Book 2: Chapter 9-Water Environment Design Considerations

Water environment applications include any installation in a predominantly water environment, such as outfalls and intakes, river, lake, and stream crossings, floating and submerged pipelines, and wetland and marsh area installations. Further, applications such as sliplining may require design consideration for external hydrostatic loads if the water table rises above the liner. Water environment design considerations include external hydraulic pressure, submergence weighting, and flotation at or above the surface.

External Hydraulic Pressure

For the purposes of this discussion, unrestrained DriscoPlex™ OD controlled polyethylene pipes are freestanding pipes that are not encapsulated in backfill or encased in grout. When installed where continuous or occasional submergence may occur, such pipes may be caused to collapse if the external hydraulic pressure exceeds the flattening resistance of the pipe.

Flattening resistance should be considered for applications such as pipes carrying gases, pipes partially full of liquids, and any application where the internal pressure is less than the static external hydraulic load.

Flattening resistance usually is not a consideration for outfall and intake lines where the end of the pipe is open to the external water environment, or for water or wastewater lines crossing under rivers, streams or lakes. Open ended lines will be pressure balanced, and the static head in a full pipe crossing a water body will usually be the same or higher than the water height above the pipeline.

Unconstrained Pipe Wall Buckling

Excessive external pressure will cause flattening. The maximum external load is determined not by material strength, but by stiffness. The pipe will flatten if the bending moment due to the load exceeds the resisting moment due to elastic stresses in the pipe. The critical external pressure above which round pipe will flatten can be estimated with Love's Equation:

$$P_{cr} = \frac{2E}{1-m^2}\left(\frac{1}{DR-1}\right)^3 \tag{9-1}$$

Where

P_{CR} = critical flattening pressure, lb/in^2
E = elastic modulus, lb/in^2 (Table 5-1)
µ = Poisson's ratio
(0.45 for polyethylene under long-term stress)
(0.35 for polyethylene under short-term stress)
DR = pipe dimension ratio

Pipe Ovality Effects

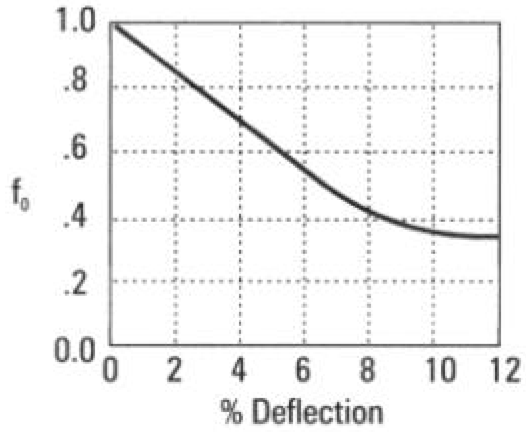
Pipe deflection will reduce flattening resistance, and lower the critical flattening pressure. The designer should apply an appropriate safety factor (2.0 or greater is typical).

$$P = \frac{f_O}{N} P_{cr} \tag{9-2}$$

Where

P = flattening pressure, lb/in^2
f_O = ovality compensation factor from Figure 9-1
N = safety factor

Figure 9-1 Ovality Compensation Factor for Unconstrained Buckling



Pipe deflection is determined by

$$\% Deflection = 100\left(\frac{D - D_M}{D}\right) \qquad \textbf{(9-3)}$$

Where

D = pipe average diameter, in
D_M = pipe minimum diameter, in

Values for external pressure resistance against flattening for selected sizes of Performance Pipe OD controlled PE 3408 pipe at selected service temperatures are presented in Table 9-2. The table values were developed using Table 5-1, Table 7-9, Figure 9-1 and a safety factor of 2.0.

Table 9-1 Selected Conversion Factors

Multiply	*by*	*To Obtain*
lb/in^2	2.307	ft H_2O
lb/in^2	2.036	in Hg
lb/in^2	0.006895	MPa
lb/in^2	0.06895	bar
lb/in^2	0.7032	m H_2O

Table 9-2 Approximate External Pressure Resistance for OD Controlled Pipe, lb/in^2

Values are for 3% oval pipe and include a 2.0 safety factor.

Service Temperature, °F	Pipe DR	50 Years	10 Years	1 Year	1000 Hours	100 Hours	10 Hours
40	9	72.8	81.7	98.1	113.0	132.2	148.5
	11	37.3	41.8	50.2	57.8	67.7	76.0
	13.5	19.1	21.4	25.7	29.6	34.6	38.9
	17	9.1	10.2	12.3	14.4	16.5	18.6
	21	4.7	5.2	6.3	7.2	8.5	9.5
	26	2.4	2.7	3.2	3.7	4.3	4.9
	32.5	1.2	1.3	1.6	1.9	2.2	2.4
	41	0.6	0.7	0.8	0.9	1.1	1.2
60	9	55.7	62.4	75.0	86.4	101.1	113.5
	11	28.5	31.9	38.4	44.2	51.7	58.1
	13.5	14.6	16.3	19.7	22.6	26.5	29.8
	17	7.0	7.8	9.4	10.8	12.6	14.2
	21	3.6	4.0	4.8	5.5	6.5	7.3
	26	1.8	2.0	2.5	2.8	3.3	3.7
	32.5	0.9	1.0	1.2	1.4	1.7	1.9
	41	0.4	0.5	0.6	0.7	0.8	0.9
73	9	52.6	58.8	70.7	81.3	95.3	107.0
	11	26.9	30.1	36.2	41.6	48.8	54.8
	13.5	13.8	15.4	18.5	21.3	25.0	28.1
	17	6.6	7.4	8.8	10.2	11.9	13.4
	21	3.4	3.8	4.5	5.2	6.1	6.8
	26	1.7	1.9	2.3	2.7	3.1	3.5
	32.5	0.9	1.0	1.2	1.3	1.6	1.8
	41	0.4	0.5	0.6	0.7	0.8	0.9
100	9	42.8	48.0	57.7	66.4	77.8	87.3
	11	21.9	24.6	29.5	34.0	39.8	44.7
	13.5	11.2	12.6	15.1	17.4	20.4	22.9
	17	5.4	6.0	7.2	8.3	9.7	10.9
	21	2.7	3.1	3.7	4.3	5.0	5.6
	26	1.4	1.6	1.9	2.2	2.5	2.9
	32.5	0.7	0.8	0.9	1.1	1.3	1.4
	41	0.3	0.4	0.5	0.5	0.6	0.7
120	9	27.9	31.3	37.6	43.2	50.6	56.8
	11	14.3	16.0	19.3	22.1	25.9	29.1
	13.5	7.3	8.2	9.9	11.3	13.3	14.9
	17	3.5	3.9	4.7	5.4	6.3	7.1
	21	1.8	2.0	2.4	2.8	3.2	3.6
	26	0.9	1.0	1.2	1.4	1.7	1.9
	32.5	0.5	0.5	0.6	0.7	0.8	0.9
	41	0.2	0.3	0.3	0.3	0.4	0.5

Submergence Weighting

A body submerged in a liquid displaces liquid equal to its volume. If the body weighs more than the weight of the liquid volume displaced, it will sink. If it weighs less, it will float. DriscoPlex™ polyethylene materials are lighter than water and pipe will float slightly above the surface when filled with water. Submerged pipe must be ballasted to keep it submerged.

Ballast weight design considers the fluids outside and inside the pipe, the liquid volume displaced, the weight of that displaced liquid volume, the weights of the submerged bodies (pipe, pipe contents, and ballast) and the environmental conditions.

Ballast Design for DriscoPlex™ OD Controlled Pipe

See Performance Pipe product literature for pipe dimensions and weights. The following is a step-by-step procedure for determining ballast weight for DriscoPlex™ OD controlled pipe.

Step 1

Determine volume of liquid displaced and buoyancy for one foot of pipe:

$$V_P = \frac{p\,D^2}{576} \quad \textbf{(9-4)}$$

$$B_P = V_P\,K\,w_{LO} \quad \textbf{(9-5)}$$

Where

V_P = displaced volume of pipe, ft^3/ft
D = pipe outside diameter, in
B_P = buoyancy of pipe, lb/ft
K = environmental multiplier (Table 9-2)
$?_{LO}$ = specific weight of the liquid outside the pipe, lb/ft^3

The environmental multiplier, K, compensates for the effects of tidal flows and currents. Unless neutral buoyancy is desired, K should be greater than 1.0.

Table 9-3 Environmental Multiplier, K

Underwater Environment	*K*
Neutral buoyancy	1.0
Lakes, ponds, slow moving streams or rivers, low currents and tidal actions	1.3
Significant stream or rover currents or tidal flows	1.5

Table 9-4 presents specific weights for various liquids. For other liquids and slurries Formula 9-6 may be used to calculate a specific weight when the specific gravity of the liquid is known. For this discussion, gasses (air, gas, carbon dioxide, etc.) in the pipe have a specific gravity of zero relative to water.

$$w_L = 62.4\,S_L \quad \textbf{(9-6)}$$

Where

$?_L$ = specific weight of liquid
S_L = specific gravity of liquid

Table 9-4 Specific Gravities and specific Weights of various liquids at 60°F (15°C)

Liquid	*Specific Gravity, S_L*	*Specific Weight, ? $_L$*
Gasoline	0.68	42.5
Kerosene	0.80	50.2
Crude Oil	0.86	53.1
Fresh water	1.00	62.4
Seawater	1.026	64.0
Brine, 6% NaCl	1.044	65.1
Brine, 12% NaCl	1.088	67.8
Brine, 18% NaCl	1.135	70.8
Brine, 24% NaCl	1.184	73.8
Brine, 6% $CaCl_2$	1.050	65.52
Brine, 12% $CaCl_2$	1.105	68.95
Brine, 18% $CaCl_2$	1.162	72.51
Brine, 24% $CaCl_2$	1.223	76.32
Brine, 30% $CaCl_2$	1.287	80.35

Step 2

Determine negative buoyancy (pipe weight and pipe contents weight):

$$V_B = \frac{p\,d^2}{576} \tag{9-7}$$

$$B_N = w_P + (V_B\,w_{LI}) \tag{9-8}$$

Where

V_B = pipe bore volume, ft^3/ft
d = pipe inside diameter, in
B_N = negative buoyancy, lb/ft
w_P = pipe weight, lb/ft
? $_{LI}$ = specific weight of the liquid inside the pipe, lb/ft^3

Table 9-5 Pipe Weight Conversion Factors

Multiply	*By*	*To Obtain*
PE 3408 Pipe weight, lb/ft	0.986	PE 2406 yellow pipe weight, lb/ft

Step 3

Determine the weight of the submerged ballast:

$$W_{BS} = B_P - B_N \tag{9-9}$$

Where

W_{BS} = weight of submerged ballast, lb/ft

Step 4

The designer must choose an appropriate ballast weight material (concrete, steel, etc.). For the chosen ballast weight material, determine the dry land weight required. Ballast weights are usually spaced every to 10-15 feet to avoid excessive pipe bending stresses during and after installation.

$$W_{BD} = \frac{L W_{BS} \, w_B}{(w_B - K w_{LO})} \qquad \textbf{(9-10)}$$

Where

W_{BD} = weight of dry ballast, lb
L = ballast weight spacing, ft
$?_B$ = specific weight of ballast material. lb/ft^3

Weight Shapes

Submergence weights are frequently made of reinforced concrete, which allows considerable flexibility of shape design. Weights are typically formed in two or more sections that clamp around the pipe over an elastomeric padding material. There should be clearance between the sections, so when clamped onto the pipe, the sections do not slide along the pipe. In general, weights are flat bottom, and bottom heavy. This prevents rolling from crosscurrent conditions. Fasteners securing the weight sections together must be resistant to the marine environment.

Figure 9-2 Concrete Weight

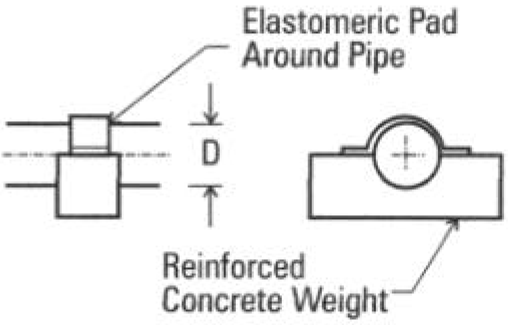


Figure 9-3 Concrete Weight