	Soil Density 110 lbs.ft³	Soil Density 120 lbs.ft³
1	0.6	0.7	0.8	.8
2	1.3	1.4	1.5	1.7
3	1.9	2.1	2.3	2.5
4	2.5	2.8	3.1	3.3
5	3.1	3.5	3.8	4.2
6	3.8	4.2	4.6	5.0
7	4.4	4.9	5.3	5.8
8	5.0	5.6	6.1	6.7
9	5.6	6.3	6.9	7.5
10	6.3	6.9	7.6	8.3
12	7.5	8.3	9.2	10.0
14	8.8	9.7	10.7	11.7
16	10.0	11.1	12.2	13.3
18	11.3	12.5	13.8	15.0
20	12.5	13.9	15.3	16.7
25	15.6	17.4	19.1	20.8
30	18.8	20.8	22.9	25.0

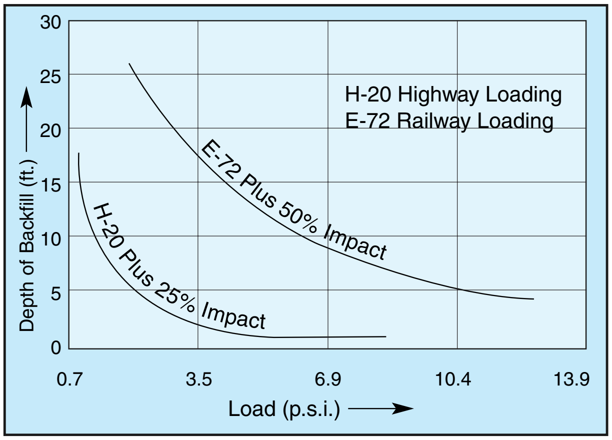

Figure 3: Live loading due to vehicle traffic

Table 3
Embedment Classes per ASTM D-2321

			Average Value of E'			
			Degree of Compaction of Embedment Material[1] (Standard Proctor)			
Class	Soil Description	Soil Group Symbol	Dumped	Slight 85%	Moderate 90%	Heavy > 95%
IA	Manufactured aggregate angular open-graded and clean. Includes crushed stone, crushed shells.	None	500	1000	3000	3000
IB	Processed aggregate, angular dense-graded and clean. Includes Class 1A material mixed with sand and gravel to minimize migration.	None	200	1000	2000	3000
II	Coarse-grained soils, clean. Includes gravels, gravel-sand mixtures, and well and poorly graded sands. Contains little to no fines (less than 5% passing #200).	GW, GP, SW, SP	200	1000	2000	3000
II	Coarse-grained soils, borderline clean to "with fines". Contains 5% to 12% fines (passing #200).	GW-GC, SP-SM	200	1000	2000	3000
III	Coarse-grained soils containing 12% to 50% fines. Includes clayey gravel, silty sands, and clayey sands.	GM, GC, SM, SC	100	200	1000	2000
IVa	Fine-grained soils (inorganic). Includes inorganic silts, rock flour, silty-fine sands, clays of low to medium plasticity, and silty or sandy clays.	ML, CL	50	200	400	1000
IVb	Fine-grained soils (inorganic). Includes diatomaceous silts, elastic silts, fat clays.	MH, CH	No date available; consult a competent soils engineer. Otherwise use E' equals zero.			
V	Organic soils. Includes organic silts or clays and peat.	OL, OH, PT	No date available; consult a competent soils engineer. Otherwise use E' equals zero.			

[1] E' values taken from Bureau of Reclamation table of average values and modified slightly herein to make the values more conservative.

B' = empirical coefficient of elastic support, dimensionless. Calculated as follows;

$$B' = (1 + 4e^{-0.065H})^{-1}$$

Where: H = burial depth to the top of the pipe in ft.

D_{avg} = mean pipe diameter (O.D. - t_{min})

For most pipe installations satisfaction of the wall buckling requirement is assured when the following equation is true;

$$\gamma_w h_w + R_w(W_C/D_{avg}) + P_v \leq q_a \tag{2.1}$$

Where; γ_w = specified weight of water (that is, 0.0361 lbs./in.³) in pounds per cubic inch.

P_v = internal vacuum pressure (that is, atmospheric pressure less the absolute pressure inside of the pipe), in pounds per square inch.

In some situations, consideration of live loads in addition to dead loads may be appropriate. However, simultaneous application of the live-load and internal vacuum transients need not normally be considered. When live loads are being considered, the buckling requirement is assured when the following equation is true;

$$\gamma_w h_w + R_w(W_C/D_{avg}) + W_L/D_{avg} \leq q_a \tag{2.2}$$

COMPRESSION

The compressive stress which will exist in the pipe wall due to anticipated burial loads (σ_C) can be estimated using the following equation;

$$\sigma_C = (W_C + W_L) / (2t_{min}) \tag{3.0}$$

Satisfaction of the wall compression is assured when the following equation is true;

$$\sigma_C \leq 800 \text{ psi} \tag{3.1}$$

CRITICAL PRESSURE FOR UNSUPPORTED PIPE:

In locations such as bogs, swamps or underwater, empty polyethylene pipelines can collapse if subjected to an excessive external/internal pressure differential. Such differential pressures may be caused by drawing a vacuum or by simply increasing the external hydraulic loading. Limiting critical pressures have been calculated from the modified Iowa Equation using a modulus (pipe stiffness) equivalent to 50 years of exposure to the critical pressure. Table 4 shows the critical pressure at 73.4°F for various pipe DRs or wall thicknesses. These critical pressures will cause full collapse of a pipe which has no initial deflection and is subjected to no stresses other than the net external pressure. However, damage can result to the pipe through excessive straining before full collapse, necessitating other safety factor considerations. For more information on the selection of pressure rating for unsupported pipe, see the section on Vacuum & External Hydraulic Overpressure.

Table 4
CRITICAL PRESSURES FOR PIPE WITHOUT SUPPORT

Dimension Ratio	Net External Critical Pressure (Pcr) (psi)
32.2	1.0
26	1.9
21	3.6
17	6.8
15.5	8.9
13.5	13.5
11	25.0
9	45.7

CRITICAL PRESSURE FOR SOIL-SUPPORTED PIPE:

Experimental work has shown that soil-supported pipe has a much greater capacity to withstand vacuum or net external pressures than pipe without support. This is particularly important when evaluating the effect of negative hydraulic transient pressures that may arise in pressure lines with sudden valve closures or pump failures. Treatment of this problem should be referred to your nearest KWH Pipe office.

Bedding Limitations:

- Always level the trench bottom, taking care to remove all sharp rocks and/or protrusions within 6 inches of the pipe.
- Ensure that the bedding material is worked into uniform contact with the pipe at the haunches.
- When bedding soil is non-compactible by its own weight, use mechanical compactions - DO NOT MECHANICALLY COMPACT DIRECTLY ON TOP OF THE PIPE - PLACE ONE FOOT OF BEDDING BEFORE COMPACTING DIRECTLY OVER THE PIPE.
- Do not allow rocks or frozen clods within a one foot bedding “envelope” around the pipe.
- See the Construction brochure for further details and burial information.

SAMPLE PROBLEM:

Problem

A 48” DR32.5 sewer pipe is to be buried with a depth of cover of 10 feet to the top of the pipe and must withstand H-20 truck traffic.

If the pipe is above the groundwater table and embedded in Type IB material (γ_S = 110 lbs/ft.) compacted to 85% Standard Proctor Density, is the pipe selection adequate?

Solution

Part 1 Deflection;

$W_C = 7.6 \times 48 = 364.8$ lbs/in.

$W_L = 1.4 \times 48 = 67.2$ lbs/in.

$r = (48 - 1.453)/2 = 23.274$ in.

$I = 1.453^3 / 12 = 0.256$ in.

$E' = 1{,}000$ psi

$$\therefore y = \frac{(1.5 \times 364.8 + 67.2)\ 0.083 \times 23.274^3}{30{,}000 \times 0.256 + 0.061 \times 1{,}000 \times 23.274^3} \qquad (1.0)$$

$= 0.828$ in.

$= 1.78$ % of the mean pipe diameter

∴ Pipe selection is adequate for deflection criteria

Part 2 Wall Buckling;

$h_w = 0.00$ in.

$R_w = 1.00$

$B' = (1 + 4e^{-0.065 \times 10})^{-1}$

$= 0.324$

$D_{avg} = 48 - 1.453$

$= 46.547$ in.

$\therefore q_a = (1/2.5)(32 \times 0.324 \times 1{,}000 \times 30{,}000 \times 0.256/46.547^3)^{0.5}\ (2.0)$

$= 11.24$ psi

Now check:

$0.0361 \times 0.00 + 1.00 \times 364.8/46.547 + 67.2/46.547 \leq q_a \quad (2.2)$

$9.281 \text{ psi} \leq 11.24 \text{ psi}$

∴ Pipe selection is adequate for buckling criteria

Part 2 Wall Compression; (3.0)

$\sigma_c = (364.8 + 67.2) / (2 \times 1.453)$

$= 148.658$ psi

$\sigma_c \leq 800$ psi (3.1)

∴ Pipe selection is adequate for wall crushing criteria

Since the selected pipe meets the requirements of all three of the design criteria the pipe selection is structurally adequate.

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Vacuum & External Hydraulic Over-Pressure

SELECTION OF APPROPRIATE DR RATING FOR UNSUPPORTED PIPE

When SCLAIRPIPE polyethylene pipe is to be subjected to a negative pressure, a pipe of sufficiently heavy wall thickness should be chosen so that it will not be permanently damaged or deformed.

This section gives guidelines for the selection of the appropriate DR rating for pipe that is not buried and thus has no external side support. For buried systems, where even light compaction will help prevent pipe collapse, higher negative pressures can be sustained. See the Systems Design section entitled “Earthloading - Design of Underground Piping Systems” for the DR selection for buried pipe.

The term “negative pressure” is defined as the sum of the internal pressure and the pressure exerted on the outside of a pipe by a fluid medium (external hydraulic pressure). Net pressure acting radially away from the pipe centerline is defined as positive and that acting towards the centerline, tending to collapse the pipe, is considered negative.

Example: If a water suction line is running under a partial vacuum of 5 psi, through a swamp at a depth of 30 ft. (equivalent to 13 psi), the net negative pressure exerted on the pipe by the outside medium and the internal fluid is 18 psi.

In installations where SCLAIRPIPE is not buried and not supported, it may be subjected to stresses that tend to deform the pipe, causing strain. If the material in the pipe wall is strained beyond permissible limits, permanent damage can occur before the pipe fully collapses. The choice of pipe wall thickness should be based on the duration and frequency of application of the “negative pressure” (external pressure or vacuum), the final ovality which will be produced throughout the life of the pipe and the resulting material strain. Additional factors that affect the collapse mechanism are temperature, the initial ovality and the previous stress history of the pipe.

Table 5 gives suggested limits on “negative pressures” for various DR ratings of SCLAIRPIPE. This table represents the worst case: a series of periodic pressure applications of varying duration, at a maximum material temperature of 73.4°F, assuming a maximum initial ovality of 2% and an effective safety factor of 2.

If a situation arises that is not covered by the restrictions of these tables, or if more definitive information is required, a qualified KWH Pipe representative should be contacted.

Table 5: ESTIMATED CRITICAL EXTERNAL COLLAPSE PRESSURE (psi) - FOR UNSUPPORTED SCLAIRPIPE¤ vs TIME UNDER CONTINUOUS EXTERNAL PRESSURE LOADING AT 73.4¡F.

Initial ovality: 2% Includes: 2:1 Safety Factor

Time Duration of Load (Creep Modulus)	SCLAIRPIPE DR									
	32.5	**26**	**21**	**17**	**15.5**	**13.5**	**11**	**9**	**7.3**	**6.3**
1 minute (110,000 psi)	3.6	6.9	13.2	24.8	32.8	49.6	91.7	167.4	313.8	488.2
1 hour (53,500 psi)	1.7	3.4	6.4	12.1	15.9	24.1	44.6	81.4	152.6	237.4
10 hours (42,500 psi)	1.4	2.7	5.1	9.6	12.7	19.2	35.4	64.7	121.2	188.6
100 hours (39,000 psi)	1.3	2.5	4.7	8.8	11.6	17.6	32.5	59.4	111.3	173.1
1,000 hours (34,000 psi)	1.1	2.1	4.1	7.7	10.1	15.3	28.3	51.8	97.0	150.9
10,000 hours (32,000 psi)	1.0	2.0	3.8	7.2	9.5	14.4	26.7	48.7	91.3	142.0
50 years (30,000 psi)	1.0	1.9	3.6	6.8	8.9	13.5	25.0	45.7	85.6	133.1

Chemical Resistance

INTRODUCTION

Outstanding resistance to both internal and external chemical attack has made the SCLAIRPIPE system the material of choice for the transport of lower temperature (below 150°F) fluids in adverse chemical environments. High-density polyethylene is chemically inert to a wide range of industrial chemicals.

The chemical, its concentration in the fluid, its temperature, its contact time with the piping material and other service conditions, determines the suitability and expected service life of the SCLAIRPIPE system for the application. For most bases, acids, inorganic salts and other chemicals, you usually apply the same design parameters as considered for water service conditions. Chemical attack of SCLAIRPIPE may be divided into three categories: OXIDATION, STRESS-CRACKING and PLASTICIZATION.

OXIDIZERS are the only group of materials which are capable of chemically degrading the SCLAIRPIPE system. Some strong oxidizers have only a gradual effect on the pipe, therefore short-term effects are not measurable. If continuous exposure is expected, chemical effects should be defined. The following oxidizers are unsuitable for long-term contact with the SCLAIRPIPE system: Nitric acid (fuming), Sulphuric acid (fuming), Aqua Regia, wet chlorine gas and liquid bromine. However, weaker solutions of mineral acids, such as battery acid or reagent nitric acid, do not attack the pipe. Other common oxidizing agents, such as hydrochloric acid, hydrofluoric acid, hydrobromic acid and hydrogen peroxide have been shown to have no measurable effects on SCLAIRPIPE after 3 or 4 years' exposure.

STRESS CRACKING AGENTS are chemicals that accelerate the cracking of polyethylene when subjected to stress, but have no chemical effect on the material itself. Although some polyethylenes are extremely sensitive to brittle fracture, SCLAIRPIPE is highly resistant to this type of failure.

PLASTICIZERS are chemicals that can be absorbed to varying degrees by polyethylene, causing softening, some loss of yield strength and some gain in impact strength. These plasticizing materials cause no chemical degradation of polyethylene and they are not solvents for the material. SCLAIRPIPE is designed to give high resistance to this absorption and consequent weakening, but if it is to be exposed continuously to these environments, an added safety factor should be applied. Some of these materials are sufficiently volatile that when they are removed, the pipe will "dry out" and return to its original strength. Intermittent exposure to these materials, therefore, has little or no effect on SCLAIRPIPE.

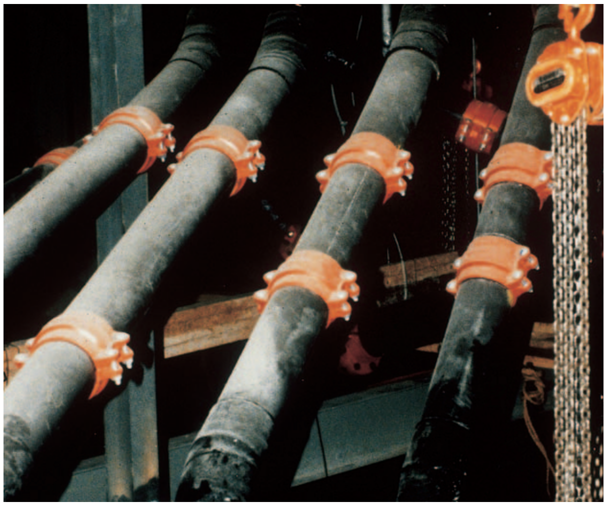
GENERAL GUIDE TO RESISTANCE OF SCLAIRPIPE TO VARIOUS CHEMICALS

This chemical resistance chart is a comprehensive listing of chemicals, concentrations and pipe resistance at two temperatures. In all cases, SCLAIRPIPE at higher temperatures should be considered to have variable resistance. Contact your KWH Pipe representative for design assistance in these applications.

CODE: R = Resistant
VR = Variable resistance, depending on conditions*
NR = Not resistant
O = Oxidizer
P = Plasticizer
SC = Potential stress-cracker

*The classification "variable resistance" is very broad. Depending on the nature of the chemical, its concentration, the service temperature and pressure and the time of exposure, SCLAIRPIPE can be either very resistant or very susceptible to attack. Therefore, when SCLAIRPIPE is said to have variable resistance to a chemical, it is strongly recommended that caution be exercised and that the specific application be discussed with a technical representative of KWH Pipe.

Installation of this 8 inch series 125 SCLAIRPIPE tailings line called for it to be supported on a trestle to maintain grade. Note the guides located at regular intervals to hold the pipe on the trestle during thermal expansion and contraction situations.



Polyethylene's abrasion resistance and chemical inertness were prime considerations in the decision to specify SCLAIRPIPE in this process pipe application.

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		73°F	120°F
Acetic acid, 20%	SC	R	R
Acetic acid, 80%	SC	VR	NR
Acetone	SC	NR	NR
Alcohol, ethyl		R	VR
Alcohol, isopropyl		R	R
Alcohol, methyl		R	R
Aluminum salts		R	R
Alums		R	R
Ammoniacal liquor		R	R
Amyl acetate		VR	NR
Aniline		R	R
Aqua Regia	O	NR	NR
Arsenic acid, 80%		R	R
Barium salts		R	R
Beer		R	R
Benzone (benzol)	P	NR	NR
Benzoic acid		R	R
Bleach plant wastes		R	R
Bleach 12.5% active chlorine		R	NR
Bleach 5.5% active chlorine		R	NR
Boric acid		R	R
Bromine, liquid	O	NR	NR
Bromic acid		NR	NR
Brine		R	R
Butadiene		R	VR
Butane		R	R
Butylene		R	R
Calcium salts		R	R
Calcium hydroxide		R	R
Calcium hypochlorite		R	R
Carbon disulfide	P	NR	NR
Carbon tetrachloride	P	N	NR
Chloric acid, 20%		R	NR
Chlorinated water		R	R
Chlorine (gas or liquid)	O	NR	NR
Chlorobenzene	P	NR	NR
Chloroform		NR	NR
Chromic acid, 50%		R	R
Copper salts		R	R
Corn Oil		R	VR
Cresol	P	NR	NR
Creosote, coatings	P	NR	NR
Cyclohexane	P	R	VR
Cyclohexanol	P	NR	NR
Detergent, synthetic	SC	R	R
Developers, photographic		R	R
Dextrin		R	R
Dichloroacetic acid		R	R
Dichlorobenzene	P	VR	NR
Dichloroethylene	P	NR	NR
Diesel fuels	P	R	VR
Diethylene glycol		R	R
Dimethylamine		VR	VR
Ethers		NR	NR
Ethylene glycol		R	R
Ethylene dichloride		NR	NR
Fatty acids		NR	NR
Ferric salts		R	R
Ferrous salts		R	R
Flourine, aqueous		VR	NR
Formaldehyde		R	R
Formic acid	O	R	NR
Fuel oil	P	VR	NR
Furfural		NR	NR
Gas, natural methane		R	R
Gasoline	P	NR	NR
Gelatin		R	R
Glycerine		R	R
Glycols		R	R
Glycolic acid		R	R
Heating oil	P	VR	VR
Hexane		R	VR
Hydrobromic acid, 20%		R	R
Hydrochloric acid, 30%		R	VR
Hydrofluoric acid, 10%		R	R
Hydrogen peroxide, 90%		R	NR
Hydrogen sulfide		R	R
Hypochlorous acid		R	R
Iodine, alc. sol.		NR	NR
Isooctane	P	VR	VR
Kerosene	P	NR	NR
Ketones		R	VR
Lactic acid, 25%		R	R
Lead acetate		R	R
Linseed Oil		NR	NR
Lubricating oils	P	VR	NR
Magnesium salts		R	R
Maganese sulface		VR	VR
Mercury		R	R
Methyl bromide		NR	NR
Methyl chloride		NR	NR
Methyl cyclohexane	P	VR	VR
Methyl ethyl ketone		R	R
Mineral oils	P	VR	NR
Mixed acids (sulfuric & Nitric)	P	NR	NR
Mixed acids (sulfuric & phosphoric)	P	R	VR
Molasses		R	R
Monochlorobenzene		NR	NR
Naphtha	P	VR	NR
Nitric acid, 0 - 50%		R	VR
Nitric acid, 60%	O	VR	NR
Nitric acid, fuming	O	NR	NR
Nitrous acid		R	NR
Oil, animal & vegetable	P	NR	NR
Oleic acid		NR	NR
Oleum		NR	NR
Oxalic acid		R	R
Paraffin		VR	NR
Perchloric acid, 10 - 70%		R	R
Petroleum, crude asphaltic		NR	NR
Petroleum, crude paraffinic		NR	NR
Phenol		VR	NR
Phosgene, gas		VR	VR
Phosgene, liquid		NR	NR
Potassium salts		R	R
Potassium permanganate, 25%		VR	VR
Propylene glycol		R	R
Pulp-mill wastes (red & black liquor)		R	R
Sea water		R	R
Sewage, residential		R	R
Silicic acid		R	R
Silicone oil		R	VR
Silver salts		R	R
Soap solution (concentrated)		R	R
Sodium salts		R	R
Sodium chlorite		VR	NR
Sodium chlorate		R	VR
Sodium hydroxide (caustic soda)		R	R
Sodium hypochlorite		R	R
Stannous chloride		R	R
Starch solution		R	R
Stearic acid		R	R
Sulfite liquor		R	R
Sulfur dioxide		R	R
Sulfuric acid, 0 - 90%		R	NR
Sulfuric acid, 90 - 100%	O	NR	NR
Sulfurous acid		R	R
Tannic acid		R	R
Tartaric acid		R	R
Tetrabromoethane	P	NR	NR
Tetrachloroethane	P	NR	NR
Tetrahydrofuran	P	NR	NR
Toluene	P	NR	NR
Transformer oil	P	VR	VR
Trichloroethylene		NR	NR
Turpentine	P	VR	NR
Urea		R	R
Vinegar		R	R
Whiskey		R	R
Xylene		NR	NR
Zinc salts		R	R

Design Considerations Related to Environment

BIOLOGICAL REACTIONS

Polyethylene is inert to biological degradation. It is indigestible, has no food value and will not support the growth of organisms of any kind.

Algae and Marine Growths:
The smooth surface of SCLAIRPIPE polyethylene pipe, particularly on the inside, discourages the adherence of algae growths. Under essentially static conditions of flow, algae may deposit on the inside walls, but they flush off readily at low velocities of flow. Barnacles, limpets and other similar types of marine growth are not attracted to the surface of SCLAIRPIPE; where they have become established, their size of growth and thickness of encurstation have been significantly smaller than those associated with other materials.

Termites, etc.:
SCLAIRPIPE is not attacked by termites, ants or other burrowing insects, or by marine worms such as teredos.

Rodents:
SCLAIRPIPE can be damaged by rodents but is not preferentially attacked by them. In ground infested by gophers or groundhogs, pipe should be placed more than 30 inches below the surface.

Toxicity:
The resin compound used in the manufacture of SCLAIRPIPE contains nothing which can be extracted by prolonged contact with water. It imparts no taste or odours to potable water. The antioxidant added to the compound to prevent thermal degradation during processing is of a type and in a quantity approved by Food and Drug control administrations in Canada, the United States, Great Britain and most European countries, for contact with food and potable water.

SUNLIGHT AND WEATHER

SCLAIRPIPE contains finely divided and thoroughly dispersed carbon black which gives virtually permanent protection against ultra-violet light. However, if pipe is intended for installation above ground, particularly in desert locations, it should be remembered that other problems may arise related to temperature differentials rather than simple degradation. These are discussed below under “Temperature”.

Exposure to conditions of alternating wetness and dryness or freezing and thawing does not require any special precaution.

TEMPERATURE

Operating Temperatures:

As with all homogeneous thermoplastic piping, polyethylene pipe loses stiffness and tensile strength as its temperature increases. SCLAIRPIPE is not normally recommended for use at temperatures in excess of 140°F. For systems where the service temperature frequently exceeds 73°F, the rated allowable working pressure of the pipe should be decreased.

The required pipe DR rating can be selected by using the minimum pressure rating, determined from Figure 4. The pipe chosen should have a long-term pressure rating at least as high as that determined from the following relationship:

$$\text{REQUIRED PIPE PRESSURE RATING} = \frac{\text{MAXIMUM OPERATING PRESSURE}}{\text{THERMAL SERVICE FACTOR}}$$

The required pipe DR rating is the closest available pressure rating above the calculated pressure rating.

The graph in Figure 4 is based on the same information as is used to derive the service life and margin of safety recommended for pipe operating at 73°F. The broken section of the curve is based on limited extrapolations of laboratory data. Care should be taken to ensure that pressure ratings determined by using this section are based on the worst possible conditions of temperature and pressure.

THERMAL SERVICE FACTOR

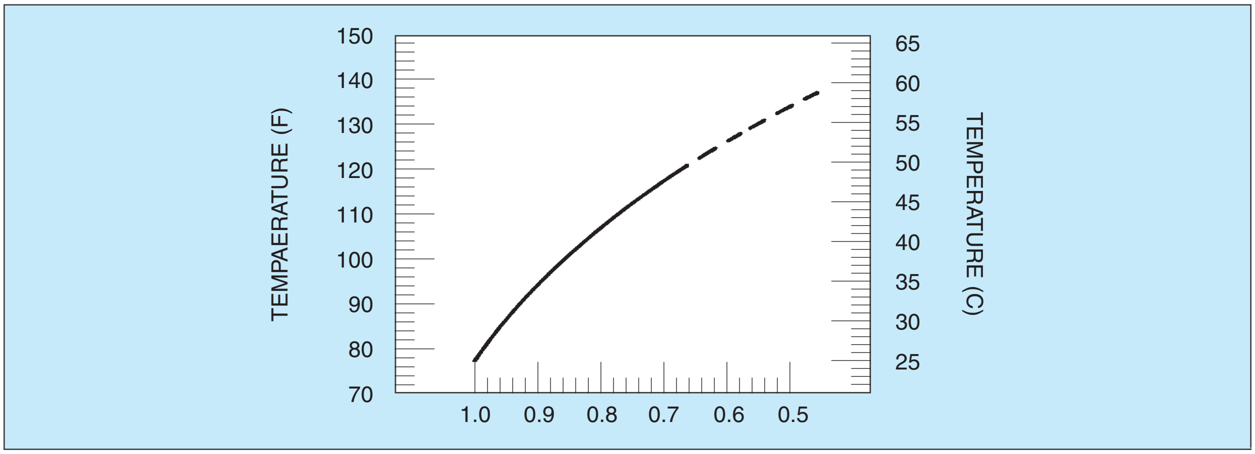

Figure 4: Thermal Service Factors for SCLAIRPIPE used at Service Temperatures higher than 73°F.

For gravity pipe in which the internal pressure is effectively zero, the service temperature should not exceed 150°F. Where there is high external stress on the pipe, the pipe DR rating may have to be selected by using the same thermal service factor as is used for pressure pipe. If the service requirements warrant a reduced service life or a different margin of safety, a qualified representative of KWH Pipe should be consulted for assistance.

Thermal Expansion:
The coefficient of thermal expansion for SCLAIRPIPE under completely unrestrained conditions is 8 x 10^{-5} in./in./°F. (14 x 10^{-5}cm./cm.°C). However, in most conditions of installation, some restraint is automatically provided. With pipes of 4 inch nominal diameter or greater, simple burial under 2 feet or more of soil usually provides ample restraint. Under these conditions, expansion or contraction due to temperature changes does not occur and no design considerations are required to provide restraint. Pipe installed in a trench should be at the temperature of the trench bottom before backfilling is started. The temperature differences after backfilling will not have any contraction or expansion effects because of the friction between the soil and pipe.

Smaller diameter pipes, i.e. $^1/_2$" to 3", should be snaked during installation in the trench, regardless of the burial depth, to increase the restraint available from friction with the soil.

If unrestrained, a pipeline installed above ground will tend to move laterally as a result of temperature changes, especially if the line is empty. If space is limited, or if the line is installed on a pipe bridge, restraining supports must be provided. When lateral movement is restricted, expansion will take place in either length or diameter, whichever is less restrained. (See Construction brochure, Surface Installation Section, for further details).

Of particular importance in design is the condition in which pipe passes from an area of adequate restraint into an area of poor restraint. Failures can result if the pipe and connections do not have adequate support at points of transition from large fixed structures to less restricting conditions. (See Construction brochure, Buried Installation Section, for further details).

Thermal Conducitivity:
Polyethylene is a relatively poor conductor of heat compared to metals. The coefficient of thermal conductivity for SCLAIRPIPE is approximately 2.5 BTU/hr/ft^2/°F. per inch of thickness. As a result, temperatures which are unevenly applied do not dissipate readily and thermal effects can be localized.

This property can be used to advantage in water systems in cold climates. The slow heat transfer inhibits freezing and, if the usual precautions are taken with respect to depth of burial, accidental freezing is practically eliminated. If the pipe does freeze, it does not burst and will resume its function upon thawing. Cyclical freezing, as in lines used for summer service only, is well tolerated but it is recommended that such lines be depressurized at shutdown. Irrigation lines have been operated in this way for many seasons without damage.

Localization of heated areas can cause noticeable deformation of the pipe. Solar heat, absorbed on one side of the pipe, is not readily conducted to the other side. Lines installed on the surface of the ground, unprotected from solar exposure, will require extensive anchoring to confine and control movement. The principle of design for such systems is to ensure that the movement is controlled over short lengths and is confined within a convenient plane where room to accommodate the movement can be provided.

INCIDENTAL DAMAGE

Despite its toughness and resilience, SCLAIRPIPE may be scuffed or scratched on the outside surface during handling. This does not affect its serviceability unless severe gouging or cutting takes place. In general, specifications should call for repair or removal of pipe which is gouged to depths greater than 10% of the wall thickness. V-shaped cuts of any depth occurring on the inside of the pipe must be removed.

At Kirkland Lake in Northern Ontario, a gravity sanitary sewer of 18 inch SCLAIRPIPE is installed in a rock tunnel. Pipe is laid above ground, tied down to wooden sleepers and secured with rock anchors.

In this mine tailings applications, 36 inch series 60 SCLAIRPIPE is installed at grade on a prepared right of way. The pipe routing incorporates a number of gentle bends to accommodate thermal expansion and contraction forces, minimizing the overall stresses on the pipe.

Complete Engineering - Our Specialty

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PLASTICS PIPE INSTITUTE

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Registered to
ISO 9002

Printed in Canada 07/02