Manhole Reference Guide

First Edition

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Performance Pipe

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Plano, TX 75026-8006
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1. Introduction

About Performance Pipe
PERFORMANCE PIPE is the successor to Plexco and Driscopipe. On July 1, 2000, Chevron Chemical Company and Phillips Chemical Company joined to form the Chevron Phillips Chemical Company LP. Performance Pipe, a Division of Chevron Phillips Chemical Company LP, succeeds Plexco and Driscopipe as North America’s largest producer of polyethylene piping products for gas, industrial, municipal, mining, oilfield, and utility applications.

Performance Pipe offers more than forty years of polyethylene pipe manufacturing experience, twelve manufacturing facilities certified to ISO 9001 in nine states, and two manufacturing facilities in Mexico.

The unmatched quality and performance of Performance Pipe polyethylene piping products is enhanced and strengthened with over four decades of quality polyolefin plastic resin production from Chevron Phillips Chemical Company.

Figure 1-1. DriscoPlex™ 2000 SPIROLITE® Manhole in Landfill Application

1 Formerly - Plexco, a Division of Chevron Chemical Company, LLP.
2 Formerly - Phillips Driscopipe, A Division of Phillips Petroleum Company
DriscoPlex™ 2000 SPIROLITE® Pipe
Performance Pipe manufactures 3/8” through 54” outside diameter controlled DriscoPlex™ polyethylene pipe and tubing, DriscoPlex™ 2000 SPIROLITE® (hereafter referred to as SPIROLITE®) 18” through 120” inside diameter controlled polyethylene profile wall pipe, molded fittings, fabricated fittings, manholes, tanks, and fabricated structures for domestic and international markets. SPIROLITE is a trademark of Chevron Phillips Chemical Company LP.

The Advantages of SPIROLITE® Polyethylene Manholes
SPIROLITE® polyethylene manholes and structures may be custom fabricated for many varied applications including municipal and industrial manholes, leachate collection, sewer lift stations, siphon structures, pump stations, wetwells and sumps with both single wall and dual contained options. SPIROLITE® manholes are lightweight making handling easy. They are resistant to a broad range of corrosive chemicals, have excellent abrasion resistance and impact toughness and provide a smooth surface for low resistance to water flow.

Figure 1-2. Manhole Terminology
SPIROLITE® manholes are available in a variety of diameters from 36” to 120” for standard manhole heights up to 40 feet. Manholes for greater depths are available. Please contact Performance Pipe. Varieties of configurations are available for manhole bases (floors), tops, and appurtenances. Bases are available with flat, gusseted, sloped, and benched bottoms. Cone tops, flat tops, and open tops are available. Details of bases, tops, and appurtenances are discussed in later chapters of this manual. Figure 1-2 illustrates a SPIROLITE® sewer manhole and identifies typical terminology and configuration.

Solid Wall Manhole Risers
Loads applied to manholes are different from loads applied to buried pipes. Unlike the direct earth loads applied to pipe, direct soil loads are rarely applied to the top of a manhole. As the surrounding soil-backfill settles around the manhole riser, shear or downdrag forces are applied to the manhole. Downdrag produces a longitudinal compressive stress in the manhole riser wall that is best resisted by solid wall construction. A hollow-core or corrugated profile wall may lack longitudinal strength and is subject to local buckling at the hollow spaces in the wall. External profile ribs or corrugations increase the downdrag by supporting the weight of the embedment soil surrounding the riser. Therefore, a smooth exterior, solid wall construction is preferred for polyethylene manholes.

Material
ID-controlled SPIROLITE® manhole risers (shafts) are manufactured to ASTM F894 “Standard Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe”. ASTM F894 requires stress-rated resins, which have established long-term strengths and high resistance to stress cracking. (Other materials may be used for manhole components that are subject to little or no stress.) The manhole barrel (riser), the base, and anti-flotation anchor connection rings are made from stress-rated HDPE compounds having a cell classification of 335444C or E in accordance with ASTM D 3350, “Specification for Polyethylene Plastics Pipe and Fittings Materials”.

Pressure Rating
SPIROLITE® manholes are normally intended for gravity flow service with or without external groundwater. For applications requiring internal pressurization, or vacuum, or for high groundwater applications, please contact Performance Pipe.
Service Temperature
Sub-freezing temperatures are well tolerated by SPIROLITE® manholes. Operating services temperatures may be from –50°F (-45°C) or lower, up to 140°F (60°C). Under some circumstances, the manholes may handle fluids at temperatures up to 180°F (82°C).

As with all thermoplastics piping products, service pressure ratings and mechanical design properties are reduced at elevated temperatures. For operating conditions above 73°F, contact Performance Pipe.

Chemical Resistance
Few materials offer better over-all resistance to corrosive acids, bases, and salts. In addition, polyethylene is unaffected by bacteria, fungi or aggressive soils.

SPIROLITE® manholes do not rust, rot, corrode, or tuberculate like traditional metal or concrete piping and manholes. Polyethylene is not subject to galvanic or hydrogen sulfide corrosion.

Fabrication
SPIROLITE® manholes and structures are fabricated using extrusion welding techniques. All manholes are tested for leakage hydraulically or ultrasonically prior to shipment from Performance Pipe’s plants.

Handling
SPIROLITE® manholes and structures weigh far less than comparable structures made from reinforced concrete. In many cases, this permits off-loading and handling with lighter equipment. Although comparatively lighter than concrete, manholes and structures are large and heavy. Careful planning, proper precautions and adequate handling equipment are necessary for safe handling. Handling and unloading instructions are provided with every shipment. Obtain these instructions from the delivery driver. See Chapter 8, for general handling information.

Installation
SPIROLITE® manholes are intended for underground installation with compacted, granular soil embedment. When manholes are to be installed in landfills, in areas of high settlement or unstable soil, or in bodies of water, consult Performance Pipe. See Chapter 8, for information about manhole installation.

UV Protection
Black SPIROLITE® manholes may be stored outdoors and unprotected for periods of 20 years or more in direct sunlight. Black polyethylene material used to make SPIROLITE® manholes contains a minimum of 2% carbon black for resistance to degradation from ultraviolet light. Non-black SPIROLITE® manholes contain sacrificial additives that provide temporary resistance to UV degradation for up to 12 months of unprotected outdoor storage. For longer periods, covering or other protection against direct exposure to sunlight is required.
Lower Life Cycle Costs
SPIROLITE® manhole’s long life, excellent corrosion resistance, and other cost saving properties provide tangible, life cycle cost benefits.

Additional Information
For additional information on use, design, and installation of SPIROLITE® and other Performance Pipe products, see The Performance Pipe Engineering Manual.

Manhole Design (ASTM F 1759)
Proper field application requires forethought and planning. SPIROLITE® manholes are complex subsurface structures that must accommodate external loads such as earth pressure, live-load pressure, and groundwater pressure. ASTM F1759, “Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications” provides a design methodology for HDPE manholes. To perform calculations, the designer/purchaser should identify all loads that could be applied to the manhole over its service life including the engineering characteristics of the soil and seasonal groundwater levels as well as the application temperature. A list of information required for performing design calculations in accordance with F 1759 is provided in Appendix B. It is the responsibility of the designer/purchaser to determine and procure any other information that may be required.

The designer/purchaser can prepare a PE manhole design in accordance with ASTM F-1759 and submit it to Performance Pipe for quotation or fabrication, or he may submit the calculation-input form, Appendix B, to Performance Pipe who will perform the ASTM F-1759 calculations and return them along with a recommendation on the manhole dimensions to the designer/purchaser for design, verification, and approval. The designer/purchaser, not Performance Pipe, is responsible for ensuring that the manhole is correctly designed and suitable for their particular application. Lastly, after an order has been placed, Performance Pipe will prepare and submit for verification and approval shop drawings of the manhole to the Engineer/Purchaser. Performance Pipe will manufacture the manhole to the approved drawings. Appendix B includes a form that lists information required for obtaining a manhole quotation from Performance Pipe.

Guide Specification
To assist the designer in preparing a specification, Appendix A provides a Guide Specification for HDPE manholes.
2. Riser Design Guidelines

Introduction
Manhole risers extend from the base of the manhole to the top and provide access to the equipment, pipes, and/or conduits at the base of the manhole. The riser must be able to withstand downdrag and radial loading from the surrounding soil and groundwater. Proper design requires knowledge of many factors including embedment material, the insitu soil, and the groundwater elevation properties. This chapter covers the design guidelines for risers given in ASTM F 1759.

Riser Description
SPIROLITE® risers (shafts) are made in nominal diameters from 36” to 120”. To minimize vertical soil loads, a uniform diameter is used from the base of the manhole to the top. SPIROLITE® manhole risers are made from pipe manufactured in accordance with ASTM F 894. The optimum wall construction for a manhole riser for underground applications is a cylinder with a smooth outer surface and a solid wall without core or profile hollows. The smooth outer surface minimizes the transfer of downdrag soil load to the riser and the solid cross section provides stable resistance to longitudinal (axial) loads. Profile or corrugated wall pipes containing external ribs or hollow cores tend to have limited use for underground manhole risers. Although ribbed or corrugated (open) profiles can reduce weight, they greatly increase the downdrag soil loading on the riser. Hollow-core profile walls are not efficient in transferring longitudinal loads and can buckle locally ‘between the cores’.

Figure 2-1 Twin Manhole Risers for a Sanitary Sewer Application
Riser Material
Performance Pipe’s SPIROLITE® manhole risers are made from a high density, extra high molecular weight polyethylene compound with a cell classification of 335444C or E for non-black product or higher per ASTM D 3350. ASTM D 3350 identifies polyethylene pipe and fittings material by a cell classification numbering system. The ASTM cell classification system identifies the PE resin, using cell classification numbers for material properties. See Table 2-1 for the cell classification values for the PE compound used for SPIROLITE® manholes.

Table 2-1 Cell Classification for Performance Pipe 335444C Material Per ASTM D 3350

<table>
<thead>
<tr>
<th>Cell Classification for SPIROLITE® HDPE</th>
<th>PROPERTY</th>
<th>Cell Classification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Density per ASTM D-1505, gm/cm</td>
<td>0.941 - 0.955</td>
</tr>
<tr>
<td>3</td>
<td>Melt Index per ASTM D-1238, gm/10 min</td>
<td>0.15 to &lt; 0.4</td>
</tr>
<tr>
<td>5</td>
<td>Flexural Modulus per ASTM D-790, psi</td>
<td>110,000 to &lt; 160,000</td>
</tr>
<tr>
<td>4</td>
<td>Tensile Strength per ASTM D-638, psi</td>
<td>3000 to &lt; 3500</td>
</tr>
<tr>
<td>4</td>
<td>Environmental Stress Crack Resistance per ASTM D-1693, Failure % = Hours</td>
<td>F&lt;sub&gt;20&lt;/sub&gt; &gt; 600</td>
</tr>
<tr>
<td>4</td>
<td>Hydrostatic Design Basis per ASTM D-2837, psi</td>
<td>1600</td>
</tr>
<tr>
<td>C or E</td>
<td>Color and Ultraviolet Stabilizer per ASTM D-3350</td>
<td>C = Black with 2% min. Carbon Black, E = Color with stabilizer</td>
</tr>
</tbody>
</table>

Modulus of Elasticity (Apparent Modulus and Stress Relaxation Modulus)
As with conventional materials, the ratio of stress to strain provides a measure for the stiffness of the material. Unlike conventional materials, however, the ratio of stress to strain for HDPE varies with both time and temperature. Under constant loading (stress), the material deformation (strain) will increase with time. The ratio of stress to strain at a given load duration time and temperature is called the Apparent Modulus of Elasticity.
When materials such as polyethylene are subjected to a constant deformation (strain), the load (stress) that maintains the constant deformation decreases over time. This phenomenon is called stress relaxation and the ratio of stress to applied strain at a given time and temperature is called the Stress Relaxation Modulus. The Stress Relaxation Modulus and the Apparent Modulus of Elasticity are nearly equal, and therefore, can be used interchangeably for most engineering design. In Performance Pipe literature, the Apparent Modulus of Elasticity and the Stress Relaxation Modulus are often referred to as the Modulus of Elasticity and this convention will be followed throughout this Guide. Values for the Modulus of Elasticity for various times and temperatures are given Table 2-2.

### Table 2-2 Modulus of Elasticity for HDPE, psi

<table>
<thead>
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<th>LOAD</th>
<th>TEMPERATURE</th>
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<tr>
<td></td>
<td>0°F</td>
</tr>
<tr>
<td>Short-term</td>
<td>260,000</td>
</tr>
<tr>
<td>1 hour</td>
<td>148,000</td>
</tr>
<tr>
<td>10 hours</td>
<td>122,000</td>
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<tr>
<td>50 years</td>
<td>59,900</td>
</tr>
</tbody>
</table>

### Allowable Strain

In the Appendix of ASTM F 1759, the allowable compressive strain value is 3.5% at 73°F and the typical allowable bending strain value is 5% for polyethylene materials with a cell class equal to or exceeding 334433C.

### Poisson’s Ratio

The Poisson’s ratio values typically used for HDPE are 0.45 for long-term and 0.35 for short-term.

### Manhole Sizes Available

Performance Pipe HDPE manholes are available with inside diameters of 36", 42", 48", 54", 60", 66", 72", 84", 96" and 120". Chapter 3 provides guidance in selecting manhole diameter based on inlet/outlet pipe sizes.

### Wall Construction

SPIROLITE® manufactures manhole risers using a spiral winding process or by conventional extrusion. In spiral winding, a flat polyethylene extrudate is wound over a rotating mandrel. Additional layers are used to increase the riser’s wall thickness. Spiral winding is an ID-controlled process. The inside diameter remains fixed regardless of the wall thickness, whereas in conventionally extruded pipe the OD is controlled and increasing the wall thickness reduces the inside diameter. Spiral winding is used for ID sizes from 36” through 120”. Conventional extrusion is used for OD sizes up to 54". When designing a manhole, it is important to recognize that spirally wound manhole risers are ID sized, where conventionally extruded risers are OD sized. For example, a 42” spiral wound SPIROLITE® riser and a conventionally extruded 48” OD riser have about the
Manhole Classification
SPIROLITE® manholes are classified according to their resistance to downdrag. When soil is backfilled and compacted around the manhole, it settles and tries to pull or drag the manhole riser down with it. The downward drag occurs because there is considerable frictional resistance at the interface between the riser and the surrounding soil. The resulting frictional force is referred to as downdrag. Downdrag causes a very slight shortening of the manhole accompanied by a transfer of longitudinal compressive force into the riser. Excessive downdrag may cause longitudinal crushing or buckling of the riser wall.

Resistance to downdrag depends on riser wall thickness and diameter. Therefore, SPIROLITE® manholes are classified on the basis of their inside diameter to minimum wall thickness ratio, known as the IDR (Inside-Diameter Dimension Ratio). Both IDR’s and SIDR’s (Standard Inside-Diameter Dimension Ratio) are used for classification. Dimensions and properties for standard SPIROLITE® manhole riser wall sections are given in Tables 2-3 through 2-8. Contact Performance Pipe for other IDR’s and SIDR’s.

Conventionally extruded pipe is typically classified by DR, which is the OD divided by the minimum wall thickness. DR or SDR is converted to IDR or SIDR by subtracting 2 from the DR or SDR value, that is, IDR = DR –2, or SIDR = SDR –2. Thus, SIDR 49 SPIROLITE® and SDR 51 conventionally extruded manhole risers have the same downdrag resistance.

The Ring Stiffness Constant (RSC) classification used for SPIROLITE® and ASTM F894 pipe is not an effective system for classification of manhole risers, because pipes of equivalent RSC may have very different resistances to downdrag. A hollow core or closed profile pipe resists downdrag with only the thin inner and outer walls of the profile. While it may have a high RSC and a high resistance to circumferential forces such as ring deflection, its resistance to downdrag is proportional to the sum of two thin wall sections. Therefore, buckling can occur within the thin inner profile section at loads substantially lower than the loads required to cause buckling of a solid wall section. A solid wall riser resists downdrag forces with its entire wall thickness. Therefore, a solid wall riser having the same RSC as a profile riser will have a significantly higher resistance to downdrag.

Manhole Color
The standard manhole color is black. Other color manholes are available. Please note that for colors other than black, the outdoor storage life (i.e. exposed to sunlight) may be a year or so because non-black materials use a different type of UV protection system. The storage life of SPIROLITE® white manholes is 3 years.
**Table 2-3. Manhole Riser Dimensions for SIDR = 49**

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<td>75.14</td>
<td>73.57</td>
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<td>84</td>
<td>87.67</td>
<td>85.83</td>
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<td>96</td>
<td>100.19</td>
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<td>120</td>
<td>125.24</td>
<td>122.62</td>
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<td>1.226</td>
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**Table 2-4. Manhole Riser Dimensions IDR = 44**

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### Table 2-5. Manhole Riser Dimensions  **SIDR = 39**

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### Table 2-6. Manhole Riser Dimensions  **IDR = 34.5**

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### Table 2-7. Manhole Riser Dimensions SIDR = 30.5

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### Table 2-8. Manhole Riser Dimensions IDR = 27

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<td>64.76</td>
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<td>129.51</td>
<td>124.76</td>
<td>4.45</td>
<td>7.343</td>
</tr>
</tbody>
</table>

### Application Limits
SPIROLITE® High Density Polyethylene (HDPE) manholes are used in industrial, municipal, landfill and rehabilitation applications including wetwells, lift stations, sumps, valve chambers, and dual containment vessels. Three common design applications of SPIROLITE® HDPE Manholes are (a) underground burial with soil backfill, (b) placement in ponds or basins as standpipe, and (c) lining existing manholes.
In preparing a design, the Engineer should give thorough consideration to the unique characteristics of each application. For example, manholes buried underground gain a substantial amount of support from the embedment, which adds resistance to hydrostatic pressures. But manholes installed in a pond or in ungrouted lining applications must resist hydrostatic pressures on the basis of their own stiffness. Each manhole should be correctly analyzed for its particular service environment whether that may be in soil, water or grout. Installation and application information is provided in this Guide. Where applications are beyond the information provided in this guide, the Purchaser or Engineer should contact Performance Pipe.

The working temperature range for SPIROLITE® HDPE manholes is generally from -50°F to 140°F (-45°C to 60°C), but this may vary depending on specific circumstances. Polyethylene is a thermoplastic material; as the operating temperature increases, the allowable compressive stress and the modulus of elasticity decrease, but the ductility of the material improves. A reverse effect occurs as the temperature decreases.

SPIROLITE® HDPE manholes have excellent resistance to many harsh and corrosive chemicals. Whenever evaluating the use of a HDPE manhole for handling chemical solutions, the Engineer should begin by consulting The Performance Pipe Engineering Manual, Book 1, for a detailed discussion on chemical resistance.

SPIROLITE® manholes are normally intended for gravity flow applications. However, if the application requires slight internal pressure or vacuum, the manhole must be designed for these conditions. The Purchaser or Engineer must take into account any pressure or vacuum in manhole. Please consult with Performance Pipe if the manhole under consideration will be subjected to pressure, negative pressure, or vacuum.

ASTM F 1759
ASTM F 1759 establishes a standard design procedure for polyethylene manhole risers. The following sections cover general considerations for selecting the correct IDR/SIDR for risers, but it is the Purchaser’s or his Engineer’s responsibility to ensure that the design meets the requirements of ASTM F 1759. Upon request, Performance Pipe will provide riser calculations in accordance with ASTM F1759 for the Engineer’s use. Calculations will only be performed if a completed and signed “F1759 Calculation Input” sheet is submitted and all inputs are provided. (See Appendix B.) The Engineer will still be responsible to evaluate the calculations and determine the suitability of the riser for the particular application.

ASTM F 1759 recognizes the use of alternate design methods, which may include empirical equations, finite element analysis (FEA), field measurements, and other suitable means. The method presented below may not be suitable for every case and is by no means the only appropriate design method.

The methodology in this section applies to manholes that are buried up to 40 feet deep in stable insitu soil formations or in compacted earthen landfills. Manholes that are installed in sanitary landfill cells, or installed deeper than 40 feet, or are used as liners (grouted or not), or as standpipes in ponds may require special design. Please consult Performance Pipe.
Earth and Groundwater Pressure

Although the manhole riser extends to the ground surface and has no soil above it, the surrounding (embedment) soil and groundwater, when present, exert considerable load on the riser. The surrounding soil exerts a radially-directed pressure, which causes ring compression in the riser. Further, as the surrounding soil settles, downdrag load develops, which causes longitudinal (axial) compression in the riser. Groundwater and any vacuum or negative pressures inside the manhole cause external hydrostatic pressures on the manhole. The following section looks at loads on the riser, including (1) radially-directed earth pressure, (2) downdrag load and (3) groundwater pressure.

(1) Radially-directed pressure

Horizontal earth pressure exists in all soil deposits. Depending on the consolidation history of the soil deposit, the horizontal pressure ranges in magnitude from a fraction of the vertical earth pressure at that same depth to several times the vertical pressure. Figure 2-2 illustrates the horizontal pressure acting on a manhole riser. The pressure increases with depth as the vertical earth pressure (overburden) increases. ASTM F1759 assumes a triangular pressure distribution. Since the manhole riser is round, the horizontal earth pressure exerts a radially-directed (squeezing) force on the manhole. Field measurements by Gartung et al. (Ref. 2-1) have shown that the Active Earth Pressure may approximate the radially-directed earth pressure against an HDPE manhole riser.

The radially-directed earth pressure is given in Equation 2-1 from ASTM F 1759. Active earth pressure will most likely vary around the circumference of the riser from uneven placement of the backfill, and is accounted for by the 1.21 coefficient in Equation 2-1.

$$ P_R = 1.21K_A\gamma H $$

(2-1)

Where:
- $P_R$ = radial pressure, psf
- $\gamma$ = soil unit weight, pcf
- $H$ = height of fill, ft
- $K_A$ = Active Earth Pressure coefficient,

$$ K_A = \tan^2 \left( 45 - \frac{\phi}{2} \right) $$

(2-2)

Where:
- $\phi$ = soil angle of internal friction, deg
(2) **Downdrag load**

Soil settlement around the manhole develops a shearing stress between the soil and the manhole which acts to "drag the manhole downward" (shortening the manhole). This process is referred to as downdrag and it creates a longitudinal (axial) compressive force in the riser wall. Downdrag is illustrated in Figure 2-3. The load in the riser wall will increase until the frictional resistance between the manhole and soil is overcome. At that point, the maximum load is reached and additional settlement will cause the soil to slip while the load in the manhole remains constant.

A smooth outer surface minimizes the amount of "downdrag". Frictional resistance is greatly increased if external ribs or corrugations are present on the outside of the riser, which in turn, create a much greater compressive load in the riser wall. (External ribs may be used beneficially to stiffen manhole risers that are used as liners in rehabilitation. In liner applications, the entire annular space between an HDPE manhole liner and its host manhole is grouted. The ribs provide extra surfaces for the grout to grip thus providing additional support to the manhole.)

![Figure 2-3 Downdrag Shear Stress on Manhole](image)

Maximum downdrag load occurs at the bottom of the riser and equals the product of the downdrag shear stress acting on the surface of the riser and the surface area of the riser. The shear stress varies in intensity from the top of the riser to the bottom as a function of the radially-directed earth pressure. For simplicity, F 1759 assumes that the radially-directed pressure varies linearly with depth. Thus, the downdrag load is equal to the product of the average shear stress and the surface area. Equation 2-3 gives the average shear stress:

$$T_A = \mu \left( \frac{P_{R1} + P_{R2}}{2} \right)$$  \hspace{1cm} (2-3)

Where:

- $T_A$ = average shear stress, psf
- $P_{R1}$ = radial pressure at top of riser, psf
- $P_{R2}$ = radial pressure at base of riser, psf
- $\mu$ = friction coefficient between riser and soil

(Martin et al. (Ref. 2-2) and Swan et al. (Ref. 2-3) suggest a coefficient of friction between a granular or granular-cohesive soil and HDPE of 0.4.)
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The downdrag load acting on the manhole that causes a compressive stress in the manhole riser wall can be calculated from Equation 2-4. The weight of caps and equipment on the top of the manhole may add longitudinal load in the riser.

\[ P_D = T_A \pi \left( \frac{D_O}{12} \right) H \]  

(2-4)

Where:
\( P_D \) = downdrag load, lbs
\( D_O \) = outside diameter of riser, in
\( T_A \) = average shear stress, psf
\( H \) = height of manhole fill, ft

(3) **Effect of Groundwater**

Groundwater typically exerts a radial pressure on the riser equal to the hydrostatic head. Since groundwater reduces the effective weight of the soil due to buoyancy, the total radial pressure applied to the riser is equal to the sum of the groundwater pressure head and the radially-directed soil pressure per Equation 2-1, calculated using the buoyant weight of the soil.

Since soil weight is reduced by groundwater, downdrag load is reduced. However, when calculating downdrag force, the effects of groundwater in reducing soil weight and in creating hydrostatic pressure are normally ignored, because downdrag forces occur during construction and during fluctuations in the groundwater level. See ASTM F 1759 for a calculation procedure in partially saturated soils. **Where manholes extend below the groundwater level or where run-off water may collect in backfill surrounding the manhole, the manhole may “float” off-grade or out of the ground.** See Chapter 7.

**Soil Support**

Adequate soil support is vital for proper manhole performance. SPIROLITE® HDPE manholes depend on the surrounding embedment for additional resistance to radial-directed earth pressure and downdrag forces. Selecting a heavy wall manhole alone will not ensure good performance if adequate soil support is not developed during installation. Backfill and compaction requirements are discussed throughout this manual and are addressed in detail in Chapter 8.

For conventional backfill in stable, insitu soils, the minimum backfill required for a manhole is Class IA, IB or II material per ASTM D 2321 compacted to a minimum of 90% Standard Proctor Density as defined by ASTM D 698. Embedment material should be placed around the manhole in a zone extending for 3.5 ft or to undisturbed ground whichever is the greater distance.

Riser deflection under load is greatly influenced by the stiffness of the embedment material. The "Modulus of Soil Reaction" (\( E' \)) characterizes the supporting capability of the embedment soil. \( E' \) is a measure of the soil stiffness and it depends on the soil type, compaction level and degree of saturation. \( E' \) values are empirically derived from back-calculated values from installed flexible pipe. Another measure of soil stiffness is Young’s Modulus, \( E_S \), which can be determined in a laboratory. Both values are used in ASTM F 1759.
Riser Design per ASTM F 1759

In the ASTM F 1759 procedures for designing manhole risers a “trial” IDR (or wall thickness) is assumed, and then checked to see that the assumed riser IDR has sufficient strength and stiffness both in the ring (radial) direction and the longitudinal (axial) direction to resist the loads. If not, a lower IDR is selected and checked. The process is repeated until a suitable IDR is found. In the riser, maximum loads typically occur at or near the base of the manhole. Equation 2-5 is the formula for IDR.

\[
IDR = \frac{ID}{t_{MIN}} \quad (2-5)
\]

Where:
- IDR = Inside-Diameter Dimension Ratio
- ID = inside Diameter (in)
- \( t_{MIN} \) = minimum wall thickness (in)

(1) Ring Compressive Thrust, Bending, and Buckling

Radially-directed earth and groundwater loads cause ring compressive thrust and ring bending in the riser. Ring compressive thrust is accompanied by a ring compressive strain. Ring compressive strain should be limited to 3.5% at 73°F, as previously presented. Likewise, ring bending strain occurs in the riser. The combined ring bending and ring compressive strain should be limited to 5% at 73°F, as previously presented.

Ring Compressive Thrust

Equation 2-6 may be used to determine ring compressive thrust.

\[
N_T = \frac{P_R}{144} (R_M) \quad (2-6)
\]

Where:
- \( N_T \) = ring compressive thrust, lb/in
- \( P_R \) = radial pressure, psf
- \( R_M \) = mean radius of riser, in

\[
R_M = \frac{ID + t}{2}
\]

Equation 2-7 may be used to determine ring compressive strain due to ring compressive thrust.

\[
\varepsilon_T = \frac{N_T}{E t} \quad (2-7)
\]

Where:
- \( \varepsilon_T \) = ring compressive strain, in/in
- \( N_T \) = ring compressive thrust, lb/in
- \( E \) = modulus of elasticity in psi
- \( t \) = minimum riser wall thickness, in
**Ring Bending**

Ring deflection normally occurs during installation. Equation 2-8 provides the ring bending moment in the riser wall from an assumed 2% deflection.

\[ M_E = 0.25 C_O D_M N_T \]  \hspace{1cm} (2 – 8)

Where:
- \( M_E \) = ring bending moment, (in-lb)/in
- \( C_O \) = 0.02 (correction for 2% deflection)
- \( D_M \) = mean riser diameter, in
- \( N_T \) = ring compressive thrust, lb/in

The ring bending strain, Equation 2-9, is obtained from the ring bending moment.

\[ \varepsilon_B = \frac{6 M_E}{E t^2} \]  \hspace{1cm} (2 – 9)

Where:
- \( \varepsilon_B \) = bending strain, in/in
- \( M_E \) = bending moment, (in-lb)/in
- \( E \) = modulus of elasticity, psi
- \( t \) = minimum riser wall thickness, in

The ring bending strain and the ring compressive strain can be added together to obtain the maximum (combined) ring strain. The combined strain is limited to 5% as presented earlier.

**Ring Buckling**

If the ring compressive thrust exceeds a critical buckling value, the riser may lose the ability to handle flexural deformation and buckle. Two equations for ring buckling are given in F 1759. If the manhole riser is above the groundwater level, the critical ring compressive thrust at buckling may be found using Equation 2-10.

\[ N_{CR} = 0.3 R_H t E^{1/3} E_S^{2/3} \]  \hspace{1cm} (2 – 10)

Where:
- \( N_{CR} \) = critical ring compressive thrust (no groundwater), lb/in
- \( R_H \) = geometry factor
- \( t \) = minimum riser wall thickness, in
- \( E \) = modulus of elasticity, psi
- \( E_S \) = Young’s Modulus of the soil, psi

The value of \( R_H \) depends on the Relative Stiffness, RS:

\[ RS = \frac{0.22 E t^3}{E_S R_M^3} \]

Where:
- \( R_M \) = the mean radius of the riser, in

Where the relative stiffness, RS, is less than 0.005, \( R_H \) equals 1.0, which is usually the case for HDPE manholes in granular or compacted granular-cohesive embedment.
Where the manhole riser or a portion of the manhole riser is below the groundwater table, the critical ring compressive thrust may be found using Equation 2-11.

\[ N_{CRW} = 0.82 \sqrt{\frac{R B' E' E t^3}{D_M}} \tag{2-11} \]

Where:
- \( N_{CRW} \) = critical ring compressive thrust, lb/in
- \( D_M \) = mean diameter, in
- \( R = 1 - 0.33(H'/H) \) for buoyancy reduction
- \( H' \) = height of groundwater from invert, ft
- \( H \) = height of fill, ft
- \( E' \) = modulus of soil reaction, psi
- \( E \) = modulus of elasticity, psi
- \( t \) = minimum riser wall thickness, in

and:
\[ B' = \frac{1}{1 + 4e^{-0.065H}} \]

Per ASTM F 1759, the ring compressive thrust, \( N_T \), given by Equation 2-6 should not exceed one-half of the critical ring compressive thrust, \( N_{CR} \) or \( N_{CRW} \), as calculated using Equation 2-10 or Equation 2-11). A higher safety factor may be used if desired by the Engineer.

The manhole top and bottom enhance the ring buckling resistance of the manhole riser. They act to stiffen the manhole against ring deformation. However, the increase in resistance is normally not considered in design as the enhancement diminishes with distance from the top or bottom.

\( (2) \) Longitudinal (Axial) Compressive Strain and Buckling

Longitudinal (axial) compressive strain in the manhole wall may be caused by any of the following: (1) the downdrag load from Equation 2-4, (2) the weight of the manhole and appurtenances attached to the wall, and (3) the weight of equipment or machines on top of the manhole. Longitudinal strain is highest at or near the bottom of the manhole. For design, the trial IDR is checked to see if the longitudinal strain from Equation 2-12 is less than the allowable compressive strain for the material (generally 3.5%) and less than the critical longitudinal axial buckling strain from Equation 2-13.

\[ \varepsilon_A = \frac{P_D + P_L + P_W}{E \pi D_M t} \tag{2-12} \]

Where:
- \( \varepsilon_A \) = longitudinal (axial) compressive strain, in/in
- \( P_D \) = downdrag force from Equation 2-4, lb
- \( P_L \) = live load including equipment, lb
- \( P_W \) = dead load including riser weight, lb
- \( E \) = modulus of elasticity, psi
- \( D_M \) = riser mean diameter, in
- \( t \) = minimum riser wall thickness, in
For solid wall riser pipes, the minimum riser wall thickness is simply the wall thickness of the riser. For closed profile or hollow core riser pipes, the minimum riser wall thickness is not the “overall wall thickness” or “equivalent solid wall thickness”, but the sum of the inner and outer skin thickness, which may be found by subtracting the height of the hollow core or profile from the “overall wall thickness”.

Local wall buckling of the structure may occur if the longitudinal (axial) compressive strain exceeds the critical axial compressive strain. Equation 2-13 gives the critical longitudinal (axial) compressive strain for an unsupported (non-buried) riser.

\[
\varepsilon_{CR} = \frac{2 t}{D_M \sqrt{3(1-\mu^2)}} 
\]

(2-13)

Where:
- \(\varepsilon_{CR}\) = critical longitudinal (axial) compressive strain (buckling strain), in/in
- \(D_M\) = riser mean diameter, in
- \(\mu\) = Poisson’s ratio for HDPE
- \(t\) = minimum wall thickness, in

For profile wall riser pipe, local wall buckling may occur between ribs or stiffened sections depending on the profile shape. For hollow-core profiles with circular cores, ASTM F 1759 permits the substitution of the equivalent solid wall thickness for the minimum wall thickness. The equivalent solid wall thickness is the wall thickness \(t\) that has a moment of inertia equal to the moment of inertia of the profile wall. This same substitution is not permitted for hollow-core profiles with square cores, as square cores are inherently unstable. See Section 7.1.2.6 of ASTM F 1759. In the case of square core profiles, the minimum wall thickness must be used in Equation 2-13.

ASTM F 1759 allows Equation 2-13 to be applied without the use of a safety factor where granular soil or compacted granular-cohesive soil surrounds the manhole. Embedment soil increases the riser’s resistance to local wall buckling, which normally enhances the safety factor. Thus for design, \(\varepsilon_A\) must be less than or equal to \(\varepsilon_{CR}\) and as stated above \(\varepsilon_A\) must also be less than 3.5%. If \(\varepsilon_A\) fails to meet either condition, a lower IDR (SIDR) manhole riser should be selected and the trial calculations repeated until an IDR (SIDR) is found where \(\varepsilon_A\) meets both conditions.

**Pond Applications**

Where manholes (such as standpipes) are placed in ponds or other standing bodies of water or in muds including muck or saturated sludge that have little or no soil support, the surrounding liquid exerts a hydrostatic pressure on the riser. In these conditions, there is little or no downdrag because the surrounding soil is essentially a liquid. The IDR (SIDR) of the riser must be sufficient to withstand the long-term external hydrostatic pressure created by the surrounding material without any soil support. Equation 2-14 gives the critical hydrostatic collapse pressure for the manhole riser. For pond standpipe applications, manhole risers may be made from pipes with a ribbed profile outer surface.
\[ P_{CR} = \frac{2E}{(1 - \mu^2)} \left( \frac{1}{IDR + 1} \right)^3 C \]  \hspace{1cm} (2-14)

Where:
- \( P_{CR} \) = critical collapse pressure, psi
- \( E \) = modulus of elasticity, psi (typically long-term and at an appropriate temperature)
- \( IDR \) = Inside-Diameter Dimension Ratio
- \( \mu \) = Poisson’s ratio (0.45 for long-term)
- \( C \) = ovality correction factor as follows:

<table>
<thead>
<tr>
<th>Ovality</th>
<th>C</th>
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<tbody>
<tr>
<td>1%</td>
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</tr>
<tr>
<td>2%</td>
<td>0.84</td>
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<td>3%</td>
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<td>0.70</td>
</tr>
<tr>
<td>5%</td>
<td>0.64</td>
</tr>
</tbody>
</table>

It is normal to anticipate some ovality in the manhole. Ovality can occur from handling, storage, and shipment.

The critical collapse pressure should be reduced by a safety factor. Typical safety factors for hydrostatic collapse are 2.5 or higher depending on the application. The reduced value should be equal to or greater than the net external pressure at the bottom of the riser from Equation 2-15. (The manhole base tends to provide an extra safety margin against collapse for the lower portion of the manhole.)

\[ \frac{P_{CR}}{SF} \geq \gamma_w \frac{H_{EXT} - H_{INT}}{144} \]  \hspace{1cm} (2-15)

Where:
- \( SF \) = safety factor
- \( H_{EXT} \) = liquid height external to manhole (ft)
- \( H_{INT} \) = liquid height inside the manhole (ft)
- \( \gamma_w \) = unit weight of liquid (pcf)

Equation 2-15 shows that the liquid head inside the manhole will offset some of the external pressure acting on the manhole. However, if the liquid level inside the manhole fluctuates, the lowest liquid level should be used.

When a manhole is submerged in a pond or body of water, the water it displaces buoys it and the resulting buoyancy force is proportional to volume of water displaced. Provisions must be made to anchor the manhole or standpipe to the pond floor to prevent floatation. See Chapter 7.
Summary
Manhole risers are subject to considerable load from soil downdrag and from radial soil and groundwater pressure. Although guidance and design recommendations are provided in this chapter, the Purchaser and the Engineer must apply their own engineering judgment and determine the appropriateness of the design recommendations for the particular application. Proper design requires knowledge of the embedment soils and familiarity with the in-situ soil and groundwater formation. The Engineer should avoid the use of open profile pipes (externally ribbed pipes) in stand-alone underground manholes. Although closed profile wall constructions with hollow cores can increase ring stiffness, longitudinal loads can exceed the local buckling strength of the net wall, which may lead to premature failures. Solid wall construction is preferred as the optimum wall construction for underground manhole risers because it has the highest resistance to downdrag loads. Profile wall manhole riser constructions are limited to applications such as manhole liners and pond standpipes where there are no downdrag loads.
3. Manhole Bases

Introduction
The manhole base serves as a bottom to the manhole and is usually the floor as well. Various base styles and constructions are available for different application needs, including bases with an invert to minimize flow disruption. While equipment may be placed on the manhole base, the primary loading on the base is from its underside. When the base is below groundwater level, water pushes up on the bottom of the base and exerts a uniform hydrostatic pressure across its surface. Generally, there is no earth load on the base. Standard manhole base options are available for groundwater pressures up to 40 ft. of head.

Flat Bases
Where there is little or no groundwater above the base, a flat base is usually economical and efficient. Flat bases range from 1” to 2” thick with 4” thick bases available on special order. When the base thickness exceeds 2”, a gusseted base can be less expensive. Flat bases can be supplied in circular or square shapes that circumscribe the manhole riser. See Figures 3-1 and 3-2. Bases may be extended to a larger size than the outer diameter of the manhole riser to provide a shelf or bench for a concrete antiflotation anchor. See Chapter 7.

Benched Bases
Benched bases provide a platform for personnel to perform maintenance work without standing in the flow stream. Benched bases incorporate a pipe invert that minimizes flow disturbance through the manhole. “High Benching”, which provides benching at the pipe crown elevation is also available. Benched bases are generally used in sanitary sewer and storm drain applications and are normally rated for up to 25 ft of groundwater head. See Figure 3-3.
Externally Gusseted Bases
Gussets or stiffeners added to the manhole base reduce stress and deflection. Where the manhole base is recessed inside of the riser, stiffeners are placed on the external side of the base. See Figure 3-4. Gussets are installed by thermal extrusion welding, typically in crossing or grid patterns. External gusseted bases provide a smooth floor, which aids maintenance work. Performance Pipe has tested gusset configurations for resistance to hydrostatic head. Gusseted bases are available for groundwater heads up to 40 ft. The purchaser should specify the anticipated groundwater head to the next highest 5-foot increment.

Internally Gusseted Bases
Internal gussets are placed inside the manhole. While they can interfere with flow and maintenance work, they allow the base to be extended radially beyond the manhole riser. See Figure 3-5. This extension makes an excellent ring or shelf on which to place a concrete anchor for antifloation. Placing a “false” bottom or floor on top of the gussets can eliminate the interference caused by the internal gussets. This style of base is available for groundwater heads up to 40 ft. The purchaser should specify anticipated groundwater head to the next highest 5-foot increment.
Warning

When wet or moist, manhole surfaces can be slippery. Use personal fall protection safety equipment when entering or working in a manhole.

Base Structural Considerations

Although the base acts as a floor for the manhole, the primary structural function of the base is to resist hydrostatic pressure against the underside of the manhole base when groundwater is present. (Earth pressure acting on the base is considered negligible because the majority of downdrag load carried in the manhole riser is transmitted directly to the foundation below the manhole riser when the foundation is constructed and prepared in accordance with Chapter 8.)

Base design requires selecting the desired floor type (invert, flat, gusseted), and then determining the proper thickness and structural gusseting required to resist groundwater pressure applied to the bottom of the manhole. In addition to applying load to the base, the groundwater pressure acts to
“uplift” the manhole, that is, groundwater pressure applied to the bottom side of the manhole base is directed upward and may push an unrestrained manhole out of the ground. Uplift is resisted by frictional forces along the manhole riser skin, the weight of the manhole and cover, and by the weight of soil above concrete anchors. Often, the manhole base is designed to extend radially beyond the perimeter of the riser so that it becomes a shelf on which a concrete anchor may be placed. See Chapter 7.

Installing the manhole in a poured (wet) concrete slab will not reduce groundwater uplift pressure against the manhole base. Because concrete does not seal to polyethylene, groundwater will seep between the polyethylene and the concrete and apply uplift pressure to the manhole base.

**HDPE Material for Manhole Bases**

Because they have a structural function, manhole bases are fabricated from stress rated polyethylene materials that meet the same requirements applied to risers. See Chapter 1 for material requirements.

**Flat Base Design Per ASTM F 1759**

ASTM F 1759 provides design information for determining the thickness required for a flat base to resist groundwater pressure. But because a flat base is structurally inefficient, gussets are frequently used to stiffen the base. Benching and inverts can also stiffen the manhole base, and sometimes gussets are combined with benching and inverts. ASTM F 1759 does not cover the design of gusseted or otherwise stiffened bases. For these types of bases, Performance Pipe has performed testing and analysis to establish the maximum recommended height of groundwater above the manhole base. When gusseted bases are required, please consult Performance Pipe.

In ASTM F 1759, the performance criteria for bases are: (1) The stress level in the base due to groundwater pressure must be kept below the allowable stress for the base material, and (2) the deflection of the base is generally limited to two percent of the base diameter for 60” and smaller manholes and to one percent of the base diameter for larger diameters. Larger deflections may be tolerated but the floor will not be level.

Equation 3-1 below from F 1759 is for calculating the stress in a flat manhole base subjected to a uniform pressure (groundwater). It assumes that the maximum stress of concern is at the center of the base:

\[
\sigma = \frac{3}{4} \frac{r^2}{p} \frac{t^2}{H_W} \tag{3-1}
\]

Where:

- \(\sigma\) = stress at center of base, psi
- \(r\) = radius of manhole base, in
- \(t\) = manhole base thickness, in
- \(p\) = hydrostatic head pressure from Equation 3-2, psi

\[
p = \frac{\gamma H_W}{144} \tag{3-2}
\]

Where:

- \(\gamma\) = unit weight of water, pcf
- \(H_W\) = height of groundwater above base, ft
The maximum stress in the base is limited to the allowable tensile stress of the base material. For SPIROLITE® manholes, the allowable material tensile stress is 800 psi at 73°F.

From ASTM F 1759, the maximum deflection of the base may be determined from Equation 3-3.

$$\delta = \frac{3}{16}(1 - \mu^2) \frac{pr^4}{Et^3}$$  \hspace{1cm} (3-3)

Where:
- $\delta$ = deflection at center of base, in
- $\mu$ = Poisson’s ratio (Long-term 0.45)
- $p$ = groundwater pressure, psi
- $r$ = manhole base radius, in
- $t$ = manhole base thickness, in
- $E$ = stress relaxation modulus, psi

The stress relaxation modulus value depends on how long groundwater is present and temp.

The actual stress and deflection observed in the base may be greater than the value from ASTM F 1759 and Equations 3-1 and 3-3. External groundwater pressure acting on the base may cause local deformation at the edge of the base and reduce restraint. When restraint is reduced, the base can deflect more. The resulting structural behavior of the base will be somewhere between that of a plate with fixed edges and a plate with free edges. The stress could be 30 percent or so higher than that predicted using Equation 3-1 and the deflection could be double that predicted by Equation 3-3.

Where the manhole is subjected to an internal negative pressure (vacuum), the negative internal pressure increases the external pressure acting on the manhole and should be added to the groundwater pressure in the above equations. When the application requires slight internal pressure or vacuum, the design Engineer must take any positive or negative internal pressure in the manhole into account. Please consult Performance Pipe.
4.0 Manhole Tops

Introduction
Safety considerations generally require that manholes have tops, not only to protect from a fall hazard but also to prevent escape of noxious gases. SPIROLITE® manholes may be supplied with a variety of different style tops. Most of these tops may be custom fabricated to provide vent pipes and special manway locations, dimensions and lids. SPIROLITE® tops are normally intended for gravity service manholes. When the manhole application requires internal pressurization or vacuum, the manhole normally requires a special top. Please consult Performance Pipe.

Unless otherwise noted, the manhole top styles in this guide are suitable for personnel and hand-carried equipment loads up to 500 pounds. When tops will be subjected to vehicular loading, ASTM F 1759 and Performance Pipe recommend a reinforced concrete cap or reinforced concrete casting around the manhole top. See Chapter 8 for concrete cap installation recommendations.

Gasketed Cone Tops
SPIROLITE® manhole cone tops are supplied with a gasketed joint for field joining to the manhole riser without welding. Gasketed cone tops are available for 48" IDR’s 43.5,30.5, and 27 and 60” IDR’s 39, 34.5, and 30.5. They are suitable for evenly distributed loads applied vertically to the cone rim of up to 1000 pounds. Typical gasketed cone tops are illustrated in Figures 4.1 and 4.2. See Table 4-1 for dimensions.

The gasketed system allows for easy field installation and a weather tight seal for up to 3 feet of external hydrostatic head. To avoid interference, the riser must extend at least 12” above the crown of the highest lateral pipe connected to the riser. See Appendix C for cone top dimensions and installation procedure.

Figure 4-1. Section View of Cone
Flat Tops
Flat HDPE tops with concentric or eccentric manways are available for all riser sizes. See Figure 4-3. Standard manway sizes include 24" IPS, 30" IPS, 36" IPS, 30"IPS and 36" IPS. Other sizes are available upon request. Gusseted flat tops for live loads such as equipment and personnel up to 500 pounds Special flat tops for loads up to 1000 pounds are available upon request. When used in conjunction with concrete slab tops, polyethylene flat tops can protect the concrete slab top against corrosion.

Manholes with flat tops are manufactured to the height specified by the Purchaser or Engineer to meet the final field grade requirements of the application. Manhole height is not easily adjusted in the field. If grade adjustment is required, a cone top should be considered. Before ordering the manhole, the Purchaser or Engineer should verify the correct manhole height.

Fabricated Flanged Manways
Tops are available with a fabricated flanged manway and a blind flange cover as illustrated in Figures 4-4 and 4-5. Flanged cover manways enhance the corrosion resistance and weather tightness of the manhole. Standard flanged cover manways are available for all riser sizes with 24" IPS, 30" IPS or 36" IPS openings, and custom sizes are available for larger manway openings. A gasket is optional. Gaskets are available in a variety of materials. Standard bolting patterns for ½” bolts diameter bolts are 8, 10, and 12 bolts respectively for 24" IPS, 30" IPS, and 36" IPS manways. Custom bolt hole patterns are available. Grade 2 steel bolts and nuts are standard. Other materials and strengths can be provided when specified. When opening the blind flange, it is common to loosen and remove all but one bolt; then swing the cover to the side.
Flanged Manway with Steel Backup Ring

Superior sealing for vacuum or low positive pressure manholes is provided by combining a HDPE manway with flange adapter, a steel backup ring, a HDPE or steel blind flange and an optional HDPE blind flange liner. For vacuum or low pressure design considerations, contact Performance Pipe. Blind flanges and backup rings for stubouts made from SPIROLITE® ID controlled pipe conform to AWWA C207 Table 1 Class B. Blind flanges and backup rings for stubouts made from conventionally extruded OD controlled pipe conform to AWWA C207 Table 1 Class D. Both are constructed with 150-pound drilling patterns. Blind flanges and backup rings are available in a various steel grades (carbon to stainless) and coatings (epoxy and zinc). The flanged manways illustrated in Figures 4.4 and 4.5 are available with a gusseted top plate for applications where increased structural strength is required.

Open Tops

Open tops are available for 36"-120" diameters for use with concrete caps or other tops where corrosion protection and slight over-spilling is not a concern. Tar-based mastics are typically used to reduce leakage between the concrete cap and riser.

WARNING

All manholes must be covered or guarded against unauthorized or accidental entry.
Manhole Top Design
A properly designed manhole top will carry the intended load of personnel and their hand carried equipment without excessive deflection. Polyethylene tops for heavier loads are available, but for vehicular loading, a concrete cap is required. See Chapter 8.

Top Loads
The design load for SPIROLITE® manhole tops is 500 pounds applied over a one-foot radius circular area at the center of the manhole. The Purchaser or Purchaser’s Engineer may specify other top loads. If so, consult Performance Pipe.

ASTM F 1759 does not provide a design methodology for manhole tops saying only that the design should be proven sufficient by testing or calculations. Manhole tops are flat plates (with or without gussets). The design equations for loaded flat plates are similar to those used for manhole bases. (1) The stress level in the top from personnel and light equipment must be kept below the allowable stress for the top material. (2) Calculated deflection is normally limited to one-half percent of the top diameter or 1/4”, whichever is smaller, per 100 pounds of load. Deflections larger than 2 percent of the manhole top diameter may be safe but uncomfortable for working personnel.

Equations 4-1 and 4-2 may be used to determine maximum design stress and deflection for a concentrated load acting over a one-foot radius area at the center of a fixed end plate. Equations 4-1 and 4-2 are from the sixth edition of Roark’s Formulas for Stress & Strain, edited by Warren C. Young (McGraw Hill (1989)).
\[ M_{\text{MAX}} = \frac{P}{4\pi} (1 + \mu) \ln \left( \frac{r}{r_o} \right) \]  \hspace{1cm} (4-1a)

\[ \sigma = 6 \frac{M_{\text{MAX}}}{t^2} \]  \hspace{1cm} (4-1b)

Where:

- \( M_{\text{MAX}} \) = maximum bending moment in top, lb-in/in
- \( P \) = load, lbs
- \( \pi \) = Pi (approximately 3.14)
- \( \mu \) = Poisson’s ratio values of 0.45 for long-term and 0.35 for short-term
- \( r \) = radius of manhole top, in
- \( r_o \) = radius of loaded area, in
- \( \sigma \) = stress at edge of loaded area, psi
- \( t \) = top thickness, in or equivalent thickness if gusseted

\[ \delta_{\text{MAX}} = \frac{3(1 - \mu^2) Pr^2}{4\pi Et^3} \]  \hspace{1cm} (4-2)

Where:

- \( E \) = modulus of elasticity, psi

Actual stress and deflection may be slightly higher than calculated, if local deformation occurs at the outer edge of the top. Error may also be introduced if deflection according to Equation 4-2 exceeds one-half the top thickness. For short-term top loading (such as workers entering and leaving the manhole), these errors do not create an unsafe condition.

The design load must be increased to accommodate the weight of closure materials such as a steel blind flange, back-up ring, bolts and nuts. For example, a 24” flange is 32” in diameter. 150-pound AWWA C207 Class D flanges are 1-7/8” thick. At 490 lbs/cu ft, a 1” thick steel back-up ring and 1” thick blind flange weigh 328 lbs. Add bolts and nuts, and the weight is about 350 lbs. From the 500 pound design load, this leaves 150 pounds. for personnel and equipment. If a full 1-7/8” thickness is used, back-up ring, blind flange and bolts weigh about 640 pounds.

The maximum stress in the top is limited to the allowable tensile stress of the HDPE material for SPIROLITE® manholes adjusted for the temperature when loaded. Long-term values for SPIROLITE® HDPE are 800 psi at 73°F and 400 psi at 140°F.
Temperature and duration of load affect the modulus of elasticity value. For example, if workers are on a top exposed to the sun in summer, the temperature of the top’s outer surface may approach 140°F. While fluid inside is generally cooler, the average temperature of the top (through its thickness) may be 120°F. In this case, a 36,900 psi modulus of elasticity value for design of 36,900 psi would be appropriate when workers are present for one hour. See Chapter 2, Table 2-2 for modulus of elasticity values for HDPE. The maximum deflection of the top should be limited to a reasonable amount that will not disturb workers or create an unsafe condition. A typical deflection limit is 2 percent of the diameter or 1-1/2 inches whichever is smaller.

Where the manhole is subjected to an internal negative pressure (vacuum), external air pressure creates a uniform pressure load on the top equal to the internal negative pressure. In designing the top to resist this load, the uniform pressure load equations for base design are used. See Chapter 3. Elevated temperature values for the modulus and strength may be required if the top is outdoors and exposed to sunlight. The **design Engineer must account for any positive or negative internal pressure in the manhole.**

Normally the manhole top is at or above ground level without soil cover. Where soil cover is desired, consult Performance Pipe. Soil cover increases the load on the top of the manhole and on the riser and must be accounted for in the design. Often, when the top is below the surface grade elevation, a concrete cap is required to reduce the earth load to an acceptable level.
5.0 Stub-Out Connections

Introduction
SPIROLITE® manholes are available with stub-out pipes for making lateral connections between the manhole and system piping. Stub-out pipes may be conventionally extruded OD-controlled pipe, such as DriscoPlex™ 4100 pipe as illustrated in Figure 5-1, or DriscoPlex™ 2000 SPIROLITE® pipe as illustrated in Figure 5-2. Stub-out pipes are available for various end connections including flanges, DriscoPlex™ MJ Adapters, and plain-ends for butt fusion, electrofusion, or mechanical coupling. SPIROLITE® stub-out pipes are available for a plain-end SPIROLITE® Closure joining, or SPIROLITE® bell and spigot joining.

Stub-out pipes may be placed at almost any orientation on the riser. Because backfill settlement and consolidation apply shear and bending loads where the stub-out penetrates the manhole riser, it is preferable to place stub-out penetrations close to the manhole's base or invert, especially with deep manholes. Stub-out pipes penetrate the riser wall to form an open channel invert or to connect to equipment, such as pumps or valves. Other options include, terminating the connection at the riser wall, or providing a drop within the manhole. See Chapter 6.0 The design Engineer should specify the orientation including the slope for gravity-flow stub-outs. The slope should be at least one-percent.

Extrusion welding is used to connect the stub-out pipe to the riser wall and to seal the penetration. When extrusion welding stub-outs onto solid wall SPIROLITE® risers, the weld fully penetrates the depth of the riser wall providing a superior connection, unlike the superficial weld resulting from the use of hollow core or profile risers. Because of the lack of penetration, superficial (surface fillet) welds do not develop the shear or bending strength of a full penetration weld. Likewise, field modifications to solid wall manholes (i.e. the addition of an extra stub-out) can be made with full penetration welds. With some sizes, there is a limitation to the maximum DR (minimum wall thickness) for the stub-out pipe. A wall that is too thin may result in stub-out distortion after welding to the riser. Consult Performance Pipe for maximum stub-out DR’s.
Plain End Stub-Outs
Plain end DriscoPlex™ pipes through 54” IPS or 48” DIPS are used to connect to system pipes using butt fusion, electrofusion or mechanical couplings. Butt fusion procedures are described in the Performance Pipe Bulletin PP750. For fusion joining, sufficient stub-out length should be specified to allow for clamping within the fusion machine. Butt fusion can be performed in the trench but it is usually necessary to over excavate the trench sides and bottom to allow adequate clearance to operate the fusion machine. Support for the butt fusion machine should be provided with blocks or a platform. Do not use the stub-out pipe to support the fusion machine. Typically, the stub-out pipe should be held in the fixed clamps of the machine. After the joint is complete and properly cooled, the machine is rotated around the pipe and lifted off. When making a butt fusion in the trench, do not lift the fused assembly out of the butt fusion machine. Any damage caused by such improper handling is the responsibility of the Installer.

For electrofusion and mechanical joining techniques, see the Performance Pipe Engineering Manual. Electrofusion and mechanical coupling connections must be made in accordance with the connection manufacturer’s instructions. When connecting to non-polyethylene piping materials, the inside diameter of the polyethylene stub-out pipe and the inside diameter of the non-polyethylene pipe should be closely matched to avoid a lip that can upset flow.

Flange Connection Stub-Outs
Flange adapters are available for DriscoPlex™ 2” IPS through 54” IPS pipes, 3” DIPS through 48” DIPS, and SPIROLITE pipe sizes from 18” through 120” diameter. A back-up ring behind the polyethylene flange adapter is required for joining to other flanges. See Figure 5-3. Flange adapter and back-up ring dimensions are provided Performance Pipe Bulletins PP1.1 through PP1.6. Standard backup rings for IPS and DIPS sized flange adapters conform to AWWA C207 Table 1 Class D. Standard steel backup rings for SPIROLITE® stub-outs conform to AWWA C207 Table 1 Class B. Both back-up rings have 150-pound drilling patterns. Back-up rings are available from various materials and steel grades with various coatings including epoxy or zinc. For connecting DriscoPlex™ 2000 SPIROLITE® pipes, back-up rings are normally “split”, i.e. supplied as two halves. See the Performance Pipe Engineering Manual for Flange information. See Performance Pipe Technical Note PP-811 TN for flange installation.
**SPIROLITE® Bell and Spigot Joint Stub-Outs**

Stub-outs for SPIROLITE® bell and spigot joints incorporate formed bells or machined spigots for connecting to SPIROLITE® pipe. See Figure 5-4. SPIROLITE bell and spigot joints meet or exceed ASTM D-3212 performance specifications in 18" through 84" diameters. Larger diameters are extrusion welded after assembly.

Polyisoprene gaskets meeting ASTM F-477 are standard. Neoprene, EPDM rubber, nitrile rubber, or other elastomeric gasket materials are available upon request. See Performance Pipe Technical Note PP 837 TN for assembly procedures.

**SPIROLITE® Closure Joint Stub-Outs**

SPIROLITE® Closure Joints are used with Spirolite Closure Pipe to provide field adjustability of laying length to match the actual laying distance in the field. SPIROLITE Closure Pipes can be field cut to the required laying length, and are joined with a closure gasket to a SPIROLITE® Closure Bell. See Figure 5-5. Appendix D “SPIROLITE® Closure Joints” illustrates the procedure for using closure joints to connect a manhole to SPIROLITE pipe. SPIROLITE® closure joints meet or exceed ASTM D-3212. SPIROLITE® closure pipe is available in 18" through 60" sizes with standard polyisoprene gaskets that meet or exceed the requirements of ASTM F-477. Neoprene, EPDM rubber, nitrile rubber, or other elastomeric gasket materials are available upon request. See Performance Pipe Technical Note PP 837 TN for closure joint assembly procedures.
SPIROLITE® Through-Pipe Sizes for Common Riser Sizes

For manholes with SPIROLITE® inverts (internal thru-pipes with benching), Table 5-1 may be used to estimate the manhole riser diameter required for various sized thru-pipes and bend angles. Shipping restrictions may affect some choices. Consult PERFORMANCE PIPE for verification of sizes. See Figure 5-7 for the convention for naming angles.
<table>
<thead>
<tr>
<th>Riser Diameter</th>
<th>Maximum Straight SPIROLITE Thru-Pipe Size</th>
<th>Miter Type*</th>
<th>Maximum SPIROLITE Pipe Miter Sizes</th>
<th>Standard Angles/Bends*</th>
</tr>
</thead>
<tbody>
<tr>
<td>36&quot;</td>
<td>30&quot;</td>
<td>Single</td>
<td>27&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>27&quot;</td>
<td>61° - 90°</td>
</tr>
<tr>
<td>42&quot;</td>
<td>33&quot;</td>
<td>Single</td>
<td>30&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>30&quot;</td>
<td>61° - 90°</td>
</tr>
<tr>
<td>48&quot;</td>
<td>36&quot;</td>
<td>Single</td>
<td>33&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>33&quot;</td>
<td>61° - 90°</td>
</tr>
<tr>
<td>54&quot;</td>
<td>42&quot;</td>
<td>Single</td>
<td>33&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>33&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>33&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td>60&quot;</td>
<td>48&quot;</td>
<td>Single</td>
<td>42&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>42&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td>66&quot;</td>
<td>54&quot;</td>
<td>Single</td>
<td>48&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>48&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>42&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td>72&quot;</td>
<td>60&quot;</td>
<td>Single</td>
<td>54&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>54&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>48&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td>84&quot;</td>
<td>66&quot;</td>
<td>Single</td>
<td>60&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>60&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>54&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td>96&quot;</td>
<td>72&quot;</td>
<td>Single</td>
<td>72&quot;</td>
<td>0° - 60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>72&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double</td>
<td>66&quot;</td>
<td>46° - 90°</td>
</tr>
<tr>
<td>120&quot;</td>
<td>96&quot;</td>
<td>Single</td>
<td>96&quot;</td>
<td>0° - 45°</td>
</tr>
</tbody>
</table>

* Other angles and number of miters available upon request.

Typical stub length from the manhole wall range from approximately 2" to 18" depending on stubout and manhole size with lengths for full fusion available. Consult Performance Pipe for laying length dimensions. Thru-sizes and angles for other riser sizes may be obtained by contacting Performance Pipe.
Figure 5-7. Convention for Naming Angles

Manhole Tee
For 48” diameter and larger pipelines, using Manhole Tee can reduce manhole riser size and cost. See Figure 5-8. Manhole Tees are manufactured for through-pipe diameters from 42" through 120" where the riser diameter is smaller than the through-pipe. The ends of the through-pipe may be plain, flanged, SPIROLITE bells or spigots or SPIROLITE Closure bells, and Manhole Tees may be supplied on bends as shown in Figure 5-8. Manhole Tees can be provided with ladders, working platforms, and flat tops or cones. See Chapter 6.0.

Figure 5-8. SPIROLITE® Manhole Tees
6.0 Appurtenances

Introduction
To increase versatility, SPIROLITE® manholes can be supplied with various appurtenances and accessories. Manholes are available with ladders, platforms (grates), drop pipes, pump mounting pads, internal platforms, lifting lugs, and other appurtenances. Figure 6-1 illustrates some of the available appurtenances and accessories. When practical, fabricated HDPE brackets and mounts that can be extrusion welded to the manhole riser wall, floor or bench are used for mechanical appurtenance mountings. Manholes can be supplied with factory-installed brackets ready for field mounting of user specified accessories.

Many of the mounting details shown in the figures are for illustration only. Mounting brackets supplied on SPIROLITE® manholes may vary from those illustrated in the figures and photographs. The style of bracketing depends on the field application and the appurtenance or accessory.

![Figure 6-1. Manhole with Appurtenances and Accessories - Drop Pipe, Ladder, and Pump Mount](image)

Drop Connections & Internal Piping
Drop connections and internal piping may be constructed using HDPE or other piping materials. When making drop connections, it is recommended the "drop" be inside the manhole, to avoid downdrag forces from embedment surrounding the manhole that could damage the connector pipe. Figure 6-2 illustrates a drop connection in a SPIROLITE® Manhole. A molded or fabricated tee with an expansion plug or a removable closure in the run leg can be used to access through-wall inlet piping.
Internal HDPE piping may be factory or field installed. For field installation, HDPE brackets can be welded to the manhole so that pipe hangers, (supplied by others), can be attached to the mounting brackets without penetrating the manhole wall. See Figure 6-2.

![Figure 6-2. Mounting Bracket](image)

For HDPE interior piping, pipe hangers should encompass the entire circumference of the pipe, and a 1/8" thick elastomer or rubber sheet should be placed around the pipe under the pipe hanger to prevent abrasion damage. Spacing recommendations from the *Performance Pipe Engineering Manual* are used for horizontal and vertical pipe bracket spacing.

![Figure 6-3. Drop Connection, Grate, & Ladder](image)  ![Figure 6-4. Steel/PP Unitized “Steps”](image)

Factory-installed HDPE piping inside a manhole can be anchored at connection points to pumps, valves or inlet/outlet pipes. Extended pipe lengths can be restrained with guides between anchor points or tack welding to the manhole wall.
Warning Lid
A removable warning lid for the top of the manway opening is available. Warning text on the lid advises that the manhole is a confined space and that a safety harness attached to a fall protection apparatus is required for entry. **Warning lids are not a substitute for properly secured manhole top closure devices (manway lids) that prevent unauthorized entry and provide structural support.**

![Figure 6-5. Fiberglass Ladder](image)

Ladders
The decision whether or not to provide a permanent ladder in the manhole rests with the **Owner, Purchaser, or the Engineer.** Performance Pipe offers aluminum-and-steel reinforced polypropylene ladders, fiberglass ladders, and steel reinforced polypropylene unitized-steps up to 40 feet in length for mounting in SPIROLITE® manholes. Ladders and steps can be installed in any diameter SPIROLITE® manhole riser provided there is adequate clearance. “Steps” are narrow ladders that do not meet OSHA width requirements for a working platform. Steps are used only to access the manhole base and to exit the manhole. If work is to be performed at intermediate places along the riser, a ladder or a ladder with working platform(s) must be used. Steps cannot be used as a working platform. Manholes equipped with ladders are normally furnished with flat tops and an eccentric opening over the ladder. Ladders can also be installed in 48" diameter manholes with cone tops. Ladders are shown in Figure 6-4 and Figure 6-5.

OSHA and Manhole Steps and Ladders
*The entrant’s employer (Owner) should determine whether or not entry into SPIROLITE® manholes meets applicable OSHA requirements.* At the time this manual was written, OSHA had not published specific dimensional requirements for manhole ladders or steps. Since ladders in manholes are fixed ladders (permanently mounted ladders), the requirements in 29 CFR 1910.27, “Fixed Ladders”, may apply. **SPIROLITE® Manholes may not meet all applicable ladder-dimensional and ladder-load requirements for fixed ladders or steps in accordance with 29 CFR 1910.27, due to limitations imposed by manway size requirements that are necessary for accommodating standard manhole rings and covers, due to surface grade adjustments made at the time of installation that lengthen the “first step” distance, locations of fixtures and equipment in the manhole, and due to vertical positioning of the ladder within the manhole.** These circumstances are
not unique to SPIROLITE® manholes. Many of these same variances also occur with manholes made from other materials.

**WARNING** – Whether or not a permanent ladder or steps are present, when entering, at all times while inside and when exiting SPIROLITE® manholes, use a safety harness attached to a fall protection system, and observe all OSHA, state, local, and other applicable confined space entry procedures including the use of a three-man crew and the use of gas detection equipment to prove the atmosphere inside the manhole is safe.

![Figure 6-6. Harness with Fall Protection System](image)

**Ladder and Step Options**
Ladder and step options are summarized in Table 6-1. Two types of ladders and one type of unitized steps are available. OSHA requires a minimum rung width of 16” for ladders, but steps may be narrower. The unitized steps offered by Performance Pipe are a narrow ladder and may be used only to access the manhole base and to exit the manhole.

**Ladders in Excess of 20 feet**
OSHA specifies that fixed ladders in excess of 20 feet require the use of fall protection devices such as a harness attached to a fall protection system, a harness attached to a permanent sliding friction brake device or an intermediate platform. See Figure 6-7. For ladders over 20 feet, the Owner or the Owner’s Engineer should select the fall protection system. The default selection is that the Owner
Figure 6-7. Ladder with Friction Brake Device

will control all manhole entries using a safety harness connected to a fall protection system.

Table 6-1. Manhole Unitized Steps and Ladder Options

<table>
<thead>
<tr>
<th>Steps/Ladder Material</th>
<th>Rung Width (in)</th>
<th>Manway Diameter (if ladder extends in manway) (in)</th>
<th>OSHA Manway Diameter (if ladder extends in manway)** (in)</th>
<th>Ladder Extensions and Grab Bars for Entry</th>
<th>Friction Brake Fall Protection Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass</td>
<td>18</td>
<td>27</td>
<td>30</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>Reinforced Polypropylene Ladder*</td>
<td>16.5</td>
<td>27</td>
<td>30</td>
<td>Available Telescoping Into ladder shaft</td>
<td>Available</td>
</tr>
<tr>
<td>Reinforced Polypropylene Unitized Vertical Steps*</td>
<td>11.5</td>
<td>24</td>
<td>30</td>
<td>Not Available</td>
<td>Not Available (Rungs are too narrow)</td>
</tr>
</tbody>
</table>

NOTES:
*Ladders and unitized steps (narrow width ladders) are reinforced with aluminum and steel.
**Manway diameter to meet headroom clearance specified in OSHA 1910.27.
***Multiple ladders may be placed in manhole to reach depth of 40 ft.

Manway Entrance and Ladder
SPIROLITE® manholes are offered with various manway designs. See Chapter 4. The manway diameter is typically based on the size of the manhole ring and cover. The Owner must specify the manway diameter. Performance Pipe offers 24” diameter and larger manways. When a ladder is used, the ladder may terminate at the top of the riser or it may extend into the manway. If the ladder extends into the manway, the manway opening can be positioned over the ladder to provide maximum clearance for an entrant through the manway. When the ladder extends into the manway,
Manway clearance is reduced. Clearance is defined as the minimum clear distance between the ladder rung and the opposite wall of the manway. OSHA 29 CFR 1910.27 specifies a 24” minimum clearance distance for ladders passing through an access hatch opening. On the other hand, ASTM C 478, *Standard Specification for Precast Reinforced Concrete Manhole Sections*, requires a minimum clearance of 18”. The Owner must decide which specification, if any, is appropriate for his manway requirements. Figure 6-8 illustrates how manway clearance is defined. Table 6-2 provides clearance dimensions for 24”, 27”, and 30” manways with ladders extending into manway. In selecting the manway size, the Owner should consider if an entrant would be required to wear an air pack.

![Figure 6-8. Manway Clearance](image)

**Table 6-2. Clearance between Ladder and back of Manway**

<table>
<thead>
<tr>
<th>Ladder Style</th>
<th>24” Manway (in)</th>
<th>27” Manway (in)</th>
<th>30” Manway (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass</td>
<td>15</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>Reinforced PP Ladder</td>
<td>16</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Reinforced PP Unitized Steps</td>
<td>19</td>
<td>22</td>
<td>24</td>
</tr>
</tbody>
</table>

Notes: Dimensions are nominal and rounded down to the nearest inch. Manufactured dimensions may vary due to tolerances. Clearances are for manways that are located eccentric to the center of the manhole riser. Exact clearance will depend on manway location.

When the ladder is located within a manway, the minimum clearance between the back of the ladder and the manway wall is 4”. This meets ASTM C 478 requirements, but does not meet OSHA 29 CFR 1910.27 requirements for a 7” minimum clearance. Performance Pipe maintains the OSHA clearance distance in the manhole riser. It is the responsibility of the Owner to determine how these clearance requirements are to be applied, and to specify clearance requirements appropriate to their application to Performance Pipe when purchasing a SPIROLITE® manhole with a ladder.

**Deflector Shield**

At the Owner’s request, Performance Pipe can provide a head deflector shield at the lower entrance of the manway to prevent an entrant from striking their head on the manhole top where required by OSHA 29 CFR 1910.27.
WARNING – Whether or not a head deflector shield is provided, wear protective headgear such as a hard hat when entering, at all times while inside, and when exiting SPIROLITE® manholes.

Surface Grade Adjustment Effect
When adjustments to surface grade are made by adding grade rings, a concrete cap or other means to build up to grade, the distance between the top ladder rung and the surface grade may not meet OSHA requirements for fixed ladders. Often the field adjustment to surface grade exceeds 6”-12”, and may violate “first step” distance criteria. The Owner is responsible for determining whether or not the “first step” distance is acceptable. Where first step distances are excessive, grab bars and ladder extensions are available for the Fiberglass and Aluminum-and Steel Reinforced Polypropylene ladders. Use of grab bars and extensions requires an acceptably sized manway. See Figure 6-9.

Because the “first step” distance could be excessive, Performance Pipe recommends using a safety harness connected to a fall protection device. However, Performance Pipe cannot interpret for the Owner whether or not this is acceptable to OSHA in meeting “first step” distance requirements.

Ladder Testing
Fiberglass ladders meet the requirements in OSHA 29 CFR 1910.27 and are capable of supporting a concentrated vertical load of 1200 pounds applied at the mid-span of the rung. Steel reinforced polypropylene unitized steps and aluminum-steel reinforced polypropylene ladders meet the load requirements of ASTM C 497, which requires the steps to meet a horizontal pull load of 400 lbs at right angles to the manhole riser wall and a vertical load of 800 lbs parallel to the wall mounts.

Platforms
Platforms are another fall protection safety alternative when the manhole vertical height exceeds 20 feet. They are also used in manhole tees where no benching is present. HDPE platforms can be factory installed in 48", 60" and 72" manhole risers. Standard platform manway and platform
manway cover diameters are 30". Each cover is supplied with two handles for easy access. Platforms can be designed to handle loads of up to 500 lbs. for men and equipment. Special riser and manway sizes are available upon request. See Figure 6-10.

**Grates**

Grates may be incorporated into the manhole by using an HDPE "grate-shelf" which is extrusion welded to the riser wall. The standard HDPE grate shelf will support grates with an evenly distributed load not exceeding 1000 lbs. The Owner or Owner’s Engineer should specify the grate material, and should obtain the grate load capacity from the grate manufacturer. See Figure 6-11.

**Pump Guide Rails & Mounting Pads**

Pump guide rails that are mounted to the manhole wall are available. See Figure 6-12. During
operation, pumps generate torque and vibration forces, therefore, any method for mounting a pump in a polyethylene manhole should use a design that does not penetrate the manhole shell and is capable of carrying the static and dynamic loads produced by the pump. Pump Mounting Pads/Blocks should be reinforced using steel or reinforced concrete. All pump mounting configurations must be reviewed and approved by the Purchaser or Engineer for the pump mount's ability to carry the loads imposed upon it.

![Figure 6.12. Pump Guide Rails](image)

Two pump mounting pad configurations are reinforced concrete mounting pads and sandwiched steel plate mounting pads.

**Reinforced Concrete Mounting Pad**

This method uses a 6" to 12" poured-in-place slab of reinforced concrete at the bottom of the manhole. **The Purchaser or Engineer must specify the concrete and the reinforcement design.** The pump is typically anchored to the concrete pad with anchor bolts that are cast into the concrete pad. This method may require the manhole depth to be increased by the thickness of the concrete, so the top of the concrete pump pad is at the required elevation. Upon request, gussets or ribs may be attached to the manhole wall or floor for extra stability for a cast in place concrete pad. To avoid handling damage, concrete slabs must be installed after the manhole has been placed. Guide rails, supplied by others, may be anchored to the concrete with anchor bolts or cast into the slab.
Sandwiched Steel Plate Mounting Pad
This method is suitable for risers up to 72" diameter, and entails sandwiching a steel or stainless steel plate between a flat HDPE manhole bottom and a HDPE flat sheet stock. The pump, and guide rails if used, may then be bolted through the HDPE into the steel plate. The anchor bolts must not penetrate the flat manhole bottom and should be gasketed to seal the steel mounting plate against corrosion. The Engineer must specify the grade and thickness of the steel plate. See Figure 6-13.

Figure 6-13. Sandwiched Steel Plate for Pump Mounting

Lifting Lugs
For reliable handling, lifting lugs can be extrusion welded at the top of Performance Pipe manholes. Figure 6-14 illustrates one style of lifting lugs available from Performance Pipe. See Section 8.0.

Figure 6-14. Lifting Lugs
Flow Control and Monitoring Devices
Flow control and monitoring devices supplied by others can be mounted inside of SPIROLITE® manhole inverts or as an internal part of the SPIROLITE® manhole.

Figure 6-15. Manhole base with Sluice Gates

Landfill Liner Welding Ring
A ring can be provided around the riser so a HDPE geofabric liner or HDPE geofabric cap can be welded to the manhole. See Figure 6-16.

Figure 6-16. Welding Ring for Fabric Attachment
7. Anti-Flotation Options

Where groundwater rises above the base of a manhole, even temporarily, an upward buoyant force is exerted on the manhole base. If the buoyant force is greater than the combination of the manhole weight and the frictional resistance between the manhole riser and the embedment soil surrounding the riser, it will push the manhole upward (i.e., the manhole will “float”). Theoretically, the frictional resistance equals (or is) the downdrag force. While Chapter 2 shows that there may be considerable downdrag force acting on the manhole riser, this force does not always fully develop. Development can be impaired by the reduction in the soil’s unit weight due to saturation and buoyancy, by fluctuations in the groundwater level, by a reduction in the coefficient of friction between the riser and the soil due to wetting, and by shrinkage of soil away from the manhole. Therefore, only a portion of the downdrag force calculated in Chapter 2 can normally be counted on to permanently resist flotation. That is, the PE to soil coefficient of friction value in Chapter 2 is conservative for downdrag calculations but is not conservative for flotation calculations. See Appendix E for information about estimating the frictional resistance against flotation. The Purchaser or Engineer should evaluate frictional resistance based on soil and groundwater conditions to determine the appropriate method to prevent flotation.

Reinforced Concrete Anchor Collars and Anti-flotation Slabs

A more positive way to prevent flotation is to anchor the manhole with a reinforced-concrete anchor collar or, where the manhole is connected into a DriscoPlex™ 2000 SPIROLITE polyethylene pipeline, to anchor the manhole by restraining the SPIROLITE thru-pipes that extend from the manhole with flat reinforced concrete slabs (anti-flotation slabs), above the pipeline embedment. Figure 7-1 shows precast anchor rings placed around SPIROLITE manhole risers. Anti-flotation slabs are discussed and illustrated in a later section of this chapter and are suitable for use with SPIROLITE pipe or 18” and larger conventionally extruded (DR) pipe. Appendix E provides formulas for evaluating flotation resistance for manholes with anchor collars and anti-flotation slabs. Because site conditions can vary significantly from project to project, it is the Purchaser or the Engineer’s responsibility to verify the adequacy of a concrete collar or anti-flotation slabs in resisting manhole flotation and to specify collar and slab dimensions and steel reinforcement for any specific project.

Concrete Anchor Collars

Reinforced concrete anchor collars are usually cast-in-place around the manhole, but they may also be precast in semi-circular pieces and joined with appropriate connectors to keep the pieces from separating. Connection devices must be corrosion resistant or protected against corrosion. See Figure 7-1. Most of the collars illustrated in this chapter are circular, but square or rectangular shapes may also be used. Rectangular collars may be more effective than circular collars when restraining manholes where through pipes are 30” and larger.
Concrete anchor collar dimensions are normally selected so that the weight of the anchor collar and the soil above the collar offset the buoyant force acting on the manhole and provide an adequate safety factor against flotation. The buoyant force acting on the manhole is equal to the weight of the volume of water displaced by the manhole and the stubout pipes under the shadow of the collar. The offsetting downward force is calculated using the weight of the concrete anchor collar plus the buoyant weight of the soil directly above it. See Appendix E for equations for dimensioning circular concrete collars.

Fixing Anchor Collars to the Manhole
Because concrete does not bond to polyethylene, the concrete anchor collar must be mechanically fixed to the manhole so that it will restrain against flotation. Fixing is accomplished by fixing the anchor to the manhole with rebar pins fitted through holes in the riser wall below the manhole base, or by providing a shelf (an Anchor Connection Ring or an Extended Base Plate) upon which the anchor may be set or poured. Figure 7-1 illustrates these options. Once an option is chosen, it must be specified when ordering the manhole.

Table 7-1. Options for Fixing Concrete Anchor Collar to SPIROLITE® Manhole

<table>
<thead>
<tr>
<th>Fixing Option*</th>
<th>Anchor Collar Construction</th>
<th>Typical Thru-Pipe Diameters (in)</th>
<th>Base Styles Available</th>
<th>Typical Relative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebar Through Riser**</td>
<td>Cast-in-Place</td>
<td>1 1/2&quot; through 54&quot;</td>
<td>Externally Gussetted Benched</td>
<td>Least Costly</td>
</tr>
<tr>
<td>Extended Base Plate</td>
<td>Precast or Cast-in-Place</td>
<td>1 1/2&quot; through 54&quot;</td>
<td>Flat Internally Gussetted</td>
<td>In Between</td>
</tr>
<tr>
<td>Anchor Connection Ring</td>
<td>Precast or Cast-in-Place</td>
<td>1 1/2&quot; through 30&quot;</td>
<td>Flat Externally Gussetted Internally Gussetted Benched</td>
<td>Most Costly</td>
</tr>
</tbody>
</table>

* Options A, B, and C are not applicable to manhole tees. **May require special riser with extra thickness near...
Rebar Through Riser with Concrete Collar

This option uses corrosion protected rebar pins that are hooked through the base of the riser and then cast into the concrete collar. Hence, the concrete collar must be poured-in-place after the manhole and rebar are in position. The rebar pins must be protected against corrosion because rebar pin failure would free the manhole to float upward. To form a hook, the end of the rebar pin is bent 90 degrees, around the smallest diameter pin that the bar will take without fracturing. A special riser with extended length below the manhole base may be required. See Figure 7-2.

Rebar Connections

The number of rebar pins required to prevent the rebar pins from pulling through the base of the manhole is shown in Tables 7-2 and 7-3. The Engineer must determine that the rebar selected is adequate to carry the upward load and must ensure that the concrete collar will not fail or crack from earth loads or stresses from thermal contraction and expansion. Tables 7-2 and 7-3 are based on using #8 or #14 rebar. Performance Pipe will typically pre-drill the required number of 1-1/4” (for #8 bars) or 1-7/8” (for #14 bars) diameter holes around the riser base. It may be necessary to place the rebar pins through the holes in the manhole riser before "setting" the manhole.

The minimum number and size of rebars shown in Tables 7-2 and 7-3 are required to prevent the rebar from pulling thorough the HDPE riser without consideration for the amount of reinforcement required in the concrete anti-flotation collar. Collar reinforcement and design is the Engineer’s responsibility.

Figure 7-2. Rebar through Riser with Concrete Collar
Table 7-2  Number of Rebar Holes in Riser Circumference Using #8 Rebar

<table>
<thead>
<tr>
<th>Riser Diameter</th>
<th>Height of Groundwater Above Manhole Bottom (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>48</td>
<td>*</td>
</tr>
<tr>
<td>54</td>
<td>*</td>
</tr>
<tr>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>66</td>
<td>8</td>
</tr>
<tr>
<td>72</td>
<td>8</td>
</tr>
<tr>
<td>84</td>
<td>8</td>
</tr>
<tr>
<td>96</td>
<td>9</td>
</tr>
<tr>
<td>120</td>
<td>11</td>
</tr>
</tbody>
</table>

*Option A cannot be used for these conditions, as manhole bases are flat without gussets.

Table 7-3  Number of Rebar Holes in Riser Circumference Using #14 Rebar

<table>
<thead>
<tr>
<th>Riser Diam.</th>
<th>Height of Groundwater Above Manhole Bottom (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>48</td>
<td>*</td>
</tr>
<tr>
<td>54</td>
<td>*</td>
</tr>
<tr>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>66</td>
<td>8</td>
</tr>
<tr>
<td>72</td>
<td>8</td>
</tr>
<tr>
<td>84</td>
<td>8</td>
</tr>
<tr>
<td>96</td>
<td>8</td>
</tr>
<tr>
<td>120</td>
<td>8</td>
</tr>
</tbody>
</table>

* Option A cannot be used for these conditions, as manhole bases are flat without gussets.
+ #14 rebar is not adequate for these conditions.
Extended Base Plate with Concrete Anchor Collar
In this option, the flat base is extended outside the riser circumference to provide a shelf beneath the concrete anchor collar to prevent floatation. This option is suitable for precast and cast-in-place collars. See Figure 7-3.

Figure 7-3. Anchor Connection with Extended Base Plate

For precast anchor collars, the collar should be dimensioned so that the clearance between the outside diameter of the manhole riser and the inner diameter of the anchor collar is one inch or less. As illustrated in Figure 7-3, any gussets required to reinforce the manhole base are installed inside the manhole. When installing the manhole, compacted foundation material should be placed level with the top of the extended base plate, so that the downward soil load on the anchor collar is uniformly distributed over the extended base plate and the foundation soil. To allow clearance for the anchor collar and placement of soil bedding under the stub-out pipes, stub-out pipes should be located in the riser to provide at least 4” clearance between the top of the anchor collar and the stub-out invert. This provides room for a “false” bottom or floor in manholes with internal gussets. (A “false bottom” or floor is not shown in Fig. 7-3.)
Anchor Connection Ring with Concrete Anchor Collar
This option utilizes an Anchor Connection Ring, which is a HDPE ring extrusion welded to the riser's outside diameter part way up the riser as illustrated in Figure 7-4. A reinforced concrete collar is positioned on top of the anchor connection ring so the weight of the soil above the collar resists upward flotation. Anchor connection rings may be placed no higher than 36" above the base of the manhole to minimize downdrag soil load transfer into the ring and the riser. Therefore, the manhole foundation material, which is Class I material compacted to 95% of Standard Proctor Density, must extend from beneath the manhole up to 4” to 6” over the top level of the anchor connection ring. As with the extended bottom option, the clearance between the outer diameter of the riser and the inner diameter of the collar is not to exceed one inch. See also Figure 8-5 in Chapter 8. Anchor connection rings are restricted to 30” diameter and smaller through-pipes.

![Figure 7-4. Anchor Connection Ring with Concrete Collar](image)

Concrete Anti-Flotation Anchor Slab
Anti-flotation anchor slabs can be used to restrain HDPE manholes by placing reinforced concrete slabs above the thru-pipes or stub-outs. Anti-flotation anchor slabs can be used for SPIROLITE pipelines and for conventionally extruded HDPE pipe where the pipe is 18” diameter or larger and DR 32.5 or lower. Where the nominal diameter of the stub-out pipe is less than 25% of the nominal diameter of the manhole, consult Performance Pipe to determine if the anticipated shear stress on the stub-out is acceptable. See Figures 7-5 and 7-6.
Together, the weight of the slab and the weight of the soil above the slab resist manhole flotation. The frictional resistance within the soil is normally ignored. See Appendix E for flotation resistance design information for concrete anti-flotation anchor slabs.

See Figure 7-5 for anti-flotation slab length, width and thickness dimensions. Slab width can vary but typically equals 48” or one pipe diameter whichever is larger. The length depends on the diameter of the pipe and the required hold down force. As illustrated in Figure 7-6, the slab is placed over the pipeline so that its long dimension or “length” is oriented perpendicular to the direction of flow.
Slab Installation
Anti-flotation anchor slabs are installed after embedment has been placed around the thru-pipe and compacted to a minimum of 95% of Standard Proctor Density. Slabs are normally placed 4” from the manhole riser wall and 6 to 8 inches above pipe as illustrated in Figure 7-5.

Figure 7-6. Typical Anti-flotation Anchor Slab Detail
8.0 SPIROLITE® Manhole Installation Guidelines

WARNING
PERFORMANCE PIPE recommends that all entries into SPIROLITE® manholes, including those containing ladders, be made using a safety harness attached to a fall protection system. The standing surfaces and walls of the manhole may be slippery, particularly when wet. Use due caution when working inside the manhole. All OSHA, local, and other applicable confined space entry procedures must be followed including the implementation of a three-man crew and use of gas detection equipment to prove the atmosphere safe.

Introduction
The key to a successful installation is achieving stable and permanent support under and around the manhole. Uniform and proper placement of the foundation and backfill materials is necessary to obtain permanent support. All applicable safety procedures should be strictly followed during handling and installation of SPIROLITE® manholes. All construction must be done in accordance with local, state, and OSHA regulations, including but not limited to:
- Trench excavation, including placement of bracing, sheathing and trench shields
- Entry and egress of trenches, pipes, and manholes
- Heavy equipment operation

Handling
Safe handling instructions are provided with each shipment of pipe and manholes. Failure to follow these instructions may result in severe injury, death, or property damage. Prior to off-loading and handling any PERFORMANCE PIPE structures, it is imperative that all personnel involved in their handling be acquainted with the Handling Instructions.

Fig. 8-1. Placing Manhole

Fig. 8-2. Manhole Trench in Landfill
The delivery vehicle and lifting equipment must be parked on level ground with stabilizers fully extended and set. Parking brakes must be set and wheels chocked where applicable. The unloading equipment should be inspected for condition and lifting capacity before use. The structure should be lifted with a crane or backhoe using slings of sufficient capacity to safely handle the load.

Structures shall be moved using the lifting lugs connected to the manhole wall. All lugs are equally spaced around the circumference. A web style strap, such as nylon, shall be connected to each lug on one end and held together with a hook on the other end (as illustrated in Fig. 1), taking care to distribute the load equally between all lugs. When standing the structure upright, do not lift by lifting lugs. Wrap straps around the structure and use the lugs as strap stops. Lift with the straps. Once the structure is vertically "righted", then the lugs may be used for lifting. The following should be met:

- Use only web style slings when lifting the structures. Do not use wire rope or other devices that may cut into the lifting lugs or provide insufficient force distribution.
- Do not sling by fewer lugs than those provided on the structure.
- Do not lift structure when containing fluid or any other materials.
- Do not stand on, under, or around structure while it is being lifted.

**Manhole Installation**  
**Warning**  
Consult the appropriate authorities on trench construction requirements. Take all safety precautions when working in or near a trench.

PERFORMANCE PIPE’s recommendations for the installation of manholes satisfy the design assumptions given in Section 4.2 of ASTM F 1759. PERFORMANCE PIPE recommends that the manholes be placed on a stable base and embedded with a compacted coarse-grained embedment material that extends radially at least 3.5 ft from the perimeter of the manhole or to undisturbed in
situ soil (whichever is greater) and for the full height of the manhole. Direct installation in new or active sanitary landfills or other fills subject to large settlements require special considerations outside the scope of these recommendations. Figure 8-3 shows PERFORMANCE PIPE’S recommendations.

Fig. 8-3. Typical Installation Recommendations for SPIROLITE® Manholes

Dewatering
The manhole trench must be dry during installation. Dewater by installing deep wells, sumps, well points, or other methods appropriate for the particular site. Maintain dewatering until completion of backfilling to prevent flotation during construction.

Foundation
The manhole should be installed on a stable foundation. All large rocks and clumps should be removed from the trench bottom. The foundation should consist of a minimum of 8" of Class I material (as defined by ASTM D 2321) compacted to a minimum of 95% Standard Proctor (as defined by ASTM D 698). Placement on a concrete slab foundation is also acceptable. In unstable insitu soils, a sub-foundation may be required to obtain a stable trench bottom. The sub-foundation can be constructed by removing weak organic or otherwise unstable soils and replacing them with stable, compacted materials.

Backfill and Compaction
PERFORMANCE PIPE recommends the use of Class I or II material as defined by ASTM D2321 for embedment of the manhole. Place in lifts not exceeding 8" and mechanically compact to the density specified by the Engineer or 90% Standard Proctor (95% under streets), which ever is higher. Compacted backfill must extend to the trench wall or undisturbed soil. This distance from the manhole (outside surface of the riser) to the trench wall must be at least 3.5 feet. See Figure 8-3.

When lateral pipe connections enter the manhole, the embedment requirements for the pipe located
within the backfill zone of the manhole must meet or exceed both the minimum requirements for the manhole, as well as, the minimum requirements for the pipe.

Concrete Anti-flotation Collars
When a concrete collar and anchor connection ring is used to resist flotation, compacted foundation material should extend above the anchor connection ring to the bottom of the concrete collar as shown in Figures 8-6 and 8-7. See Chapter 7, “Anti-Flotation Options”.

Fig. 8-6 SPIROLITE® Manhole Installation with Anti-Flotation Collar

Fig. 8-7 Detail of Concrete Anti-flotation Collar Installation
Flowable Fills
When placed correctly, flowable backfill material, including materials such as concrete, cementitious grout or controlled density fill (CDF), can provide reliable manhole support. Precautions must be taken to avoid buckling and/or floating the manhole during placement of flowable fill. These precautions may include filling the manhole with water, placing flowable fill in lifts, and strutting the inside of the manhole. **The Owner or Owner’s Engineer should review and approve the installation procedure for each flowable backfill application.** PERFORMANCE PIPE disclaims any and all liability for manholes that are damaged during the placement of flowable backfill.

Finishing Manhole to Grade
Manholes with cone tops can, in most cases, be field adjusted to accommodate the final grade. The riser may be cut to remove excess riser height, provided it is not obstructed by a ladder or other appurtenance and is cut even and square. The cone top may then be placed on the riser. A concrete grade ring or course of bricks may be placed on the cone’s shoulder to support the cast iron ring and to make any final grade adjustments. See Appendix C, “SPIROLITE® Manhole Cone Installation.”

Manholes with flat tops are manufactured to the appropriate height specified by the Owner or Owner’s Engineer to accommodate the final field grade required. The height of such manholes can not be easily field adjusted. Before ordering the manhole, the Owner should verify the correct height.

Vehicular Loads Require Reinforced Concrete Manhole Caps
Wheel loads from cars, trucks and other vehicles can produce significant force on buried manholes and therefore must be considered in design. The most common loading used for design is the H-20 highway loading. The American Association of State Highway and Transportation Officials (AASHTO) publishes wheel loads for the standard H-20 highway loading.

！WARNING！
When SPIROLITE® manholes are installed in streets, under pavement, or where there is vehicular traffic, a concrete cap must be placed over the manhole to provide independent support for the vehicular load. Failure to do so may result in property damage, injury or death.

HDPE manholes will normally not be adequate to resist vehicular loads without use of a rigid cap or slab. The cap or slab is typically made from reinforced concrete and transmits the majority of the vehicular load into the soil instead of the manhole riser. Ultimately the responsibility for the design of the rigid cap rests with the Owner’s Engineer. For convenience, typical concrete cap designs are shown in Figures 8-8, 8-9, and 8-10 for manholes with cone tops and for flat top manholes. If the Owner’s Engineer chooses to incorporate these details into contract specifications, he/she must review and approve them for structural competence.
The concrete used to form caps typically has a minimum of 3000 psi compressive stress and may be pre-cast or poured-in-place. When pouring caps in place over a flat manhole top, the Engineer should determine, based on the stiffness of the top, whether or not a form is required to carry the static head of the wet concrete to prevent excessive top deflection of the manhole. Figure 8-8 shows a typical concrete cap for a manhole with a cone top.

![Fig. 8-8. Poured in Place Concrete Caps for 48" and 60" PE Cone Tops](image)

Figure 8-9 shows concentric and eccentric manhole caps for 48”, 60” and 72” diameter manholes. A side view of this cap along with installation details is shown in Figure 8-10.

![Fig. 8-9. Concentric and Eccentric Manhole Caps for HDPE Flat Top Riser (Plan View)](image)
This chapter is intended for use as a guide to support the Owner and Owner’s Engineer in the preparation of project specific installation specifications. It is not intended for use as installation instructions, and should not be used in place of a professional design engineer. In preparing installation specifications, the Engineer must evaluate each site’s unique soil and groundwater conditions, the intended manhole function and the expected quality of construction and inspection. All of the considerations are beyond the scope of these guidelines.
9. Dual Containment Manholes

Where leakage poses a risk of environmental concern or manhole contents need protection against inflow from a contaminated site, DriscoPlex™ 2400 DCS dual-containment manholes can provide an extra level of protection. A dual-containment manhole consists of inner and outer vessels separated by an annular space that provides for leak detection systems and monitoring. DriscoPlex™ 2400 DCS Dual-containment manholes can be constructed with dual-contained inlet and outlet pipes that may be fused to DriscoPlex™ 2400 DCS dual-containment system piping.

DriscoPlex™ 2400 DCS Manholes come in two styles, “DCS-DW” and “DCS-GW”. Both offer vessel within a vessel protection. If the manhole wall is damaged, both provide a reservoir in the base to contain fluid until it can be pumped out. The capacity of the lower base reservoir depends on the size and style of the DCS manhole.

The DriscoPlex™ 2400 DCS-DW Manhole

The DriscoPlex™ 2400 DCS-DW manhole is a vessel within a larger, outer vessel. For full inner vessel support, gussets can be installed in the annular space between the inner and outer vessels. When gussets are provided, the ID of the inner vessel must be at least 12 in. less than the ID of the outer vessel. The inner vessel has a separate base, and separate tops are available, if desired. The Purchaser should specify inner and outer vessel diameters when ordering.
The DriscoPlex™ 2400 DCS-GW Manhole
The DriscoPlex™ 2400 DCS-GW manhole maintains the vessel within a vessel design, but uses a proprietary, patent-pending design to minimize the annulus between the inner and outer vessels, and maximize inner vessel wall support without gussets in the annular space.

Figure 9-3. Accessory Installation on DCS-DW Manhole
Accessories
Fabrication can include leak detection and/or reservoir evacuation piping. Leak detection wiring (by others) can be installed through the leak detection-monitoring pipe.

Most accessories and appurtenances, such as ladders and anchor connection rings, that are available on standard manholes are available for DriscoPlex™ 2400 DCS manholes.

Figure 9-4. DriscoPlex™ 2400 DCS Piping with DCS-DW Manhole

DCS Manhole Engineering Considerations
Outer vessel engineering considerations are different from those for the inner vessel. The outer vessel acts as a manhole riser and is primarily subjected to earth and groundwater pressures including downdrag loading, but its resistance to loads is enhanced by support from the manhole embedment soil. Usually, the riser is treated as structurally independent and designed per ASTM F 1759. See Chapter 2.

Although the outer vessel is supported by the embedment soil, the inner vessel may or may not be supported. The inner vessel derives its support from contact with the outer vessel either directly or through gussets in the annular space.

Inner Vessel Engineering Considerations
In normal operation, the inner vessel is subject only to internal head pressure from fluid contents. Most manholes are subject to internal gravity pressure and significant internal pressure occurs only if the pipeline surcharges. In some applications, such as a wet well, the manhole may routinely fill to a portion of its capacity before engaging pumps. The inner vessel wall and base must have sufficient thickness to withstand anticipated internal head pressure at the operating temperature.
For the DCS manhole to operate effectively, the inner and outer vessels must perform properly if fluid enters the annular space. While this may be an unlikely occurrence, it must be considered. Fluid in the annular space causes an internal hoop stress in the outer vessel wall. This is usually not a controlling design limit because downdrag design requirements for the outer vessel wall generally result in a wall of sufficient thickness to handle an internal head-pressure equal to the height of the manhole. But fluid in the annular space also exerts an external pressure on the inner vessel, that if excessive, can cause collapse of the inner vessel. Establishing an appropriate safety factor against collapse is a primary design consideration for the inner vessel. In Chapter 2, Equation 2-14 provides the allowable external collapse pressure for a long cylindrical tube. Inner vessel collapse resistance can be increased when (1) annular space gussets are used, or (2) the outer vessel supports the inner, or (3) the length to diameter ratio is such that the base and top stiffens the inner vessel.

Resistance to internal and external pressure is affected by elevated temperature and the expected duration of internal or external pressure. Design specifications for maximum fluid temperature, internal head-pressure, and duration and annular space head pressure are required when ordering a DriscoPlex™ 2400 DCS manhole.

Testing
All DriscoPlex™ 2400 DCS manholes are tested for leakage into the annular space before shipment. Testing may be by low pressure air or vacuum.
APPENDIX A: Guide Specification for HDPE Manholes

SECTION 1 - GENERAL

SECTION 1.1 SCOPE:

1.1.1 This guide specification covers the requirements of High Density Polyethylene manholes in nominal sizes of 36"-120".

SECTION 1.2 DEFINITIONS:

Under this standard, the following definitions apply:

1.2.1 Purchaser: The person, firm, corporation or government agency engaging in a contract or agreement to purchase pipe according to this standard.

1.2.2 Inspector: The authorized representative of the purchaser entrusted with the duty of inspecting pipe produced and witnessing tests performed under these standards.

1.2.3 Inspection: Inspection of the pipe and the tests by the inspector.

SECTION 2 - MATERIALS

SECTION 2.1 BASIC MATERIALS

2.1.1 Base Materials: The riser shaft, top, base and stubout pipes shall be made of PE plastic compound meeting the requirements of cell classification 335444C or higher as defined in ASTM D-3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials. The Manufacturer shall certify that the materials used to manufacture manholes meet these requirements. White or other colored pigments may be added to the base resin provided such formulations are agreed to by Purchaser and Manufacturer.

Exception:

1. Rotamolded cones shall be made of medium density polyethylene.

2.1.2 Other Materials: Materials other than those specified under base materials may be used as part of the profile construction, for example, as a core tube to support the shape of the profile during processing, provided these materials are compatible with the base PE material. Examples of suitable materials include polyethylene and polypropylene.

2.1.3 Rework materials: Clean rework material of the type described in Section 2.1.1 or Section 2.1.2 and generated from the manufacturer's own production, may be used provided the material is of the same cell classification as the base PE material and allows the manufacturing of manhole risers that meets all the requirements of this specification.

2.1.4 Gaskets: Rubber gaskets shall comply in all respects with the physical requirements specified in the non-pressure requirements of ASTM F-477.

2.1.5 Lubricant: The lubricant used for assembly of gasket joints shall have no detrimental effect on the gasket or on the pipe.

SECTION 2.2 MANUFACTURER'S QUALITY CONTROL

2.2.1 The pipe and fitting manufacturer shall have an established quality control program responsible for inspecting incoming and outgoing materials. At a minimum, incoming polyethylene materials shall be inspected for density per ASTM D-1505, melt flow rate per ASTM D-1238, and contamination. The resin supplier shall certify all incoming polyethylene materials. The Manufacturer shall verify certification and approve incoming materials before processing into finished goods.

SECTION 3 - REQUIREMENTS

SECTION 3.1 MANHOLE FABRICATION

3.1.1 The manhole shall be fabricated to meet the design requirements of ASTM F-1759, “Standard Practice for Design of High-Density Polyethylene (HDPE) Manholes for Subsurface Applications” based on soil and installation information supplied by the Purchaser or the Engineer.

3.1.2 Riser Shaft: The riser shaft shall be manufactured in accordance with ASTM F-894, shall be of solid wall construction only, and shall be specified by the Standard Inside-Diameter Dimension Ratio (SIDR) or the Inside-Dimension Ratio (IDR). The riser SIDR or IDR shall be of a sufficient wall thickness that the manhole meets the requirements of Section 3.1.1.

3.1.3 Joints: Where required, the manhole riser shall be manufactured with an integrally wound bell and spigot joint, an extrusion welded joint, or a fused joint. Joining shall be accomplished in accordance with the manufacturer’s recommendations.

SECTION 3.2 SHOP DRAWINGS

3.2.1 Upon request complete shop drawings of the manholes shall be submitted to the Engineer for approval.

SECTION 3.3 WORKMANSHIP

3.3.1 The riser and stubout pipes shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions or other
SECTION 3.4 PIPE MANUFACTURER

3.4.1 PE Pipe and manholes shall be produced by the same manufacturer.

3.4.2 Acceptable manhole manufacturers are:
   a. Performance Pipe
   b. Engineered approved equal.

SECTION 4 - INSPECTION AND TESTING

SECTION 4.1 INSPECTION REQUIREMENTS:

4.1.1 Access: The inspector shall have free access to the inspection area of the manufacturer's plant.

4.1.2 Testing: All manholes shall be hydrostatically tested unless otherwise agreed to by the Manufacturer and Purchaser.

4.1.3 Certification: As the basis of the acceptance of the material, the manufacturer will furnish a certificate of conformance to these specifications upon request. When prior agreement is being made in writing between the purchaser and the manufacturer, the manufacturer will furnish other conformance certification in the form of affidavit of conformance, test results or copies of test reports.

SECTION 5 - INSTALLATION

SECTION 5.1

5.1.1 Unloading: Manholes can be unloaded from the truck by using a boom and sling arrangement. Manholes shall be handled per the Manufacturer's written recommendations. The Manufacturer will provide lifting lugs to assist with handling unless otherwise agreed to by the Manufacturer and Purchaser.

5.1.2 Installation: Achieve stable and permanent support under and around the manhole. Install the manhole in a dry trench. Place sufficient crushed stone or other Class I material to provide a stable foundation. The thickness of the foundation layer shall be a minimum of 8 inches. Compact the foundation material to 95% Standard Proctor density. Alternatively, the manhole can be set on a properly designed reinforced concrete slab on a stable foundation.

5.1.2.1 Backfilling: The embedment surrounding the manhole shall extend to at least 3.5 feet or to the trench wall, whichever is the greater distance, for manholes placed in stable insitu soils. In unstable soil, the embedment shall extend to a distance equal to at least one manhole diameter (but not less than 3.5 feet) or to the trench wall, whichever is the greater distance. Embedment shall be placed from the invert to the top of the manhole. The embedment shall consist of Class I or II material compacted to at least 90% Standard Proctor density in 12" lifts. Place backfill evenly around the manhole to prevent moving the manhole out of alignment.

5.1.3 Concrete Anchors: Where required to prevent flotation, concrete anchors shall be constructed as shown in the Engineer's design drawings.

5.1.4 Concrete Tops: When vehicular loads are present, a concrete top shall be constructed as shown in the Engineer's design drawings.

5.1.5 Manhole Entry: Manholes present confined space and fall hazards. All entrants shall follow applicable OSHA confined space entry procedures and use a fall protection device for all entries.

SECTION 6 - DELIVERY

6.1.1 Manholes and fittings shall, unless otherwise specified, be prepared for standard commercial shipment.
APPENDIX B. F 1759 Calculation Input

Customer Name _____________________________________________

1. Manhole Application: (Give brief description)
________________________________________________________________________________________________________________
________________________________________________________________________________________________________________

Is Manhole located in a landfill cell or in wastefill material? Yes No Is Manhole located in a pond or body of water? Yes No

2. Manhole Dimensions:
Height, H = _______ ft
Inside Diameter, I.D. = _______ in Or Outside Diameter, O.D. = _______ in

Dual Containment Manhole Only:
Dual containment: Inner Vessel I.D. = _______ in Outer Vessel I.D. = _______ in
Maximum Fluid Height in Inner Vessel, H\textsubscript{dc} = _______ ft (Worse case, assume damage to manhole.)

3. Buried Applications:
Maximum height of fill above manhole base, H\textsubscript{f} = _______ ft
Maximum height of groundwater above manhole base, H\textsubscript{w} = _______ ft
Saturated soil unit weight, γ\textsubscript{s} = _______ pcf
Dry soil unit weight, γ\textsubscript{d} = _______ pcf
Embedment Material: (Extends a minimum of 3.5 ft from wall of riser to undisturbed trench wall.)
Crushed rock or Class I per ASTM D-2321
Other____________________________
Coarse grain soils with little or no fines, GW, GP, SW, SP containing less than 12% fines. Class II per D-2321
Compaction level _________ % Std. Proctor
Modulus of Soil Reaction, E' = _________ psi.

4. Pond Applications:
Maximum height of water outside manhole from manhole base, H\textsubscript{w} = _______ ft Is Manhole perforated?___________

5. List all chemicals and concentrations in fluid flow stream or otherwise in contact with manhole:
________________________________________________________________________________________________________________
________________________________________________________________________________________________________________

6. Manhole Temperature:
Normal operating temperature of fluid stream, T\textsubscript{o} = _______ °F
Maximum temperature of fluid stream, T\textsubscript{max} = _______ °F
Maximum temperature of soil/fill, T\textsubscript{e} = _______ °F

7. Maximum Internal Positive Pressure, P = _______ psig
8. Maximum Vacuum, ie. Negative Pressure, V = _______ psig

_________________________________________
(Customer Signature)

___________________
(Date)
APPENDIX C: DriscoPlex™ 2000 SPIROLITE™ Manhole Cone Installation

The DriscoPlex™ 2000 SPIROLITE® manhole is finished to grade with a cone, a ring and a cover. See Figure E-1. The cone must be encased in reinforced concrete when there is traffic loading.

Figure E-1. DriscoPlex™ 2000 SPIROLITE® Manhole Cone – 48” and 60”

GRADE ELEVATION ADJUSTMENT

Grade elevation adjustments are made by trimming the length of the manhole riser when shortening is required, or by placing a course of bricks and mortar or a concrete grade ring on the cone shoulder when lengthening is required. The manhole riser should be trimmed before placing the manhole in the trench.

1. Before cone installation, determine the desired grade elevation for the cone shoulder, including allowance for the height of the manhole ring and the cover that are placed on the shoulder of the manhole cone.

2. Determine the required riser length by subtracting the manhole invert elevation from the cone shoulder grade elevation and deducting the height of the cone. Cone heights are 23 in. for a 48 in. manhole cone and 18 in. for a 60 in. manhole cone as measured from the cone shoulder to the top of the manhole riser. See Figure E-1.
Figure E-2. Cone Installation

<table>
<thead>
<tr>
<th>M.H. DIA</th>
<th>CONE HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>48&quot;</td>
<td>23&quot;</td>
</tr>
<tr>
<td>60&quot;</td>
<td>18&quot;</td>
</tr>
</tbody>
</table>

NOTE:
REINFORCEMENT DETAILS TO BE PROVIDED BY ENGINEER.
3. Compare the required riser length from step 2 with the actual manhole riser length and determine the required manhole riser trim length or the required height for the concrete grade ring or bricks and mortar to be placed on the cone shoulder after installation.

4. If the manhole was purchased with a built-in ladder, contact Performance Pipe before cutting the ladder or its mounting brackets.

5. Double-check all measurements and dimensions before cutting the manhole riser. “Measure twice; cut once”. Mark a cut line around the top of the manhole riser using a "wrap-around" tape. Cut the top edge of the manhole riser squarely.

**ASSEMBLING THE CONE**

1. Clean the top edge of the manhole riser before installing the shoulder gasket. Remove any shavings and wipe with a clean cloth.

2. Fit the shoulder gasket over the end of the manhole riser. The gasket must be square to the manhole wall and the fins point downward as illustrated in Figure E-3.

3. Clean the inside surface of the cone bell. Apply lubricant to the entire interior surface of the cone bell, to the gasket "fins", and to the leading edge of the gasket. **Do not apply lubricant to the underside of the gasket or to the manhole riser.**

4. Place the cone over the manhole riser so that it is centered and rests uniformly on the shoulder gasket.

![Figure E-3. Correct Gasket Orientation](image)
5. Push the cone down onto the manhole riser by applying steady force with a backhoe bucket. Place one 4x4 or two 2x8 pieces of lumber that have been nailed together across the manway opening of the cone. Apply a steady downward force using the backhoe bucket. Push steadily until the cone slides over the gasket and bottoms out against the end of the cone bell. See Figure E-4.

**Figure E-4. Installing the Cone with a Backhoe Bucket**

6. Inspect the joint from the inside. The edge of the gasket must be visible completely all around the inside top edge of the manhole riser. If not, the gasket may have rolled down and the cone must be removed, the riser, gasket and cone bell cleaned, and reassembled. See Figure E-5.

**Figure E-5. Gasket Location after Assembly**
The following information is provided to show how SPIROLITE® Closure pipe may be used in the field to place Spirolite manholes within Spirolite pipelines. Closure joints are required because SPIROLITE® pipe is manufactured in standard laying lengths of 20 ft. and 13 ft and SPIROLITE® pipe cannot be field cut and inserted into a bell. If a manhole or a SPIROLITE® pipe fitting is required to be at specific locations and that location does not coincide with the end of a standard laying length of pipe, closure joints may be required to accommodate the irregular distances.

Specific instructions for joining Spirolite® pipe and Spirolite® Closure pipes can be found in Technical Note PP 837.

A closure pipe is a special outside diameter (OD) controlled solid wall length of SPIROLITE® pipe that can be field cut and inserted into a special bell called a closure bell. The following figures illustrate how the closure pipe is used to complete a connection between a SPIROLITE® manhole manufactured with closure bells and a SPIROLITE® pipe.

Figure 1 shows a manhole located in a pipeline at a distance that is less than a full pipe length (13 ft or 20 ft) from the last installed piece of profile wall SPIROLITE® pipe. Closure pipe, which can be field cut to any length, will be used to accommodate this gap. The closure pipe will be cut to a length that equals the distance between the inside end of the bell of the profile wall pipe and the inside end of the closure bell of the manhole (Fig. D-1). Because the closure pipe has a standard SPIROLITE® bell at one end and a standard SPIROLITE® spigot at the other end, when it is cut the spigot end can be used to join to the bell of the installed profile pipe (Fig. D-2). A shoulder gasket (also called a closure gasket) is placed on the other end and inserted into the closure bell of the manhole (Fig. D-3).
Fig. D-2. Spigot end of Cut Closure Pipe Joined to Profile Pipe Bell

Fig. D-3. Plain End of Cut Closure Pipe Joined to Closure Bell on Manhole
The other half of the closure pipe containing the bell is fitted with another shoulder gasket in a similar manner as before and installed into the other closure bell of the manhole (Fig. D-4). The bell end of the closure pipe then receives the spigot end of the next length of profile wall SPIROLITE® pipe and pipe laying continues as before.

**Fig. D-4. Join Plain End of Cut Closure Pipe to Other Closure Bell on Manhole**

**Closure Connection of SPIROLITE® Pipe to a Spirolite Fitting**

Fittings are installed in the same manner as manholes with the possible exception that the pipe may have to be pulled onto the fitting.
APPENDIX E. Anti-Flotation Example Calculations

The information in this Appendix is offered only as a guide. If flotation conditions could exist, measures to counteract flotation such as concrete anchor collars or slabs are recommended. Because each installation is site specific and construction dependent, the Owner or Engineer must determine if concrete anchors are required to prevent flotation, evaluate flotation resistance and establish appropriate safety factors.

**Flotation Equation**

Flotation is prevented when the downward forces, $F_{DOWN}$, acting on the manhole exceed the upward thrust due to buoyant forces, $F_{UP}$. A safety factor, $SF$, is usually applied as shown in Equation E-1.

$$\frac{F_{DOWN}}{SF} \geq F_{UP} \quad (E-1)$$

When Equation E-1 is not satisfied, flotation prevention such as concrete anchor collars or slabs is required.

**Downward Forces**

The downward forces resisting flotation in Equation E-2 include the weight of the manhole and its contents, $W_{MH}$, the weight of concrete caps or other equipment on top of the manhole, $W_{CC}$, the weight of soil above the manhole stubouts, $W_{SO}$, and frictional resistance force between the soil and manhole, $F_R$. See Figure E-1. These forces may be referred to as hold down forces.

$$F_{DOWN} = W_{MH} + W_{CC} + W_{SO} + F_R \quad (E-2)$$

![Figure E-1. Buoyant and Restraining Forces on Submerged Manhole](image-url)
Manhole Weight, $W_{MH}$
Manhole weight may be obtained from the manufacturer.

In addition to the weight of the manhole, the weight of internal concrete pads for mounting pumps and other heavy equipment permanently in the manhole are considered part of $W_{MH}$.

Weight of Concrete Cap, $W_{CC}$
The weight of the concrete cap and any equipment permanently placed on top of the manhole are part of the downward force.

Weight of Soil above Stubouts, $W_{SO}$
The weight of the soil above stubouts can contribute to anchoring the manhole. However, flotation creates shear stress across the stubouts that depends on the stubout DR and diameter and should not exceed 400 psi. Where shear stress can exceed 400 psi, do not include the weight of soil above the stubouts as an anchoring downward force in Equation E-2 and consider using a concrete anchor collar. For 12” and smaller diameter stubouts, the contribution to resisting flotation is not considered.

When calculating the acting soil weight above the stubout, arching is usually ignored and only the weight of the column of soil directly above the stubout is considered. The column of soil above the stubout is assumed to extend laterally for a length of one stubout pipe diameter. Thus for a 24” diameter stubout having 10 ft of cover, the soil column would be 2 ft wide by 2 ft long by 10 ft high. See Equation E-3. When below groundwater level, soil weight is lessened due to buoyancy.

$$W_{SO} = \frac{D_S^2}{144} (\gamma_B H_{WS} + \gamma (H_C - H_{WS})) \quad (E-3)$$

Where:
- $D_S$ = Stubout Diameter (in)
- $\gamma$ = Unit weight of Soil (pcf)
- $\gamma_B$ = Buoyant unit weight of Soil (pcf)
- $H_{WS}$ = Height of groundwater above stubout (ft)
- $H_C$ = Height of cover above stubout (ft)

There are slight inaccuracies in Equations E-3, E-7, E-10a, and E-11, because the projection of the stubout is curved where the stubout joins the manhole, but these calculations treat the projection as a rectangle. This creates a slight discrepancy between calculated and actual projected area (or volume). If in doubt, the Engineer can perform a more detailed calculation.
Shear Stress in Stubouts
In addition to the weight of the soil above the stubout, frictional forces also act to resist flotation. It is conservative to ignore soil weight and frictional forces when calculating soil anti-flotation resistance, but it is not safe to ignore these forces when checking for shear stress on the stubouts. While determining actual forces is complex, a conservative approach is to calculate shear by assuming that the uplift force on the manhole is resisted entirely by the stubouts. If the resulting shear stress across the stubout is less than 400 psi, the stubout may be used to resist flotation, but if the stress exceeds 400 psi, an anti-flotation collar that does not apply shear stress to the stubout must be used. Determining the actual force on the stubout (soil weight and friction) is beyond the scope of this guide. Equation E-4 gives the shear stress, $\tau$, across the stubout, where $D_M$ is the stubout mean diameter, $t$ is the stubout wall thickness, and $F_{U1}$ is that share of the uplift force resisted by the stubout (for two equally sized stubouts, $F_{U1}=F_U/2$).

$$\tau = \frac{F_{U1}}{\pi D_M t} \quad (E \cdot 4)$$

Minimum Frictional Resistance Force, $F_R$
In many cases, the frictional resistance of the soil surrounding the manhole will resist the upward movement of the manhole. Frictional resistance depends especially on the coefficient of friction between HDPE and soil, $\mu$, and the soil’s angle of internal friction, $\phi$, which is affected by the soil type, degree of saturation, groundwater level, density, and soil placement. Frictional resistance development can be impaired by fluctuations in the groundwater level and by the shrinkage of soil away from the manhole. The Engineer must evaluate frictional resistance based on geotechnical data and determine whether if the analysis given below is applicable.

Downdrag and uplift resistance forces are determined in the same manner, but are calculated using different values for the coefficient of friction, $\mu$. The design worst case for downdrag occurs when the coefficient of friction is high, which causes high compressive load in the manhole riser, but the design worst case for uplift resistance occurs when the coefficient of friction is low and where there is less soil contact against the manhole. For riser design, typical coefficient of friction values are between 0.4 and 0.5, but for flotation resistance, typical values are 0.1 to 0.2. The frictional force that resists flotation is a minimum frictional resistance force.

Friction between the manhole and the soil is usually reduced when the soil is saturated or is below the groundwater level. For a partially submerged manhole, as illustrated in Figure E-2, the soil friction angle and coefficient of friction used for the portion of the manhole above the groundwater level will be different from the values used for the portion below the groundwater level. Therefore the portions above and below the groundwater level are calculated separately. The resulting values are summed to determine total frictional resistance to flotation.
The following equations are for general information and are based on assumptions that may or may not be applicable for any specific project. Capillary action may extend saturated soil above the groundwater level. The Engineer must determine applicability for a specific project or installation.

The first significant assumption is that the radial earth pressure acting on the sides of the manhole equals the active earth pressure, and can be determined using Equations E-5a and E-5b. Equation E-5a applies to that part of the manhole that is above the groundwater level and E-5b applies to that part below the groundwater. See Figure E-2.

![Figure E-2. Assumed Pressure Distribution for Manhole Partially Below Groundwater](image)

The second significant assumption is that the coefficient of friction, \( \mu \), between soil and HDPE is 0.2 for dry soil and 0.1 for wet (including saturated) soil.

\[
P'_R = K'_A \gamma_B H_W
\]

\[
P_R = K_A (\gamma (H_{MH} - H_W))
\]

Where:

- \( P_R \) = Radial earth pressure above groundwater level (psf)
- \( K_A \) = Active earth pressure coefficient for soil above groundwater (See Equation 2-2)
- \( H_{MH} \) = Height of manhole from base to top (ft)
- \( P'_R \) = Radial earth pressure below the groundwater level (psf)
- \( K'_A \) = Active earth pressure coefficient for soil below groundwater (See Equation 2-2)
The average frictional resistance (shear) stress, $T_A$, in psf along the manhole riser wall can be determined by multiplying the average radial earth pressure by the friction coefficient. See Equation 2-3. Since there are two pressure distributions being considered, one above the groundwater level and the other below, each distribution must be calculated separately.

\[
T_A = \mu \left( \frac{P_{R1} + P_{R2}}{2} \right) \quad (2 - 3)
\]

Where:

$P_{R1} = \text{Radial pressure at top of pressure distribution, psf}$

$P_{R2} = \text{Radial pressure at bottom of pressure distribution, psf}$

The pressure distribution is triangular for that portion of the manhole above the water level and thus $P_{R1}$ (the pressure at the top of the manhole) equals zero and $P_{R2}$ equals the pressure at the top of the groundwater level from Equation E-5a. For the portion of the manhole below the water level, $P_{R1}$ equals the pressure at the top of the groundwater level from Equation B-5a and $P_{R2}$ equals the pressure at the bottom of the manhole or at the top of the stubouts from Equation E-5b.

The minimum frictional resistance force, $F_R$, for the above and below groundwater portions can be determined using a form of Equation 2-4 (downdrag load), where $D_O$ is the outside diameter of the manhole.

\[
F_R = T_A \pi \left( \frac{D_O}{2} \right) H_{MH} \quad (2 - 4)
\]

The above and below groundwater frictional resistance forces are summed to obtain the total minimum frictional resistance force. When solving Equation 2-4, the full outside diameter of the manhole cannot be used if stubouts and the weight of the soil above the stubouts are added into Equation E-2. Equation 2-4 must be modified as shown in Equation E-6 to remove stubout diameters otherwise the soil weight above the stubouts would be counted for resistance twice. $D_{S1}$ and $D_{S2}$ are the outside diameters of the stubouts.

\[
F_R = T_A \left( \frac{\pi D_O - D_{S1} - D_{S2}}{12} \right) H_{MH} \quad (E - 6)
\]

For smaller diameter stubouts where the soil weight above the stubout is not used, frictional resistance is determined using the entire surface of the riser wall from the level of the stubouts to the ground surface. When stubouts are present, a decision whether to include the frictional resistance of the portion of the riser below the top of the stubouts (stubout crown) must be made.

*Flotation resistance for manhole tees is normally determined using only the weight of soil above the through pipe. Therefore, the minimum frictional resistance term in Equation E-2 is zero for manhole tees.*
In some cases where manholes are submerged, a slight upward movement that mobilizes passive soil resistance may occur. For correctly designed manholes this movement does not usually cause hydraulic problems.

**Upward Forces**

Upward forces that try to lift the manhole off-grade include the buoyant force acting on the manhole and buoyant forces acting on the lengths of stubout pipes that contribute to uplift resistance. The upward force equals the displaced volume of groundwater and is equivalent to the submerged volume of the manhole and the stubouts. Where the weight of the manhole and stubouts are ignored in the downward force equation, \( E-2 \), the outer diameter of the manhole may be used for \( D_{o} \) in Equation \( E-7 \).

\[
F_{U} = \pi \frac{D_{o}^{2}}{576} \gamma_{w} H_{w} + \pi \gamma_{w} \frac{D_{S1}^{3}}{6912} + \pi \gamma_{w} \frac{D_{S2}^{3}}{6912} + \ldots...
\]

(E - 7)

Where \( \gamma_{w} \) is the unit weight of water (pcf) and other terms are as previously defined. \( D_{o} \) is the manhole diameter, \( D_{S1} \) is the diameter of the first stubout, \( D_{S2} \) is the diameter of the second, etc. (See the discussion “Upward Force with Concrete Collar” below.)

**Safety Factor**

The Engineer is responsible for determining an appropriate safety factor against flotation based on site-specific conditions and the nature of the application. Performance Pipe recommends safety factor of at least two for frictional resistance calculations. For dead load weight calculations such as the weight of soil above the stubouts, a lower safety factor may be acceptable. Different safety factors should be applied individually in Equation \( E-2 \) rather than to their sum as shown in Equation \( E-1 \).

When the safety factor against flotation is not sufficient, an anchor collar, anti-flotation slabs or other hold down methods are required.

**Concrete Collar Calculations**

When concrete collars are used, the Engineer must determine collar diameter, thickness and reinforcement. In determining the hold down resistance of the collar, the Engineer must consider whether stubouts are located above or below the concrete collar. When stubouts are located above the collar, the amount of soil above the collar is reduced, and the stubout increases the buoyant upward force on the manhole. Therefore, the downward force in Equation \( E-2 \) and the upward force in Equation \( E-7 \) must be modified for use with concrete anchor collars.

The equations below are for circular collars. The equations may be modified for rectangular collars.
Downward Force with Collars
When modified for concrete collars, Equation E-2 becomes:

\[ F_{\text{DOWN}} = W_{\text{MH}} + W_{\text{CC}} + W_{\text{CL}} + W_{\text{SCL}} \]  \hspace{1cm} (E-8)

Where:
- \( W_{\text{CL}} \) = weight of concrete collar (lbs)
- \( W_{\text{SCL}} \) = weight of soil above the concrete collar (lbs)
- \( W_{\text{CC}} \) = weight of concrete cap (lbs)
- \( W_{\text{MH}} \) = weight of manhole (lbs)

Whether placed above or below the stubouts, when a concrete collar is used to prevent flotation, the weight of the soil above stubouts, \( W_{\text{SO}} \), and the frictional resistance between the soil and the manhole riser, \( F_{\text{R}} \), are not included in the calculation (Equation E-8). These effects are within the vertical projection of the concrete collar, and if included in the downward force calculation, the effects would be counted twice.

Buoyant Weight of the Concrete Collar, \( W_{\text{CL}} \)
The buoyant weight of the concrete collar may be determined using Equation E-9.

\[ W_{\text{CL}} = \frac{\pi}{6912} \left[ (D_0 + 2w_{\text{CL}})^2 - D_0^2 \right] (t_{\text{CL}}) (\gamma_{\text{C}} - \gamma_{\text{W}}) \]  \hspace{1cm} (E-9)

Where:
- \( W_{\text{CL}} \) = weight of concrete collar (lbs)
- \( w_{\text{CL}} \) = width of concrete collar (in) (See Fig. 7-1, 7-2, or 7-3.)
- \( t_{\text{CL}} \) = thickness of concrete collar (in) (See Fig. 7-1, 7-2, or 7-3.)
- \( \gamma_{\text{C}} \) = unit weight of concrete (pcf)
- \( \gamma_{\text{W}} \) = unit weight of water (pcf)

Weight of Soil above Concrete Collar, \( W_{\text{SCL}} \)
To determine the downward force of the soil above the collar multiply the volume of the soil projection above the collar by the unit weight of the soil. It is conservative to ignore soil friction between the soil cylinder above the collar and the surrounding soil and friction between the vertical cylinder of the collar and the soil. Friction between the vertical face of the collar and the soil is ignored as well. In a more detailed analysis the Engineer could include these factors.

Buoyancy reduces the unit weight of soil when the soil is below the groundwater level. Therefore, the weight of soil above the collar, \( W_{\text{SCL}} \), is divided into the weight above groundwater level and the weight below and the resulting weights are added together.
For the portion of the soil below the groundwater level, Equation E-10a may be used to determine soil weight, $W_{SCLGW}$, above the collar. $H_{WCL}$ is the water height above the top of the collar and all other terms are as previously defined. When the collar is below the stubouts, the weight of the soil displaced by the stubout is removed from $W_{SCLGW}$ by the subtraction terms in Equation E-10a. If the collar is located above the stubouts, the subtraction terms may be omitted.

$$W_{SCLGW} = \frac{\pi}{576} \left[ (D_0 + 2w_{CL})^2 - D_0^2 \right] H_{WCL} \gamma_B - \frac{\pi w_{CL} D_{S1}^2}{6912} \gamma_B - \frac{\pi w_{CL} D_{S2}^2}{6912} \gamma_B - \ldots$$ \hspace{1cm} (E-10a)

Equation E-10b may be used to determine the soil weight on the collar from soil located above the groundwater table $H_{CL}$ is the height of soil above the concrete collar, and other terms are as previously defined. If the collar is located below the stubouts, the weight of soil displaced by the stubouts must not be included in the calculation. The weight of soil displaced by the stubouts is included in Equation E-10a or in Equation E-10b depending on whether the stubouts are above or below the groundwater level. Equation E-10a is shown with the subtraction terms included. Equation E-10b is shown without them.

$$W_{SCLB} = \frac{\pi}{576} \left[ (D_0 + 2w_{CL})^2 - D_0^2 \right] (H_{CL} - H_{WCL}) \gamma_D$$ \hspace{1cm} (E-10b)

The total weight acting downward on the concrete collar, $W_{SCL}$, is the sum of $W_{SCLGW}$ and $W_{SCLB}$. When concrete collars are placed on anchor connection rings, the subtraction terms for the stubouts in Equation E-10a are zero.

**Upward Force with Concrete Collar**

Equation E-11 gives the upward force acting on the manhole.

$$F_U = \pi \frac{D_0^2}{576} \gamma_W H_W + \pi \gamma_W w_{CL} \frac{D_{S1}^2}{6912} + \pi \gamma_W w_{CL} \frac{D_{S2}^2}{6912} + \ldots$$ \hspace{1cm} (E-11)

**NOTE** – There are slight inaccuracies in Equations E-7, E-10a, E-11 and E-15, because the projection of the stubout is actually curved where it joins the manhole, and this will cause a slight discrepancy between calculated and actual volume. If in doubt, the Engineer can perform a more detailed calculation.

**Safety Factor with Concrete Collar**

The downward force divided by a Safety Factor should equal or exceed the upward force determined using Equation E-1. The Engineer should determine an appropriate Safety Factor. Where there is considerable soil friction, the safety factor can be lower than where there is little soil friction. Soil friction is not considered in the calculations.

*The Engineer may choose other methods to calculate the hold down resistance of concrete collars, such as traditional anchor pullout calculations. Other calculation methods are beyond the scope of this manual.*
In cases where manholes are submerged, some slight upward movement may occur as soil resistance mobilizes above the concrete anchor collars. For properly designed manholes this slight movement is usually not sufficient to cause hydraulic problems.

**Concrete Anti-Flotation Slab Calculations**

When concrete anti-flotation slabs are used, the Engineer must determine the anti-flotation slab design dimensions, including length, width, thickness and steel reinforcement. Suggested slab dimensions are illustrated in Figure E-3. The minimum slab width dimension along the stubout should be 48” or one pipe diameter whichever is greater. Slab length depends on the diameter of the stubout pipe and the required hold down force. As illustrated in Figure E-3, the slab is centered over the pipeline with its length oriented perpendicular to the direction of flow.

![Fig. E-3. Anti-Flotation Slab Terminology](image)

When anti-flotation slabs are used, manhole flotation is restrained by the stubouts. That is, flotation force is transmitted to the anti-flotation slabs through shear across the stubouts. Therefore, stubout shear stress should be calculated.

Anti-flotation slabs are most effective when they are symmetrically placed on opposite sides of the manhole. They may be applied to slight bends, but large angle bends typically require further analysis that is beyond the scope of this manual. For stubout pipes less than 18” in diameter or less than 25% of the manhole diameter, anti-flotation slabs are not recommended.

Calculations for the anti-flotation slabs are similar to calculations for concrete anchor collars. Downward forces including the buoyant weight of the slabs and the soil above the slab are calculated and a safety factor is applied. This value must exceed the upward force that includes the buoyant force on the manhole and on the portion of the stubout located below the slab. As with the concrete collars, the downward force from Equation E-2 and the upward force from Equation E-7 must be modified.
Downward Force with Anti-flotation Slabs, \( F_{DOWN} \)

Equation E-2 can be modified for concrete collars as follows:

\[
F_{DOWN} = W_{MH} + W_{CC} + W_{AF} + W_{AFS} \tag{E-12}
\]

Where:
- \( W_{AF} \) = (buoyant) weight of concrete anti-flotation slab (lbs)
- \( W_{AFS} \) = weight of soil above the anti-flotation slab (lbs)

Soil friction resistance force acting on the manhole, including the portion of the manhole below the anti-flotation slabs and acting on the pipe, is usually not considered.

Buoyant Weight of the Anti-Flotation Slab, \( W_{AF} \)

The buoyant weight of the concrete anti-flotation slab may be determined using Equation E-13.

\[
W_{AF} = LW\frac{t_{AF}}{12}(\gamma_C - \gamma_W) \tag{E-13}
\]

Where:
- \( L \) = length of anti-flotation slab (ft) See Fig. E-3 for dimensions.
- \( W \) = width of anti-flotation slab (ft)
- \( t_{AF} \) = thickness of anti-flotation slab (in)
- \( \gamma_C \) = unit weight of concrete (pcf)
- \( \gamma_W \) = unit weight of water (pcf)

Weight of Soil above Anti-Flotation Slab, \( W_{AFS} \)

The weight of soil above the slab is determined by multiplying unit weight of the soil above the slab by the volume of soil above the slab. Soil friction between the soil directly above the slab and the surrounding soil mass is usually ignored. In soils having a relatively high angle of internal friction, the safety factor can be reduced somewhat to account for the development of frictional resistance against flotation in the soil mass. *The Engineer may choose alternate calculation methods to assess anti-flotation slab the hold down resistance such as classical anchor pullout calculations but, this calculation is beyond the scope of this manual.*

Because anti-flotation slabs are located above the stubouts, the contributions of soil weights above and below groundwater level can be combined in the same equation without becoming too complicated. Equation E-14 gives the soil weight, \( W_{AFS} \).

\[
W_{AFS} = LW(\gamma(H_{AF} - H_{WAF}) + \gamma_BH_{WAF}) \tag{E-14}
\]

Where:
- \( H_{AF} \) = Height of soil above the anti-flotation slab (ft)
- \( H_{WAF} \) = Height of groundwater level above the anti-flotation slab (ft)
The soil unit weight, \( \gamma \), in Equation E-14 is typically the dry soil unit weight, and the buoyant weight, \( \gamma_B \), is the saturated soil unit weight less the unit weight of water. For a conservative result, the dry unit weight can be used in the buoyant weight calculation.

When anti-flotation slabs are placed over stubouts on opposite sides of the manhole, the total downward weight from both slabs is determined by doubling the Equation E-14 value.

**Upward Force with Anti-Flotation Slab**

Equation E-15 gives the upward force acting on the manhole, using previously defined parameters.

\[
F_U = \pi \frac{D_o^2}{576} \gamma_w H_w + \pi \gamma_w W \frac{D_s^2}{576} + \pi \gamma_w W \frac{D_s^2}{576}
\]

(E-15)

**Example Calculations for Manhole Anti-flotation Resistance**

**Example 1: Anti-flotation Resistance of a 72” Manhole with Concrete Collar**

**Given:** A 72” diameter manhole buried 10 feet deep with 7.5 feet of groundwater above the base. The manhole has two 30” diameter stubouts. An Engineer determined that the friction values given below will develop and that the other soil properties are as defined:

**Stable soil conditions with the following values:**

- Soil angle of internal friction (assume same \( \phi \) for above and below groundwater): \( \phi = 30 \text{ deg} \)
- Coefficient of friction between pipe and soil: \( \mu = 0.1 \) (wet), \( \mu = 0.2 \) (dry)
- Manhole SIDR: \( \text{SIDR} = 39.0 \)
- Minimum concrete collar thickness: \( t_{CL} = 8 \text{ in.} \)
- Dry soil unit weight: \( \gamma_D = 110 \text{ pcf} \)
- Saturated soil unit weight: \( \gamma_S = 110 \text{ pcf} \)
- Concrete unit weight: \( \gamma_C = 150 \text{ pcf} \)
- Water unit weight: \( \gamma_W = 62.4 \text{ pcf} \)
- Safety factor (Soil Friction): \( SF = 2 \), (Soil Weight): \( SF = 1.5 \)

(For conservative analysis, the saturated unit weight of soil was chosen to be the same as the dry unit weight of soil.)

**Dimensional Parameters:**

- Manhole riser approximate inside diameter: \( ID = 72 \text{ in} \)
- Manhole riser approximate outside diameter: \( OD = 75.7 \text{ in} \)
Find: (1) Is a concrete anchor collar required? (2) If so, find diameter of concrete collar.

This example is provided as an illustration only. The results obtained and the formulas used should not be applied to specific applications without the judgment and approval of the Engineer.

Step (1): Determine Safety Factor against flotation in Equation E-1
Find the downward forces from Equation E-2 using values and parameters given.

Find the weight of soil above the stubouts, $W_{SO}$.
The weight per stubout is:

$$W_{SO} = \frac{32.8^2}{144} \times (47.6 \text{ pcf}(4.5 \text{ ft}) + 110 \text{ pcf}(7 \text{ ft}) - 4.5 \text{ ft}) = 3655 \text{ lbs}$$

Find the minimum frictional resistance to uplift, $F_R$.
Determine the radial pressure on the manhole wall above and below the groundwater level.
Using Equation 2-2, $K_A = 0.333$ based on $\phi = 30$ degrees. $P_R$ at 2.5 ft from the top of the manhole (top of the groundwater level) is:

$$P_R = 0.333(110 \text{ pcf}(10 \text{ ft} - 7.5 \text{ ft})) = 92 \text{ psf}$$

$P_R'$ at the base of the manhole is:

$$P_R' = 92 \text{ psf} + 0.333(110 \text{ pcf} - 62.4 \text{ pcf})7.5 \text{ ft} = 211 \text{ psf}$$

The frictional resistance stress, $T_A$, from the manhole top to the groundwater level is:

$$T_A = 0.2\left(\frac{0 + 92 \text{ psf}}{2}\right) = 9.2 \text{ psf}$$

$$T_A' = 0.1\left(\frac{92 \text{ psf} + 211 \text{ psf}}{2}\right) = 15.2 \text{ psf}$$

$T_A$ from the top of the groundwater level to the base of the manhole is:

The frictional resistance force, $f_R$, for the above groundwater portion of the manhole can be determined using Equation E-6.
The frictional resistance force, \( f_R' \), for the below groundwater portion of the manhole is:
\[
f_R' = 15.2 \text{ psf} \left( \frac{\pi 75.5 \text{ in} - 2(32.8 \text{ in})}{12} \right) 7.5 \text{ ft} = 1629 \text{ lbs}
\]

The total minimum frictional resistance force, \( F_R \), is:
\[
F_R = f_R + f_R' = 328 \text{ lbs} + 1629 \text{ lbs} = 1957 \text{ lbs}
\]

**Find Total Downward Force with Safety Factor**

Equation E-2 can be solved for the total downward force with safety factors applied to individual terms. \( W_{MH} = 0 \) and \( W_{CC} = 0 \) are assumed. A safety factor of 1.5 has been applied to the weight of the soil above the stubout and a safety factor of 2.0 has been applied to the frictional resistance force.
\[
F_{DOWN} = 0 + 0 + \frac{2 \cdot 3655 \text{ lbs}}{1.5} + \frac{1957 \text{ lbs}}{2.0} = 5852 \text{ lbs}
\]

**Upward Forces**

Upward forces include the buoyancy force on the manhole and on one-diameter stubout lengths .
\[
F_U = \pi \left( \frac{72 \text{ in}}{576} \right)^2 62.4 \text{pcf}(7.5 \text{ ft}) + (2)\pi(62.4 \text{pcf}) \left( \frac{30 \text{ in}}{6912} \right)^3 = 14,756 \text{ lbs}
\]

The unit weight of water is \( \gamma_W \) (pcf). \( D_{S1} \) is the diameter of the first stubout; \( D_{S2} \) is the diameter of the second and etc. . (See note after Equation E-11.)

Anti-flotation measures are required. A concrete collar is to be used.

\[
F_{DOWN} = 5852 \text{ lbs} < F_{UP} = 14,756 \text{ lbs}
\]

**Shear stress in stubouts**

Had the downward force exceeded the upward force the next step would be to check the shear stress in the stubouts. The stubouts resist the upward force in holding down the manhole, therefore the shear stress equals:
\[
\tau = \frac{14,756 \text{ lbs}}{2\pi (31.4 \text{ in}) 1.4 \text{ in}} = 53.5 \text{ psi} < 400 \text{ psi}
\]

An allowable long-term shear stress at 73°F of 400 psi is typically used.
Step (2) Determine Width of Concrete Anchor Collar (assume thickness is 8”)

Figure E-4 illustrates a concrete anchor collar placed on an anchor connection ring placed 36” above the manhole invert and above the 30” stubout pipes.

![Fig. E-4. Concrete Anti-flotation Anchor Collar](image)

The width of the concrete collar is determined by assuming a trial width. The downward and upward forces are calculated for the trial width and compared to determine if the safety factor is adequate. If not, another trial width is selected. This process continues until a width that produces an adequate safety factor is determined.

(Generally, the soil located above the collar, not the weight of the collar, provides the primary restraint. Therefore, it is usually more efficient to increase collar width than thickness.)

Assume a trial width of 18”. The maximum collar ID is the manhole OD (assume 76”) plus 2” or 78”. The collar OD is 114”. For simplicity, assume the top of the anchor ring is 3-1/2 ft above the manhole base.

The next step is to find the downward forces acting on the collar.

**Buoyant Weight of the Concrete Collar**

The buoyant weight of the concrete collar can be determined using Equation E-9.

\[
W_{CL} = \frac{\pi}{6912} \left[ (78 \text{ in} + 2(18 \text{ in}))^2 - (78 \text{ in})^2 \right] (8 \text{ in}) (150 \text{ pcf} - 62.4 \text{ pcf}) = 2200 \text{ lbs}
\]
Weight of Soil above Concrete Collar, \(W_{SCL}\)

The weight of the soil above the concrete collar but below the groundwater level is:

\[
W_{SCLGW} = \frac{\pi}{576} \left[ (114 \text{ in})^2 - (78 \text{ in})^2 \right] 4 \text{ ft}(47.6 \text{ pcf}) = 7174 \text{ lbs}
\]

Although the stubout terms are included in Equation E-10a, they are not included in this example because the anchor connection ring and the concrete collar are located above the stubouts. The stubout terms are included when the concrete collar is placed at the base of the manhole below the stubouts.

The soil weight acting down on the collar from soil located above the groundwater table is:

\[
W_{SCLB} = \frac{\pi}{576} \left[ (114 \text{ in})^2 - (78 \text{ in})^2 \right] (10 \text{ ft} - 7.5 \text{ ft}) 110 \text{ pcf} = 10,362 \text{ lbs}
\]

The total soil weight acting downward on the concrete collar, \(W_{SCL}\), is the sum of \(W_{SCLGW}\) and \(W_{SCLB}\) or 17,536 lbs. With safety factors applied, the downward force is:

\[
F_{DOWN} = \frac{W_{CL}}{SF} + \frac{W_{SCL}}{SF} = \frac{2200 \text{ lbs}}{1.2} + \frac{17,536 \text{ lbs}}{1.4} = 14,359 \text{ lbs}
\]

Upward Force with Concrete Collar

The upward force acting on the manhole is determined using Equation E-11:

\[
F_U = \pi \frac{72^2}{576} 62.4 \text{ pcf}(7.5 \text{ ft}) + (2) \pi 62.4 \text{ pcf}(18 \text{ in}) \frac{(30 \text{ in})^2}{6912} = 14,144 \text{ lbs}
\]

With the desired safety factor, the 18" wide collar satisfies Equation E-1:

\[
F_{DOWN} = 14,359 \text{ lbs} > F_{UP} = 14,144 \text{ lbs}
\]

Example 2: Anti-flotation Resistance of a 72” Manhole with Anti-flotation Slabs

Given: Determine the size for a set of concrete anti-flotation slabs that are placed over the 30” diameter 1.42” thick (DRISCOPLEX™ 2000 SPIROLITE RSC 160) stubouts for the 72" diameter manhole given in Example 1.
The same trial-and-error method used for Example 1 is used for the anti-flotation slabs. Assume the following trial dimensions:

\[ t_{AF} = 12 \text{ in} \]
\[ W = 4 \text{ ft} \]
\[ L = 6 \text{ ft} \]

**Find the buoyant weight of the two anti-flotation slabs, \( W_{AF} \):**

\[
W_{AF} = 2 \cdot (6 \text{ ft}) (4 \text{ ft}) \frac{12 \text{ in}}{12} (150 \text{ pcf} - 62.4 \text{ pcf}) = 4204 \text{ lbs}
\]

**Find the weight of soil above the anti-flotation slabs.**

The weight of soil above the slabs is determined by multiplying the volume of soil located directly above the slab by the unit weight of the soil. Equation E-14 is used to determine the soil weight, \( W_{AFS} \), for each slab. For two slabs, the weight is doubled. Friction within the soil mass is not considered.

\[
W_{AFS} = 2 \cdot (6 \text{ ft}) (4 \text{ ft}) (110 \text{ pcf} (10 \text{ ft} - 7.5 \text{ ft}) + (110 \text{ pcf} - 62.4 \text{ pcf}) (7.5 \text{ ft} - 4.0 \text{ ft}) = 21,197 \text{ lbs}
\]

**Find the downward force with anti-flotation slabs.**

The Engineer should apply a safety factor to each weight term. The safety factors used should be based on site conditions and the application end use. Because a manhole weight of zero has been assumed and there are no concrete caps or other weights, the downward force becomes:

\[
F_{DOWN} = \frac{4202 \text{ lbs}}{1.2} + \frac{21,197 \text{ lbs}}{1.4} = 18,642 \text{ lbs}
\]

**Find the upward force applied to the manhole.**

The upward force acting on the manhole is determined using Equation E-15.

\[
F_U = \pi \frac{(72 \text{ in})^2}{576} - 62.4 \text{ pcf} (7.5 \text{ ft}) + (2) \pi (62.4 \text{ pcf})(4 \text{ ft}) \frac{(30 \text{ in})^2}{576} = 15,675 \text{ lbs}
\]

**Compare the downward and upward forces.**

\[
F_{DOWN} = 18,642 \text{ lbs} > F_{UP} = 15,675 \text{ lbs}
\]

The downward force exceeds the upward force in proportion to the applied safety factor.

**Shear Stress in Stubout Pipe**

Next, check shear stress in the stubouts.
\[ \tau = \frac{15,675 \text{ lbs}}{(2\pi)(31.4 \text{ in})(1.4 \text{ in})} = 57 \text{ psi} < 400 \text{ psi} \]