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An American National Standard

Standard Guide for Construction Procedures for Buried Plastic Pipe[1]

This standard is issued under the fixed designation F1668; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide describes installation techniques and considerations for open-cut construction of buried pipe. Although this guide was developed for plastic pipe, the concepts of providing the appropriate soil support, care in handling, correct joining techniques, proper soil compaction methods, and prevention of installation damage may apply to any pipe.

1.1.1 Plastic pipe refers to thermoplastic and fiberglass pipe.

1.1.2 Thermoplastic pipe refers to pipe fabricated from polyvinyl chloride (PVC), polyethylene (PE), acrylonitrile-butadiene styrene (ABS), cross-linked polyethylene (PEX), chlorinated polyvinyl chloride (CPVC), or polypropylene (PP). A list of specifications for these products is given in Appendix X2.

1.1.3 Fiberglass pipe refers to a glass-fiber-reinforced thermosetting-resin pipe. A list of ASTM specifications for these products is given in Appendix X2.

NOTE 1—Appendix X2 cannot be considered inclusive because there may be unlisted, recently adopted ASTM specifications for new products that may be installed using this guide.

NOTE 2—Only a few of the ASTM specifications listed in Appendix X2 include the associated fittings. While this guide applies to the installation of pipe, couplings, and fittings, no attempt was made to list all the possible fitting specifications that may be used in conjunction with the pipe specifications. Consult each specification or manufacturer for appropriate fitting standards.

1.1.4 For simplification, the term pipe will be used in this document to mean pipe sections, fittings, and couplings.

1.2 This guide contains general construction information applicable for plastic pipe and supplements the installation standards for the various types of pipe as described in Practices D2321, D2774, D3839, F690, and Guide F645.

NOTE 3—This guide is not applicable for gas pipe applications as additional requirements may apply.

1.3 Flexible pipe, such as thermoplastic and fiberglass, are typically designed to rely on the stiffness of the soil surrounding the pipe for support. The contract documents should describe the requirements of an appropriate soil support system. The construction practices described in this guide can be instrumental in attaining the required soil stiffness.

1.3.1 A discussion of the interaction between a buried pipe and the surrounding soil and the importance of attaining proper soil support is in Appendix X1.

1.3.2 Following these guidelines will be helpful in preventing local deformations in the pipe.

1.4 This guide does not cover underwater installation, pipe that needs to be supported on piling, perforated pipe used for drainage, or gas pipelines.

1.5 Pipelines through areas described as "expansive soils," "collapsing soils," landfills or water-logged land (such as swamps) should be constructed using site-specific installation procedures and are not discussed in this guide.

1.6 This guide is not intended to cover all situations. Specific pipe characteristics, fluid transported, local site conditions, environmental concerns, or manufacturer's recommendations may require different guidelines.

1.7 The construction practices presented in this guide may be affected by the installation requirements of owners, specifying organizations, or regulatory agencies for pipelines crossing roads and highways, other pipelines or cables, or waterways such as streams, drainage channels, or floodways.

1.8 Culverts or pipe that are used as passages through water retaining embankments (for example, earth dams) may be constructed using the principles of this guide, if appropriate provisions are made to prevent water movement along the outside of the pipe (using impervious soils, cutoff collars, head walls, etc.).

1.9 The values stated in SI units are to be regarded as the standard. The inch-pound units in parentheses are given for information only.

NOTE 4—There is no similar or equivalent ISO standard covering the primary subject matter of this guide.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

[1] This guide is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water.

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***A Summary of Changes section appears at the end of this standard**

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D8 Terminology Relating to Materials for Roads and Pavements
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
D4914 Test Methods for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit
D5030 Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit
F412 Terminology Relating to Plastic Piping Systems

Pipe Installation:

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
D2774 Practice for Underground Installation of Thermoplastic Pressure Piping
D3839 Guide for Underground Installation of "Fiberglass" (Glass-Fiber Reinforced Thermosetting-Resin) Pipe
F645 Guide for Selection, Design, and Installation of Thermoplastic Water- Pressure Piping Systems
F690 Practice for Underground Installation of Thermoplastic Pressure Piping Irrigation Systems (Withdrawn 2012)[3]

Soil Testing:

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
D2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
D4564 Test Method for Density and Unit Weight of Soil in Place by the Sleeve Method (Withdrawn 2013)[3]
D4653 Test Method for Total Chlorides in Leather
D4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
D4959 Test Method for Determination of Water Content of Soil By Direct Heating
D5080 Test Method for Rapid Determination of Percent Compaction

Joining Practices:

D2657 Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D2855 Practice for the Two-Step (Primer and Solvent Cement) Method of Joining Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Pipe and Piping Components with Tapered Sockets
D6938 Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
F402 Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
F913 Specification for Thermoplastic Elastomeric Seals (Gaskets) for Joining Plastic Pipe
F2164 Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

Other ASTM Standards:

C94/C94M Specification for Ready-Mixed Concrete
F1417 Practice for Installation Acceptance of Plastic Nonpressure Sewer Lines Using Low-Pressure Air

2.2 *American Water Works Association (AWWA) Standards:*[4]

C651 Disinfecting Water Mains
C904 Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping system Using Hydrostatic Pressure

2.3 *American Association of State Highway and Transportation Officials (AASHTO) Standard:*

Standard Specification for Highway Bridges[5]

2.4 *Uni-Bell PVC Pipe Association Standard:*

UNI-B-13 Recommended Performance Specification for Joint Restraint Devices for Use with Polyvinyl Chloride (PVC) Pipe[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D8, D653, D883, D1600, and F412 unless otherwise indicated. Abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.1.1 The definitions and descriptions of soil are in accordance with the Unified Soil Classification System as presented

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.

[5] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

[6] Available from the Uni-Bell PVC Pipe Assoc., 2655 Villa Creek Dr., Suite 155, Dallas, TX 75234.

in Classification D2487. Soils may be identified and described in the field using the procedures stated in Practice D2488.

NOTE 5—The terms describing an installation cross-section are illustrated in Fig. 1. Other terms related to parts of the pipe are illustrated in Fig. 2.

NOTE 6—These terms may be different from the ones used in Practices D2321, D2774, D3839, or F690. The terms in this guide are used to describe the construction sequence and are not meant to replace or conflict with other standards.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *backfill*—material placed over the embedment up to the ground surface.

3.2.2 *bedding*—material placed in the bottom of the trench on top of the foundation soil to provide uniform support for the pipe.

3.2.3 *embedment*—material placed around the pipe that provides side support.

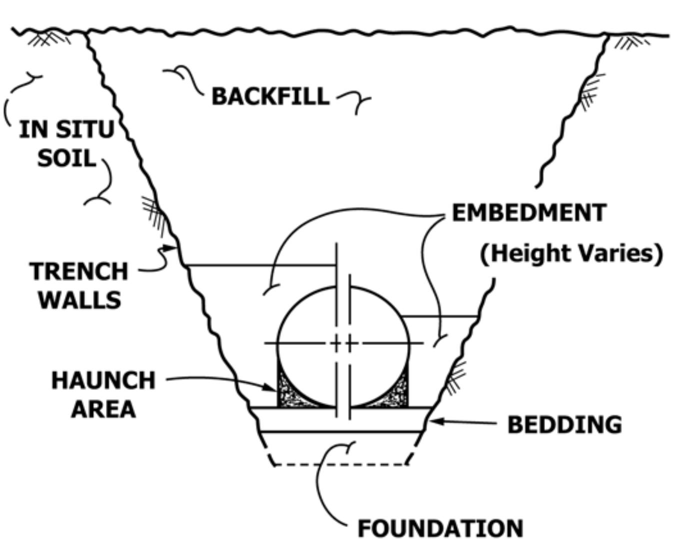
3.2.4 *foundation soil*—material in the bottom of the trench that is (*1*) undisturbed and remains in place; (*2*) removed and replaced by another material, (*3*) displaced by another material; or (*4*) removed and then recompacted into place.

3.2.5 *haunch area*—the area of the embedment under the pipe from the bottom of the pipe up to the springline, as illustrated in Fig. 1.

3.2.6 *in situ material*—the in-place soil or rock that a trench is excavated through that is either (*1*) naturally formed or deposited; or (*2*) manmade.

3.2.7 *manufactured aggregates*—aggregates that are products or byproducts of a manufacturing process (such as slag), or natural aggregates that are reduced to their final form by a manufacturing process such as crushing.

3.2.8 *springline*—a line along the length of the pipe at its maximum width along a horizontal plane. **(F412)**



NOTE 1—This drawing is illustrative only. Trench dimensions and slope vary with depth and soil conditions.

FIG. 1 Trench Cross Section Terminology

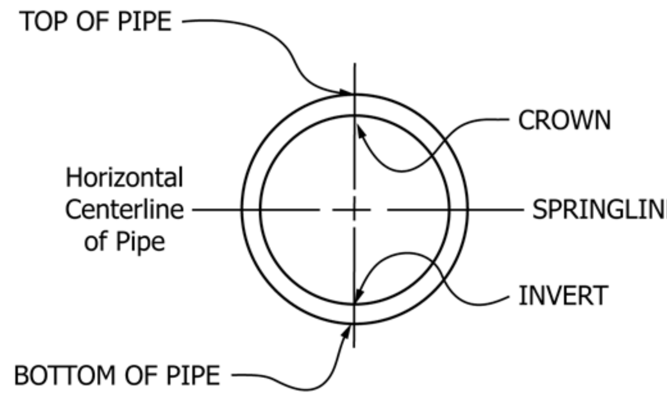


FIG. 2 Pipe Terminology

4. Significance and Use

4.1 This guide may be used as a reference of acceptable open-cut construction practices for the proper installation of buried fiberglass and thermoplastic pipe. This guide may be used as follows:

4.1.1 Installation contractors have an awareness of the level of workmanship required and use this information for bidding purposes and during construction.

4.1.2 Construction inspectors have a reference of acceptable installation practices.

4.1.3 Specification writers may use this guide as a reference in contract documents.

4.1.4 Designers may review this information during planning and design for factors to consider in the preparation of plans and specifications.

4.1.5 The owner of the pipeline may use this guide as a reference for restoration of proper pipe support and embedment when original construction is disturbed due to repairs, modifications, or construction of adjacent or crossing pipelines or cables.

4.2 This guide should not be used to replace project specification requirements, manufacturer's recommendations, plumbing codes, building codes, or ASTM installation standards, but may be used to supplement that information.

5. Inspection, Handling, and Storage

5.1 *Load Inspection*—The pipe should be packaged or loaded as recommended by the supplier. The receiver of the pipe should be aware of (*1*) the loading and packaging requirements for each mode of transportation used; (*2*) the continuance of proper handling in any multiple loading and unloading before arrival; and (*3*) any transportation incident (wreck). Before unloading, the receiver should examine the load for transportation damage, particularly if the load has shifted, packaging is broken, or if there are signs of rough treatment. Damage may also have been caused from overtightening tie-down straps or from the tie-down straps not being located at the same point along the pipe barrel where the pipe supports are located. The pipe should be examined for abrasion due to (*1*) bells, couplings, or other joint surfaces being in contact with each other or any hard object or surface; and (*2*) unpadded metal tie-down straps.

5.2 *Pipe Inspection*—Each load of pipe should be inspected and inventoried for conformance to product specifications and contract documents. Pipe markings vary according to ASTM specification, the type of pipe, and the manufacturer. In general, these markings include: ASTM specification, pipe class or pressure designation, cell classification, pipe diameter, date of manufacture, name or trademark of the manufacturer, and plant identification. In some circumstances, the plant inspector's approval mark may also be required. Pipe intended for the conveyance of potable water is evaluated, tested, and certified for use by an acceptable certifying organization when required by the regulatory authority having jurisdiction. The seal or mark of the laboratory making the evaluation should be on the pipe. Observe the unloading, uncrating, storage and distribution of the pipe, as applicable, and inspect each pipe section for damage, such as cuts, cracks, or gouges. Depths of cuts and gouges should be compared to allowable limits in the pipe specifications, contract documents, or manufacturer's recommendations.

5.2.1 Damaged pipe may or may not be repairable depending on the type of pipe.

5.2.1.1 Repairable pipe should be repaired in accordance with the manufacturer's recommendations.

5.2.1.2 Pipe that cannot be repaired should be clearly marked to prevent usage, in a manner acceptable to the supplier, and then removed from the job.

5.2.2 Gaskets should be checked for conformance to contract documents and inspected for transportation damage. If two or more types of gaskets are being used, the different gaskets should be clearly identified by appropriate markings. Specifications F477 and F913 cover the requirements for two types of gaskets.

5.2.3 All solvent cements, primers, cleaners, adhesives, and lubricants should be marked, or otherwise certified, for conformance to applicable standards and regulations.

5.3 *Nested Pipe*—The pipe interiors and exteriors should be inspected for transportation damage. Follow manufacturer's recommendations for unloading, or proceed as follows: The pipe should be removed starting with the inside pipe (smallest diameter). The pipe should be removed with a padded forklift boom and without touching other pipe.

5.4 *Handling*—Handling of the pipe to prevent damage should be in agreement with manufacturer's requirements. Typically, handling procedures will include the following precautions:

5.4.1 Avoid rough handling or dropping of the pipe and resting the pipe on hard objects that would create a point loading on the pipe. Pipe sections should not be rolled over rough or rocky ground. Prevent objects from being dropped on or impacting the pipe.

5.4.2 Move individual sections of pipe too heavy to be lifted manually with a fabric sling, a pair of slings, or with appropriate lifting equipment. Do not use chains, wire ropes, backhoe buckets, or hooks.

5.4.3 Move packaging units only with forks or slings that go under the packaging units. Packaging is not normally designed to be lifted by a chain or cable attached only to the top of the unit.

5.4.4 The flexibility and impact resistance of PVC, PE, ABS, and PB pipe are reduced as the temperature approaches freezing. Use extra care when handling these pipes during cold weather. (**Warning**—Unloading pipe may be hazardous and the unloading steps must always follow the supplier's instructions.)

5.5 *Storage*—Store the pipe in accordance with the manufacturer's recommendations. Depending on the material, typical precautions may be as follows:

5.5.1 Store pipe under appropriate protective cover for adverse weather conditions or if the unprotected storage time might exceed the manufacturer's recommendation.

5.5.2 Store pipe under conditions that will minimize dirt and foreign matter accumulating on the sealing surface and in the interior of the pipe to reduce future cleaning.

5.5.3 Store pipe in a manner that prevents bulges, flat areas, ovalization, or any other abrupt change in pipe curvature. If the pipe or packaging units are stacked, never exceed the stack height allowed by the manufacturer. If the pipes are not stored in their packaging units, use the original shipping supports. If this is not possible, store the pipe with supports that prevent the bells, spigots, couplings, or any other joint surface from contact. Space the supports at intervals along the pipe to prevent longitudinal sag. Use chocks, with or without fabric (or rope) tiedowns, to prevent the pipe from rolling.

5.5.4 Protect the pipe from excessive heat or harmful chemicals. Use cleaning solutions, detergents, solvents, etc., only in accordance with the manufacturer's recommendations.

5.5.5 Protect gaskets from harmful substances such as dust and grit, solvents, and petroleum-based greases and oils. Do not store gaskets close to electrical equipment that produces ozone. Some gaskets may need to be protected from sunlight.

5.6 *Stringing*—When distributing the pipe along the pipeline alignment, the same precautions mentioned in 5.4 should be followed. In addition, the pipe should be blocked to prevent any possibility of rolling, due to a slight slope, wind, wash-out, or accidental bumping. Pipe with bells and spigots should be supported along the barrel of the pipe to prevent deformation of the jointing ends. Supporting the pipe on two or more wooden blocks, sandbags, or earth mounds, will help prevent dirt accumulating on the sealing surfaces and inside the pipe and, where appropriate, provide a space to slip any pipe-lifting slings under the pipe.

6. Trench Excavation

6.1 *Excavation*—Excavate trenches so that sidewalls will be stable under all working conditions. Slope trench walls or provide supports in conformance with all local and national standards for safety. Open only as much trench as can be safely maintained.

6.1.1 The amount of open trench and the length of time trenches remain open may be restricted for other reasons such as pedestrian safety, traffic disruptions, etc.

6.2 *Minimum Trench Width*—The trench width, normally specified in the contract documents, is based on design and construction factors such as pipe outside diameter, installation methods, and inspection requirements. Specific activities in the trench that might influence the width would be joining procedures, checking gaskets, compacting soil into the haunch area and beside the pipe, and soil density testing.

6.3 *Supported Trench Walls*—Sheeting, bracing, shoring, or trench shields should be used in the following conditions:

6.3.1 Where required by national or local safety regulations.

6.3.2 Where sloped trench walls are not adequate to protect personnel in the trench from slides, caving, sloughing, or other unstable soil conditions.

6.3.3 Where necessary to (*1*) prevent structural damage to adjoining buildings, roads, utilities, vegetation, or anything else that cannot be moved, or (*2*) prevent disruptions to businesses, provide traffic access, or similar concerns.

6.3.4 Where necessary to remain within the construction easement or right-of-way.

6.4 *Sheeting or Shoring*—When supports such as trench sheeting, shoring, bracing, or trench jacks are used, ensure that the pipe support and any compacted soil around the pipe is maintained throughout installation. Ensure that sheeting is sufficiently tight to prevent washing soil out of the trench wall from behind the sheeting. Provide tight support of trench walls below viaducts, existing utilities, or other obstructions that restrict driving of sheeting.

6.4.1 Unless otherwise directed, sheeting should be left in place to preclude loss of support of foundation and embedment materials. When the top of sheeting is to be cut off, make a cut 0.5 m or more above the top of the pipe. Leave all vertical and horizontal braces in place. Top cross bracing may need to be installed after the sheeting is cut off. Sheeting that is to be left in the trench shall be constructed of materials that will not corrode or rot, resulting in a loss of support for the pipe.

6.4.2 Ensure that pipe and foundation and embedment materials are not disturbed by support removal. Avoid use of vibratory extraction equipment. Fill voids left upon removal of supports and compact all material to required densities.

6.5 *Trench Shields*—A trench shield or box is a rigid structure that can be moved along the trench to protect workers from potentially unstable trench walls.

6.5.1 *Application*—A shield can be used in two different ways, as follows:

6.5.1.1 *Trench Wall Support*—The trench is excavated from inside the shield. The trench box is lowered as the material is excavated.

6.5.1.2 *Protect Workers*—The trench shield is placed into an existing excavation.

6.5.2 *Soil Compaction*—Improper use of trench boxes while compacting the embedment soil can significantly affect the deflection of flexible pipe and compromise the structural integrity of the pipe. Do not compact embedment soil against the walls of a trench shield and then move the shield creating a void between the compacted embedment and the trench wall. The embedment soil must get completely compacted between the pipe and the trench walls. Typical methods used to attain full compaction between the pipe and the trench walls are as follows:

6.5.2.1 Provide bottom cutouts in the wall of the trench box so that embedment material can be compacted directly against the trench walls. A cutout area at the bottom of the shield on the trailing edge allows the shield to be moved forward laterally.

6.5.2.2 In some conditions, a "subtrench" may be excavated below the bottom of the trench shield. The depth of the subtrench is limited by safety regulations.

6.5.2.3 The shield is raised vertically in about 30-cm (12-in.) increments and the soil compacted below the bottom edge of the shield from the pipe to the trench wall. This operation is continued until the specified height of compacted soil is reached.

6.6 *Trench Walls*—The type of soil and the density of the trench walls may have a significant effect on the performance of the pipe and the soil-pipe system. If the conditions of the trench walls encountered are not as assumed in design, the pipeline designer shall be notified and alternative provisions made. The anticipated conditions should be stated in the contract documents.

6.7 *Contaminated Areas*—If the trench excavation encounters an area contaminated with significant concentrations of pollutants comprised of low-molecular weight petroleum products or organic solvents, there may be restrictions on the type of pipe and gaskets that are used. If a previously unknown contaminated area is encountered, all appropriate entities shall be notified and the contamination identified. (**Warning—** Working in excavated trenches may be hazardous. Follow all safety regulations.)

7. Groundwater Control During Construction

7.1 The pipe should not be installed in standing or running water. Control of both surface and subsurface water (groundwater) may be required.

7.2 *Groundwater*—When groundwater is present in the trench excavation, dewatering may be necessary to maintain stability of *in situ* and imported materials. As appropriate, use sump pumps, wells or well points, or drainage blankets to remove and control water in the trench. When excavating while controlling groundwater, ensure that the groundwater is below the bottom of the cut to prevent washout from behind sheeting or sloughing of exposed trench walls. The water should be controlled in the trench before, during, and after pipe installation and control maintained until the embedment is installed and sufficient backfill has been placed to prevent flotation of the pipe. To prevent loss of soil support, dewatering methods should be used that minimize removal of fines and the creation of voids in native materials.

7.2.1 *Drainage Blankets*—Free-draining materials may be used for all or a portion of the foundation or bedding to drain water along the trench to sumps or other outlets for removal. Perforated drainage tubing may be used to supplement the flow capacity of the drainage blanket. Select a gradation for the drainage materials to minimize migration of fines from surrounding materials, or use a geotextile separator.

7.2.2 *Sump Pumps*—If direct pumping from sumps is used, the pumps should be submersible or self-priming, so that intermittent flows may be discharged. Diaphragm pumps are generally more suitable when muddy water is to be pumped, while centrifugal pumps are best for pumping large quantities of water. Regardless of the specific type of pump used, a standby pump should be readily available in case the operating pump stops or becomes clogged.

7.2.3 *Wells or Well Points*—Lowering of the water table with wells or a well-point system is an effective means of controlling groundwater in permeable soils and may eliminate the need for sheeting or shoring. However, when the water table is lowered, subsidence of the ground in the surrounding area may occur. Structures close to the dewatered area may also settle and develop structural damage or cracking.

7.3 *Surface Water*—Drainage should be controlled in the vicinity of the excavation by grading and ditching the ground surface to prevent runoff and surface water from running into the trench.

7.4 *Flotation*—If groundwater is encountered, potential flotation of the pipe following construction should be evaluated. If required, construct the pipeline to prevent flotation. Anti-flotation restraints, such as collars or anchors, may be required in some circumstances.

8. Foundation

8.1 *Requirements:*

8.1.1 The foundation is the material beneath the pipe that prevents excessive settlement or excessive differential settlement of the pipeline. If the native material is unsuitable, remove it (overexcavate) and replace with suitable material.

8.1.2 A description of what material is unsuitable for the foundation and what soil is suitable as a replacement material should be part of the contract documents.

8.1.3 Not all foundation problems may be anticipated in the design stages. If any unusual conditions are encountered during trench excavation, site-specific modifications may be required. Any changes during construction shall be approved by the specifying organization.

8.2 *Construction Considerations*—The following guidelines are recommended for the foundation:

8.2.1 A foundation is considered to be stable for laying pipe when a person can walk on the surface without sinking into the soil or can walk without feeling the soil move underfoot. If the trench bottom is unstable, gravel, cobbles, crushed rock, slag, crushed shell, or other durable inert material may be worked into the soil until the trench bottom is stable. In many cases, the unstable soil will have to be excavated and replaced with one of these materials until the foundation is stable.

8.2.1.1 Appropriate geotextiles may be used for stabilizing quick and unstable trench bottoms.

8.2.2 Some contract documents require that when the trench bottom is in rock, the minimum bedding thickness be increased.

8.2.3 If the trench bottom is inadvertently overexcavated below the intended grade, fill the overexcavation with compatible foundation material and compact to a density equivalent to the *in situ* material. (This may not be necessary for extensive lengths of overexcavation, where the pipeline grade is not critical.)

8.2.4 If trench sidewalls slough prior to installation of the pipe, remove all sloughed and loose material from the trench.

8.2.5 Selection of material for the foundation may be affected by the recommendations in Sections 7, 17, and 18.

9. Bedding

9.1 *Requirements:*

9.1.1 The bedding is material placed on the bottom of the trench to provide uniform support for the pipe. Since the pipe is laid directly on the bedding material, place the bedding so that the pipe will be at the proper elevation and slope. Where the trench is excavated in rock, the bedding also serves as a cushion for the pipe and is typically thicker than normal. When rock is excavated, the minimum bedding thickness is the distance between any point of rock and the pipe, pipe bell, coupling, or fitting.

9.1.2 The thickness, type of soil, and degree of compaction for the bedding should be specified in the contract documents. If not described, contact the specifying organization for specific instructions. Any change during construction shall be approved by the specifying organization.

9.1.3 The maximum particle size permitted in the bedding material is typically related to the type of pipe being installed. The allowable maximum particle size should be stated in the contract documents.

9.1.4 For some soil conditions, a bedding may not be specified and the pipe is laid directly on the trench bottom. However, a bedding should be constructed if the foundation contains alternating hard and soft areas, rock particles larger than permitted in the embedment material, or if rock is unexpectedly encountered. Continuous evaluation of the trench bottom during excavation may be required. Shaping the trench bottom to fit the curvature of the pipe is not recommended.

9.1.5 Selection of material for the bedding may be affected by the recommendations in Sections 7, 17, and 18.

9.2 *Construction Considerations*—Recommended steps in the placement of the bedding are as follows:

9.2.1 Remove any loose rocks, large dirt clods, and debris from the trench.

9.2.2 Do not use material for bedding that contains organic matter, stumps or limbs, frozen earth, debris, manmade waste, or other unsuitable materials.

9.2.3 If the soil in the bottom of the trench excavation is suitable for use as the bedding material, remove the soil and then place it back on the trench bottom. This is useful in obtaining an even thickness of bedding and avoids high and low areas or hard and soft spots beneath the pipe.

9.2.4 Place the bedding material so the pipe will be at the proper grade when laid on the bedding. Anticipate settlement of the pipe into uncompacted soil. Do not apply pressure to the pipe (such as with a backhoe bucket) to push the pipe down to grade.

9.2.5 Place the bedding material so each section of pipe will have a uniform bearing for the length of the pipe, except at bell-and-spigot (or other protruding) joints. Do not use soil mounds or any blocking to bring the pipe to grade.

9.2.6 When the pipe has joints that form an offset on the outside of the pipe, such as bell-and-spigot joints, excavate bell holes in the bedding so that the bell does not rest on any part of the bedding or foundation.

9.2.7 When appropriate, excavate sling holes in the bedding to facilitate removal of the slings.

10. Laying

10.1 Lay the pipe in accordance with the manufacturer's recommendations. Typical laying practices may include the following:

10.1.1 Lower pipe too heavy to be handled manually carefully into place on the bedding using a pair of fabric slings. Do not use chains, wire ropes, or hooks. The pipe must never be thrown, rolled, or dropped into place.

10.1.1.1 Nylon slings with a colored wear-indicator are recommended for handling pipe. The slings should be discarded when the outer fabric layer has worn enough to expose the brightly colored inner layer. On these slings, the load capacity is usually indicated by numbers sewn into the fabric.

10.1.2 Avoid excessive bending of the pipe, if the pipe is assembled above ground and lowered into the trench. Bending should be within the limits recommended by the pipe manufacturer for the kind, type, grade, wall thickness, and diameter of a specific pipe.

10.1.3 Whenever pipe laying or joining is interrupted, protect the ends of the pipe so that people, animals, water, dust, dirt, mud, or foreign matter is kept out of the pipe.

10.1.4 Appropriate precautions should be taken on slopes to prevent separation of gasketed joints or pipe slippage, such as laying the pipe uphill or anchoring the pipe in place.

11. Joining

11.1 Plastic pipe may be joined to pipe of similar or dissimilar material using a number of different techniques. Use a technique suitable for the particular pipes being joined together. Manufacturers should be consulted for specific instructions not covered by contract documents.

11.2 Commonly used procedures, joining materials, and fittings are listed in Section 2.

11.3 Use the manufacturer's recommended techniques, tools, and equipment to join the pipe. Successfully joining pipe requires skill, knowledge, and experience. New personnel should be trained under the guidance of skilled installers. Detailed written procedures and visual aids for training personnel are usually available from manufacturers of pipe and joining equipment.

11.4 Unequal forces due to fluid pressure at changes in pipeline alignment or reduction in pipe size or at the end of a line may create a separation force at joining locations. These forces shall be accounted for as follows:

11.4.1 Bonded joints in pressure systems (such as heat fused, adhesive bonded, or solvent cemented), shall be designed and constructed to withstand the separation forces.

11.4.2 Joints and fittings in gasketed joint pressure systems should be restrained by mechanical restraint devices or thrust blocks to compensate for these pull-out forces. See Section 19.

11.5 *Gasket (Elastomeric Seal) Joints*—Pipe with gasketed joints are assembled section by section in the bottom of the trench. The bell end of the pipe should face the direction of laying. The sealing surfaces of the bell and spigot should be cleaned and inspected for damage. If lubricant is used, apply as recommended by manufacturer. Align the pipe sections, insert the spigot into the bell, and push until the insertion position marked on the pipe is reached or to the position recommended by the pipe manufacturer. Mark pipe insertion points if necessary. Protect the end of the pipe during assembly, and do not use excessive force that may result in damage to the pipe or dislodged gaskets. The following practices are recommended when joining the pipe:

11.5.1 When lubricant is required, use only the lubricant supplied or recommended for use by the manufacturer. Use lubricant liberally and apply to the bell, spigot, or gasket, or any combination thereof, as recommended by the manufacturer. The lubricated surfaces must be protected from dirt or grit until the joining is complete. Keep the containers of lubricant covered to prevent contamination with grit or debris.

11.5.2 Examine any splices in the gasket and discard if any separation exists. As recommended by the manufacturer, some pipe to be assembled with the gasket in the spigot groove should have the tension in the gasket equalized in an approved manner.

11.5.3 Use a bar and wooden block, padded come-alongs, or mechanical equipment with a padded push frame to push the spigot into the bell. Use caution when using power equipment that makes it difficult for the operator to judge when the pipe is overinserted. Be careful when using equipment that may apply uneven, non-aligned pressure such as the bucket of a backhoe. Equipment with pneumatic tires that may slip on loose or cohesionless bedding material shall be used with caution to prevent sudden, uncontrolled thrusts that may damage the pipe. Do not stab or swing one section of pipe into another pipe. Do not overinsert the pipe.

11.5.4 Following assembly of the joint, check the pipe for line and grade.

11.5.5 Small changes in direction for horizontal and vertical angle points, long radius curves, or alignment corrections may be made by a joint angle change (an unsymmetrical closure of the joint with a normal joint opening on one side of pipe and a wider space on the opposite side of pipe). Limit the amount of angle so that the seal between the gasket and the pipe remains intact. The permissible angular movement varies considerably among pipe manufacturers. The pipe manufacturer's literature should state the maximum permissible angle change and the recommended procedure. Typically, the pipe is joined as if the pipeline alignment were straight and then the last pipe section moved (pulled) to the desired angle.

11.5.6 With some types of gasketed joints, the gasket may be checked using a feeler gage to see if the gasket has been dislodged, twisted, or pinched during assembly. The pipe may leak where a gasket is not in the correct location. Check the gasket around the complete circumference of the pipe.

11.5.7 If joining is not successful, disassemble the joint, inspect for damage, reclean all joint components, and reassemble using a new gasket (except when using nonremovable-type gaskets). If a nonremovable-type gasket is damaged, replace the pipe section (or coupling).

11.5.8 If the pipeline is near another pipeline carrying petroleum products, or traverses an area contaminated with petroleum products, special petroleum-resistant gasket material may be required. When two different types of gaskets are being used, mark the gaskets or packaging to prevent misuse.

11.5.9 Pipe transporting potable water shall be joined with gaskets and lubricants that meet all regulations for products used in potable water systems.

11.6 *Solvent Cemented Joints*—When making solvent-cemented joints, follow the recommendations of both the pipe and solvent cement manufacturer or the recommendations of Practice D2855. All contractor, inspection, and testing personnel shall be aware of the safety precautions for using solvent cement as in Practice F402. If full entry is not achieved, disassemble or remove and replace the pipe. Allow freshly made joints to set for the recommended time before moving, burying, or otherwise disturbing the pipe. Axial restraint of the joined sections may be required during curing, to prevent movement from thermal expansion or contraction which could damage the joint.

11.6.1 Cold-temperature conditions slow the cure of solvent cements. Solvent cements containing tetrahydrofuran (THF) and other solvents that are immiscible in water are less reliable in wet conditions.

11.7 *Heat Fusion Joints*—Make heat fusion joints in conformance with the recommendations of the pipe manufacturer or the recommendations of Practice D2657 for polyolefin pipe excluding polyethylene pipe and Practice F2620 for polyethylene pipe. Pipe may be joined outside of the trench excavation and then lowered into position, provided the pipe is supported and handled in a manner that precludes damage. Allow heat-fused joints to cool for the minimum prescribed time before moving the pipe. When moving large-diameter pipelines, avoid excessive stressing of the joints.

11.7.1 Changes in direction for horizontal and vertical angle points, long radius curves, or alignment corrections may be made by slightly bending the pipe. The minimum pipe-bending radius is usually stated in the manufacturer's literature. Too much curvature of the pipe can create excessive diametral deformation or excessive bending stresses which can induce pipe failure. Bracing or blocking the pipe should not be used to force curvature.

11.8 *Adhesive Bonded Joints*—Make adhesive-bonded joints in conformance with the recommendations of the pipe manufacturer. Some fiberglass pipe are joined using adhesives to bond bell-and-spigot joints on tapered couplings. The following precautions are typically part of the procedure:

11.8.1 Clean and roughen bonding surfaces just before use.

11.8.2 Wet both bonding surfaces well with properly mixed adhesive.

11.8.3 Avoid voids or pockets in the bond line.

11.8.4 Keep the adhesive as thin as possible.

11.8.5 Hold the joint or coupling tightly together for the entire cure time.

11.9 *Other Fiberglass Joining Systems*—Other types of joining methods for fiberglass pipe include mechanical couplings, butt joints with laminated overlay, bell-and-spigot with laminated overlay, or flanged joints. These joints should be made in conformance with the recommendations of the pipe manufacturer since equipment and procedures may be unique for each manufacturer's product.

12. Embedment

12.1 *Requirements:*

12.1.1 The embedment is the material placed around the pipe. The embedment and the pipe act together as a pipe-soil structure to support the external loads on the pipe.

12.1.1.1 The embedment may extend from the bottom of the pipe, up to a specified level somewhere between the springline of the pipe and about 15 to 30 cm (6 to 12 in.) over the top of the pipe, depending on the individual requirements of the owner or specifying organization.

12.1.2 The type of material, the degree of compaction, and the allowable maximum particle size for the embedment should be specified in the contract documents. If not specified, contact the specifying organization for specific instructions. Any change during construction shall be approved by the specifying organization.

12.1.2.1 Describe manufactured aggregates in accordance with Appendix X2 of Classification D2487. Materials such as slag, cinders, and shells should be evaluated for particle strength and degradation.

12.2 *Construction Considerations*—The following operations are recommended for installation of the embedment:

12.2.1 Before placing embedment materials, remove any rocks larger than the allowable maximum particle size, large dirt clods, sloughed soil from trench walls, or any debris from surface of bedding.

12.2.2 Do not use material for the embedment that contains organic material, stumps or limbs, frozen earth, debris, man-made wastes, and other unsuitable materials.

12.2.3 Do not drop the embedment material directly on the pipe if it is determined that damage may result. In this case, use chutes or other means to direct or divert the flow of material to the sides of the trench.

12.2.4 Distribute the embedment material evenly along the trench and equally on both sides of the pipe to maintain alignment. Do not dump the material into a large pile in the trench prior to spreading into a layer for compaction. A large mass of material against the pipe may push the pipe out of alignment or create a flat or depressed area on the pipe. Small wedges of material in the haunch area may be useful to minimize movement of the pipe during placement of the embedment material.

12.2.5 Construct the lifts of material evenly on each side of the pipe. There should not be more than one lift thickness difference in elevation of the material on one side of the pipe from the other.

12.2.6 As recommended in Section 14, use a compaction method appropriate for the type of soil and the degree of compaction required.

12.2.7 Placing and compacting material into the haunch area is essential. Take particular care to ensure that proper pipe support is obtained in this area. After the embedment is complete, an inspection test pit (an excavation down through the embedment) is a useful technique to examine the haunch area to see if the embedment material is firm and in complete contact with the pipe.

12.2.8 When compacting material in the pipe haunch area, prevent the pipe from raising due to the compactive effort. When the trench is inundated with water as part of the compaction method, prevent the pipe from floating.

12.2.9 The embedment material beside the pipe, in combination with the pipe stiffness, provides the resistance against excessive pipe deflection due to external loads on the pipe. The specified degree of compaction must be attained. This can be evaluated by different methods, such as the following:

12.2.9.1 Measure the degree of compaction by testing as discussed in Section 14.1.

12.2.9.2 Evaluate the compactive effort by watching equipment coverage and number of passes, the addition of water, and the use of the proper materials and lift thicknesses. These correlations may be established by testing at the beginning of the project or by local experience.

12.2.9.3 Measure the deflection of the pipe during and after construction. Various techniques are described in Section 20.

12.2.10 When compacting material close to the pipe, the compaction equipment shall not contact the pipe. Impacting the pipe may cause misalignment, cracks, gouges, or areas of excessive local deformation. Extra care may be required in cold weather because of the reduced flexibility and resistance to impact of thermoplastic pipe.

12.2.11 When compacting material at the sides of the pipe, too much compactive effort may cause a reduction in the horizontal diameter of the pipe and a proportional increase in the vertical diameter. This increase in vertical diameter should not exceed the allowable limits.

12.2.12 When compacting material over the top quarter of the pipe, place at least 30 cm (12 in.) of loose material over the pipe before compacting directly over the pipe with handheld or walk-behind compaction equipment. Do not use ride-on compaction equipment, until at least 1 m (3 ft) of material is placed over the pipe.

13. Backfill

13.1 *Requirements:*

13.1.1 The backfill is the material placed over the embedment soil (and the pipe) up to the ground surface.

13.1.2 The material requirements and any compaction required should be indicated in the contract documents. Requirements may vary significantly depending on terrain, surface use, etc., (13.2.5 to 13.2.8). Any change during construction shall be approved by the specifying organization.

13.2 *Construction Considerations*—Use the following guidelines for the backfilling operations:

13.2.1 Generally, most soil may be used for backfill with exceptions as discussed. The soil should be free of stumps and limbs, construction debris, manmade waste, or any other unsuitable material, particularly anything that would be a hazard during any future excavation of the backfill area.

13.2.2 In backfill that is within 30 cm (12 in.) of the pipe, do not use materials that contain particles larger than the allowable maximum particle size. In the area of the backfill between 30 cm and 1 m (3 ft) of the pipe, do not use material containing rock particles or hard clods of soil or frozen chunks with a maximum dimension larger than 15 cm (6 in.).

13.2.3 Do not use heavy equipment (wheel loads similar to, or greater than, AASHTO H-20 wheel loads) within 1 m (3 ft) of the pipe, when placing or compacting backfill. Check the weight of construction equipment against allowable design loads. Do not use hydrohammers or similar compactor equipment within 1.5 m (4.5 ft) of the top of the pipe, and then only if the soil over the pipe has been previously compacted.

13.2.4 When using a backfill material that will settle excessively, such as organic materials, frozen soil, large clods or chunks of soil loosely placed, mound the ground surface over the trench or make other provisions to prevent a depression over the pipe.

13.2.5 Compact backfill soils in trenches through cultivated land, areas where leaving a mound over the pipeline alignment may not be acceptable, or on steep slopes to a minimum of 85 % "standard Proctor" density. Backfill on steep slopes may also need a layer of riprap (gravel or cobbles) or be revegetated to prevent erosion. Diagonal trenches on the surface may be useful in diverting the water to the sides to prevent erosion down the slope.

13.2.6 Under roads and highways, shoulders, aprons, curbs, and walks, backfill should be compacted to at least 95 % "standard Proctor" density or to the level required by the owner of the road or to local or state requirements. Do not use organic soils such as OH, OL, or PT or high volume change soils such as CH in these circumstances.

13.2.7 Where waterways (natural or manmade) cross the pipeline, select materials with low permeability and compact to minimize infiltration of water into the backfill. Restore the bed of the waterway as much as possible to the original condition.

13.2.8 Restore the soil support and installation details for any pipeline or cable crossing to the original condition or to the requirements of the owner or regulatory agency.

13.2.9 Backfill all trenches as soon as possible. Open trenches are hazardous and sudden rainstorms, floods, etc., may damage the pipe or installation by floating the pipe or washing unsuitable material into the trench.

14. Compaction of Soil

14.1 *Compaction of Soils Containing a Significant Amount of Fines*—Soils that are classified as SM, SC, GM, GC, CL, CH, ML, or MH (or a borderline soil or dual symbol soil beginning with one of these symbols, for example, SC/GC, CL-ML) contain more than 12 % fines and should be compacted with impact tampers, rammers, or with sheepsfoot rollers as indicated in Table 1. These soils are compacted to a specified percent of a laboratory maximum density such as "standard Proctor" (Test Method D698) or "modified Proctor" (Test Method D1557). The maximum density occurs at an optimum moisture content. Less effort is required to meet the specified density when the moisture content of the soil being compacted is within two percentage points of the optimum moisture. A rapid method of determining the percent compaction and moisture variation may be used as described in Test Method D5080. For compaction levels of 90 % standard Proctor and higher, the compacted lift thickness should not exceed 15 cm (6 in.).

TABLE 1 Criteria for Soil Compaction to 90 % Standard Proctor or Higher

Soil Type	Appropriate Compaction Methods	Compacted Lift Thickness	Laboratory Compaction Standard	In-Place Density Test[A]
Clean gravels GW, GP[B]	Vibratory plate or vibratory roller	30 cm	Percent relative density	D1556
	Internal vibrators	Length of vibrator	D4253 and D4254	D6938
Coarse-grained with fines GM, GC, SM, SC[B]	Rammer or tampers or sheepsfoot roller	15 cm	Percent Proctor	D4564
Fine-grained CL, ML, CL-ML, CH, MH[B]				D4914
			D1557 D5080	D5030
Clean sands SW, SP[B] Dual symbol soils with 5–12 % fines GW-GM GW-GC GP-GM GP-GC SW-SM SW-SC SP-SM SP-SC	Use compaction method and laboratory compaction test that results in highest in-place density.			

[A] These tests are applicable for all soil types.
[B] Or any borderline soil that begins with these symbols.

14.2 *Compaction of Soils Containing Few Fines*—Soils that are classified as GW, GP, SW, or SP (or a borderline soil beginning with one of these symbols, for example, GP/SP) contain less than 5 % fines and should be compacted with surface plate vibrators, vibratory rollers, or internal vibrators as indicated in Table 1. These soils are compacted to a specified percent relative density (Test Methods D4253 and D4254). The compacted lift thickness should not exceed 30 cm (12 in.) when compacted with surface plate vibrators or vibratory rollers or should not exceed the length of the internal vibrator. Trial test areas may be useful in determining the size of the internal vibrators required, the spacing of their insertion into the soil, and appropriate amount of water. When using water and internal vibration, take care to prevent flotation of the pipeline.

14.2.1 In some cases, the degree of compaction of SW or SP soils may be controlled using "standard Proctor" or "modified Proctor" values, if the laboratory test results in a clearly defined compaction curve. The resulting in-place density of the soil shall be equal to or greater than the density that would be required using the relative density criteria.

14.2.2 Impact tampers or sheepsfoot rollers may be used to compact these soil types. In this case, the compacted lift thickness should not exceed 15 cm (6 in.).

14.3 *Compaction of Soils Containing Some Fines*—Soils that are classified as GW-GM, GW-GC, GP-GM, GP-GC, SW-SM, SW-SC, SP-SM, or SP-SC contain 5 to 12 % fines and may behave as a soil containing a significant amount of fines (see 14.1) or a soil containing few fines (see 14.2). The method of compaction and the method used to measure the level of compaction should be the method (14.1 or 14.2) that results in the higher in-place density as indicated in Table 1.

NOTE 7—Soils may be compacted to densities below 90 % standard Proctor (D698) by several different methods such as wheel rolling, equipment travel, puddling, jetting, ponding, or sluicing. The lift thickness will depend upon the method and the type of soil.

14.4 *Determination of the In-Place Density of Soils*—The in-place density of any *in situ* or fill soil should be determined in accordance with Test Methods D1556, D2167, D6938, D4564, D4914, or D5030. The applicable test method will depend upon the type of soil being tested, moisture content of the soil, and maximum particle size in the soil. The moisture content of the soil should be determined in accordance with Test Methods D2216, D4653, D4944, or D4959.

14.4.1 When using the nuclear density-moisture gages (Test Method D6938), the gage should be site-calibrated in the proximity of the pipe and in the excavation unless otherwise indicated by the gage manufacturer.

15. Pipe-Structure Connections

15.1 Where differential settlement is expected (such as at the ends of casing pipe, where the pipe connects to a rigid structure such as a manhole or anchor block) or where the pipe connects to appurtenant structures such as valves and fittings, follow the contract documents or manufacturer's recommendation. In the absence of any such instructions, provide a system capable of accommodating or minimizing the anticipated settlement. This may be accomplished by one of the following methods:

15.1.1 Place a gasketed joint within a half pipe diameter of the face of the structure and a second gasketed joint within one to two pipe diameters of the face of the structure (preferably with the joint near where the pipe support changes from undisturbed to disturbed foundation soil). This system of two joints and a short length of pipe may accommodate differential settlement up to the rotational capacity of the joints.

15.1.2 Attach the pipe to the structure with a watertight yielding boot that permits rotation and translation, or use any specially designed variable joint.

15.1.3 Provide firm support for the pipe from the structure to the *in situ* foundation by backfilling any excavation next to the structure with a high slump, low-strength lean concrete, soil-cement slurry (flowable fill), cement-stabilized sand, or soils compacted to a high density.

15.1.4 Shaping the foundation to avoid abrupt changes in support.

15.2 Special appurtenances such as vertical risers, service connections, and manholes may experience large dragdown loads as the backfill settles. These structures should be installed or supported to minimize any load on the pipe.

16. Installation Through Casings

16.1 The pipe may have to be placed within a casing which has been installed under a railroad, highway, or other obstacle to normal trenching procedures. The construction of casings should be in conformance with the requirements of the owner of the railroad or highway or the regulatory agency responsible. In the absence of any such requirements, the following precautions should be observed:

16.1.1 The inner surface of the casing material should not cause damage to the pipe when the pipe is inserted into the casing. The rubbing surfaces may be lubricated or the pipe overwrapped with a protective material to facilitate insertion within the casing. Petroleum products, which would damage gaskets, should not be used.

16.1.2 The pipe should not rest on the bell when placed or pushed into the casing. Skids may be strapped to the pipe or casing spacers may be used to create a clearance between the bells and the casing.

16.1.3 When the pipe is jacked through the casing, take care not to damage the pipe or joints. Do not exceed the maximum push force recommended by the manufacturer. To avoid overinsertion of spigots on some gasketed pipe, the ends of skids or spacers should be flush with the spigot insertion line and contact the bell when the pipe is pushed into the casing.

16.1.4 In order to avoid differential settlement at the ends of the casing, the requirements for type of soil and level of compaction of the pipe embedment shall be followed right up to the ends of the casing. Other methods of preventing or accommodating differential settlement are described in Section 15.

16.1.5 To prevent movement, secure the inner pipe by suitable blocking that will not result in excessive load concentrations, or by partially or completely filling the void space with sand or grout.

16.1.5.1 If the space is filled with grout, do not exceed the pipe manufacturer's recommended allowable external grouting pressure. When grouting, prevent the pipe from floating.

17. Migration of Soils

17.1 When coarse, open-graded material is placed adjacent to a finer material, fines may migrate into the coarser material under the action of the hydraulic gradient from groundwater flow. Significant hydraulic gradients may occur in the pipeline trench during construction when water levels are being controlled by various pumping or well-pointing methods, or after construction when permeable underdrain or embedment materials act as a "french" drain under high-fluctuating groundwater levels. Field experience shows that migration may result in significant loss of pipe support and cause deflections that exceed design limits. The gradation of the bedding, embedment, backfill, and adjacent materials shall be compatible in order to minimize migration. In general, where significant groundwater flow is anticipated, avoid placing coarse, open-graded materials adjacent to finer materials, unless methods are employed to impede migration, such as the use of an appropriate soil filter or filter fabric along the boundary of the incompatible materials.

18. Trench Plugs

18.1 If the bedding or embedment is constructed using cohesionless, free-draining soils, a path is created for water to flow easily (french-drain effect) alongside the pipe. In areas where there is high groundwater, the pipeline crosses streams or aquifers, or the natural groundwater flow would be affected or even diverted by the free-draining material, trench plugs of compacted cohesive, impervious soils may be constructed at intervals along the pipeline. (See Fig. 3.)

18.2 When the type of backfill material or the placement of the backfill material to a lower density than the *in situ* soil would divert any intercepted groundwater movement, trench plugs of compacted cohesive soil may be constructed in the backfill over the pipe to prevent the flow of water along the trench backfill.

19. Joint Restraints

19.1 *Pressure Pipe:*

19.1.1 For pipelines that include gasketed joints and fittings, joint restraints may be necessary at certain points in the system in order to prevent possible separation of the fitting or the pipe joint. Unequal forces due to water pressure result in thrust loads at valves, pumps, and reducers, and at changes in pipeline alignment, such as elbows, tees, wyes, and at dead ends. Joint restraints include mechanical restraints, thrust blocks, and anchor blocks.

19.1.2 A mechanical restraint attaches to the pipe or fitting on each side of the joint and physically prevents joint separation. There are various types of mechanical restraint devices and design and installation should follow recommendations of the manufacturer. UNI-B-13 is a performance specification for mechanical restraint devices used with PVC pipe.

19.1.3 A thrust block is constructed to transfer the thrust load from the pipe to a wider load-bearing soil surface, as shown in Fig. 4. The dimensions of the thrust blocks should be such that point loading on the pipe is minimized.

19.1.4 For upward thrusts, anchor blocks may be necessary, as shown in Fig. 4, at valves and vertical direction changes. Anchor blocks also may be required on slopes steeper than 20° (0.3 slope), since pipelines have a tendency to creep downhill.

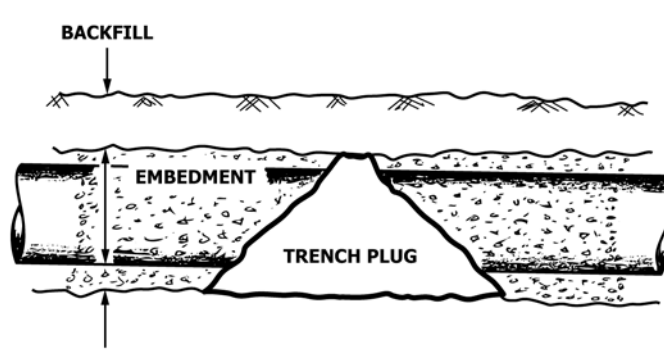


FIG. 3 Trench Plug

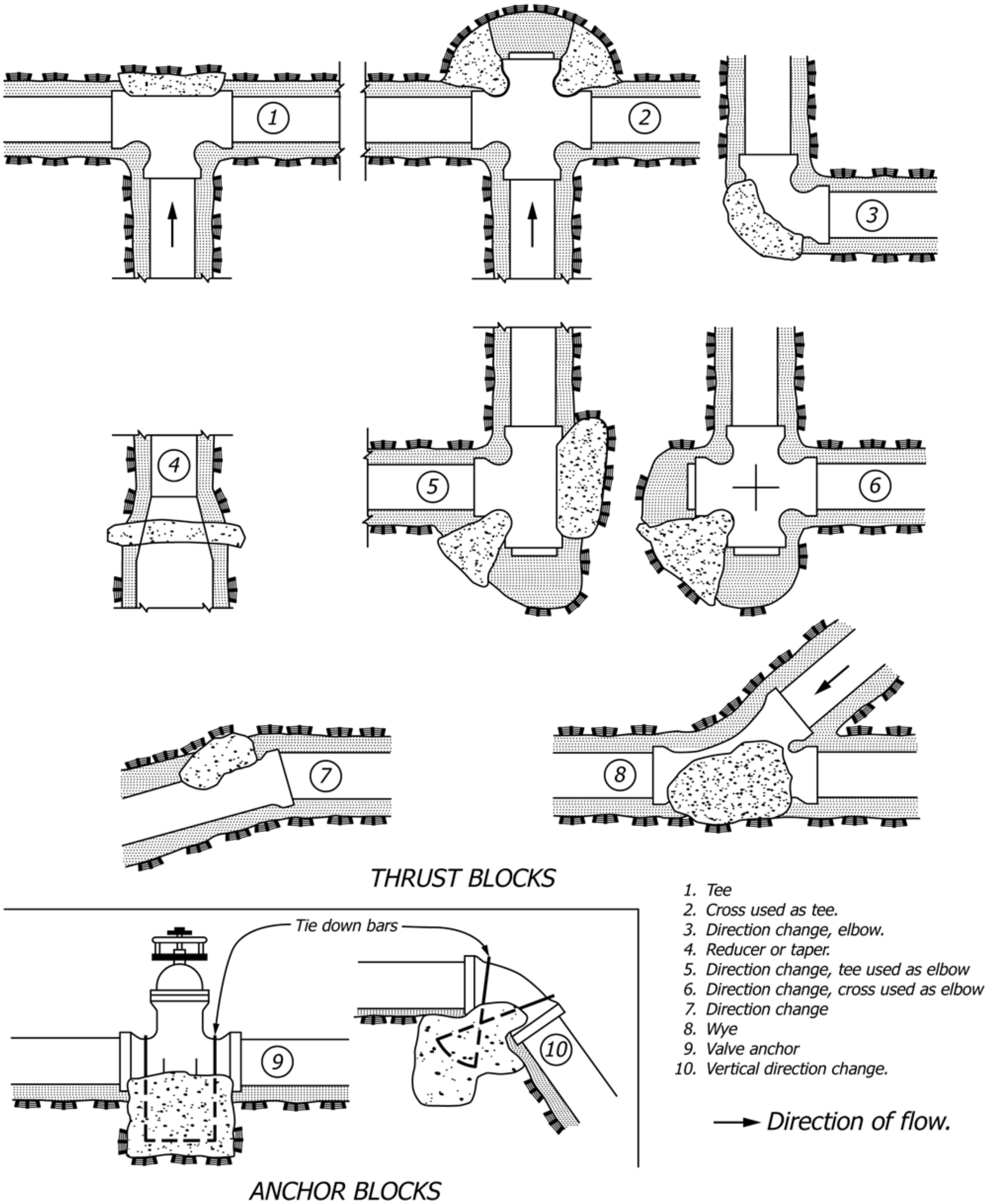


FIG. 4 Thrust and Anchor Block

Anchor blocks are placed at intervals to support the weight of the uphill pipe. The size of the tie bars should be evaluated for point-loading effects.

19.2 *Non-Pressure Pipe*—Joint restraints may be necessary for some gravity flow systems where there are direction changes in pipelines with high flow velocities. For these cases, the principles of 19.1 can apply to non-pressure pipe.

19.3 *Thrust and Anchor Block Construction:*

19.3.1 The thrust or anchor block should be constructed in accordance with the contract documents. In the absence of any instructions, the concrete should have a compressive strength of 20 MPa (3000 psi) or more, and a slump between 8 and 13 cm (3 and 5 in.). Mix and transport ready-mixed concrete in accordance with Specification C94/C94M.

19.3.2 The thrust block acts to distribute forces between pipe or fittings and the trench wall. The size of the thrust block should be adequate to prevent pipe movement.

19.3.3 Excavate the thrust or anchor block cavity in undisturbed soil and framed with compacted soil or wood to hold freshly poured concrete. Any thrust bearing surfaces of earth should be undisturbed.

20. Inspection

20.1 *Cleaning*—Before visual or deflection inspection, or both, some pipelines may need to be cleaned by a cleaning ball, high-velocity jet of water, or other appropriate method.

20.2 *Visual Inspection*—The pipeline should be visually monitored during construction to check alignment, presence of debris and obstructions, excessive deflection or deformation, and connections. The inspection may be made by personal observation, photography, video, or visual lamping. Pay special attention to pipe under high fills, through casings that were grouted, or in areas of difficult construction.

20.3 *Deflection Testing—Non-Pressure Pipe*—The deflection of the vertical diameter of the pipe may be monitored throughout the installation sequence for conformance to the requirements of the contract documents. Field measurements of pipe deflection serve as a check of installation quality. Optional devices for deflection testing include electronic deflectometers, calibrated video cameras, or a properly sized "go, no-go" mandrel. Deflection measurements may be made directly with extension rulers or tape measures in lines that permit safe entry.

20.4 *Deflection Testing—Pressure Pipe*—Usually only larger diameter pressure pipe with deflection as a design consideration are monitored for deflection. The principles of 20.3 may also apply when checking pressure pipe installations for deflections.

20.4.1 Pipe with deflections that exceed the allowable value should be evaluated to see if remedial action needs to be taken, such as: (*1*) remove and reinstall pipe; (*2*) uncover pipe and recompact embedment; or (*3*) replace the pipe. The pipe should not be jacked or otherwise forced into a round shape while buried.

NOTE 8—There are methods to re-round pipe, while the pipe remains underground. The owner, specifying agency, and pipe manufacturer should all be consulted before any re-rounding procedure is used.

21. Leak Testing

21.1 The integrity of a pipeline should be demonstrated by a leak test which is conducted after installation and prior to placement into service.

21.2 *Air Method—Non-Pressure Pipe*—Test gravity sewer lines for leaks using low-pressure air in accordance with Test Method F1417.

21.3 *Water Method—Pressure Pipe*—For pressure testing using water (also referred to as hydrotesting), follow the directions in the contract documents or in the manufacturer's literature. For polyethylene pipe test per Practice F2164. For other pipe types, the section on hydrostatic testing in AWWA may be used as a reference and includes an equation for determining allowable leakage. General testing procedural and safety precautions are as follows:

21.3.1 Allow sufficient time for solvent-cemented or adhesive bonded joints to cure or heat-fused joints to cool.

21.3.2 Allow sufficient time for any concrete thrust blocks to cure.

21.3.3 To avoid the difficulties of locating leaks in pressure pipelines, the joints may be left exposed or the testing performed in short segments, or both. Some backfill is required to anchor the pipe against movement when pressurized.

21.3.4 A visual inspection and deflection check should be performed prior to pressure test to identify any potential problems.

21.3.5 With air valves open at the high points, slowly fill the pipeline with water, limiting the flow velocity to prevent surges and air entrapment. The allowable filling rate is shown as follows:

Air Valve Size, mm (in.)	Maximum Filling Rate, m^3/s (ft^3/s)
25 (1)	0.015 (0.54)
50 (2)	0.06 (2.2)
100 (4)	0.24 (8.7)
150 (6)	0.55 (19.6)
200 (8)	0.98 (34.9)
250 (10)	1.54 (54.5)

21.3.6 Ensure that all entrapped air is released from the line while filling.

21.3.7 The pipeline may be filled but not pressurized before the responsible parties are ready to conduct the test(s).

21.3.8 If the line does not hold a constant pressure, check to see if a temperature change or entrapped air may be the cause. If the pipeline is determined to be leaking and the location is not apparent, try checking the fittings and connections, use leak detection equipment, or test the line in smaller segments to isolate any leaks.

21.3.9 Repair all visible leaks and any leakage in excess of the permitted allowance and recharge and retest the line following the same procedure. (**Warning**—Pressure testing pipe may be hazardous and it is extremely important to follow all safety precautions, such as those outlined in Test Method F1417.)

22. Disinfection

22.1 Pressure pipelines intended for the transport of potable water should be disinfected and flushed in accordance with the instructions of the owner, specifying agency, regulatory agency, or other authority.

23. Keywords

23.1 backfill; compaction control; embedment; fiberglass pipe; field tests; pipe; soil classification; thermoplastic pipe; underground installation

APPENDIXES

(Nonmandatory Information)

X1. PIPE-SOIL INTERACTION

X1.1 Flexible pipe, such as thermoplastic and fiberglass pipe, are designed to transmit the load on the pipe to the soil at the sides of the pipe. Load on a buried pipe is created by the backfill soil placed over the top of the pipe and any surcharge or live load on the backfill surface over the pipe. As the load on the pipe increases, the vertical diameter of the pipe decreases and the horizontal diameter increases. The increase in horizontal diameter is resisted by the strength, or stiffness, of the soil at the sides of the pipe.

X1.1.1 The deflection of a buried pipe may be calculated by one of several different methods, such as the Iowa Formula developed by Professor M. G. Spangler. The Iowa Formula, and the many variations, may be expressed in general terms as:

$$\text{pipe deflection} = \frac{\text{load on the pipe}}{\text{pipe stiffness} + \text{soil stiffness}}$$

X1.1.2 This interaction of pipe and soil provides a pipe-soil structure capable of supporting earth fills and surface live loads of considerable magnitude. The design, specification, and construction of the buried flexible pipe system should recognize that embedment materials shall be selected, placed, and compacted so that pipe and soil act in concert to carry the applied loads without excessive strains from deflections or from localized pipe wall distortions.

X1.2 *Initial Deflection*—Initial deflection is the deflection in the installed and backfilled pipe immediately after backfilling.

X1.3 *Final Deflection*—Final deflection is the total long term deflection of the pipe and consists of initial deflection adjusted for time dependent factors.

X1.4 *Time-Dependent Factors*—Time-dependent factors include consolidation of the embedment material and native trench soils, as well as loading changes due to trench settlement over time. These changes typically add to initial deflections and depend upon rainfall, water table, soil types and their placement method, and initial degree of compaction. Time-dependent factors are traditionally accounted for by adjusting load-induced deflections by a time-lag factor. The time-lag factor is the ratio of final load-induced deflection to initial load-induced deflection.

X1.5 *Deflection Criteria*—The amount of deflection is often set as a limit for the design and acceptance of buried flexible pipe installation. Deflection limits for specific pipe systems may be derived from both structural and practical considerations. Structural considerations include pipe cracking, yielding, strength, strain, and local distortion. Practical considerations include such factors as flow require-ments, clearance for inspection and cleaning, and maintenance of joint seals.

NOTE X1.1—Some specifications for thermoplastic pipe, such as Specifications D3034, F679, F714, F894, and F949, provide recommended limits for installed deflections (for example, deflection at some designated time period after backfilling).

X1.6 *Local Deformation*—Deflections may not be indicative of strain levels arising from local distortions caused by non-uniform embedment stiffness or localized loadings. The amount of deformation depends upon the stiffness of the pipe and specific loading conditions. If local distortions might be significant, methods for controlling and monitoring distortion levels should be established. Local deformations may be caused by uneven bedding, uneven compaction of the embedment, hard and soft spots in the foundation, large rock particles against the pipe, and backfill soil (or equipment) impact against the pipe. Lack of adequate compaction of embedment material in the haunch zone may result in local deformation even if the soil at the springline of the pipe is adequately compacted. The provisions of this guide are specifically recommended to prevent local distortions. If local deformations occur, they should be evaluated to see if potentially harmful strains have been created.

X1.7 *Embedment Density*—Embedment density requirements should be determined during the design process, based on deflection limits established for the pipe, pipe stiffness, and installation quality control, as well as the characteristics of the *in situ* soil. The type of soil and degree of compaction for the embedment for the pipe should be clearly specified in the contract documents.

X1.8 *Embedment Width for Adequate Support*—In certain conditions, the width of embedment material is significantly increased to ensure that adequate embedment stiffness is developed to support the pipe. These conditions arise where *in situ* lateral soil resistance is weak or negligible, such as in very poor native soils (for example, peat, muck, or soft, low density soils). The embedment width should be based on an evaluation of parameters such as pipe stiffness, embedment stiffness, nature of *in situ* soil, and magnitude of earth and live loads.

X2. PIPE SPECIFICATIONS

X2.1 *Acrylonitrile-Butadiene-Styrene (ABS):*[7]

D1527 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80
D2282 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, (SDR-PR)

X2.2 *Polyethylene (PE):*

D2104 Specification for Polyethylene (PE) Plastic Pipe, Schedule 40
D2239 Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D2447 Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter
D2737 Specification for Polyethylene (PE) Plastic Tubing
D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
F405 Specification for Corrugated Polyethylene (PE) Pipe and Fittings[8]
F667 Specification for Large Diameter Corrugated Polyethylene Pipe and Fittings[8]
F714 Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter
F771 Specification for Polyethylene (PE) Thermoplastic High-Pressure Irrigation Pipeline Systems
F810 Specification for Smooth Wall Polyethylene (PE) Pipe for Use in Drainage and Waste Disposal Absorption Fields[8]
F892 Specification for Polyethylene (PE) Corrugated Pipe with a Smooth Interior and Fittings[8]
F894 Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe

X2.3 *Polyvinyl Chloride (PVC):*

D1785 Specification for Polyvinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120
D2241 Specification for Polyvinyl Chloride (PVC) Pressure-Rated Pipe (SDR Series)
D2665 Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings
D2729 Specification for Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
D3034 Specification for Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
F679 Specification for Polyvinyl Chloride (PVC) Large-Diameter Plastic Gravity Sewer Pipe and Fittings
F789 Specification for Type PS-46 Polyvinyl Chloride (PVC) Plastic Gravity Flow Sewer Pipe and Fittings
F794 Specification for Polyvinyl Chloride (PVC) Profile Gravity Sewer Pipe and Fittings Based on Controlled Inside Diameter
F949 Specification for Polyvinyl Chloride (PVC) Corrugated Sewer Pipe With a Smooth Interior and Fittings

X2.4 *Chlorinated Polyvinyl Chloride (CPVC):*

F441 Specification for Chlorinated Polyvinyl Chloride (CPVC) Plastic Pipe, Schedules 40 and 80
F442 Specification for Chlorinated Polyvinyl Chloride (CPVC) Plastic Pipe (SDR-PR)
D2618 Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Pipe and Fittings for Chemical Waste Drainage Systems

X2.5 *Fiberglass:*

D2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D3262 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe
D3517 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe
D3754 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe

X2.6 *Polyolefin:*

F1412 Specification for Polyolefin Pipe and Fittings for Corrosive Waste Drainage Systems

X2.7 *Cross-linked Polyethylene:*
AWWA C904 Cross-Linked Polyethylene (PEX) Pressure Pipe, ½ in. (12 mm) Through 3 in. (76 mm) for Water Service

X2.8 *Polypropylene:*

F2389 Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems

[7] All of the standards listed in Appendix X2 are in the *Annual Book of ASTM Standards*, Vol 08.04.
[8] Only for uses other than subsurface land drainage.

SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F1668 – 08) that may impact the use of this standard.

(1) 1.1.2 was revised.
(2) Note 3 was added.
(3) Section 2 was revised
(4) Table 1 was revised.
(5) 14.4 was revised.
(6) X2.7 and X2.8 were added.