Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High-Density Polyethylene Pipe for Water Applications

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User-friendly guidelines for the placement of high-density polyethylene (HDPE) pipe with mini-horizontal directional drilling (HDD) equipment have been developed by the Municipal Advisory Board (MAB) of the Plastics Pipe Institute (PPI). Previously available as Technical Report TR-46 and published in 2009, "MAB Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of HDPE (PE4710) Pipe in Municipal Applications" emphasizes the applications for potable water and sewer projects and provides detailed information for both iron pipe size (IPS) and ductile iron pipe size (DIPS) constructed of the latest PE4710 material.

The MAB-7 provides information analogous to that provided in the American Society for Testing and Materials (ASTM) F1962, "Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings," but at a level appropriate for the less-complex mini-HDD technology and typical project characteristics.

The MAB-7 includes the following 10 main sections, as well as six supporting appendices:

- Scope
- Referenced Standards and Specifications
- Terminology
- Preliminary Site Investigation
- Safety and Environmental Considerations
- Regulations and Damage Prevention
- Pipe Design and Selection Considerations
- Bore Path Planning and Drill Rig Setup
- Implementation
- Completion

The document is readily available to the public via the website of PPI at http://plasticpipe.org/pdf/mab-7-mini-hdd-guide.pdf.

Background

Figures 1 and 2 illustrate typical mini-HDD equipment, and pilot boring and back-reaming operations, including placement (pullback) of the product pipe, such as for water distribution applications.

Mini-HDD is typically employed for boring segments less than 600 ft in length, at depths up to 15 ft, and placing pipes up to 12 in. in diameter. In contrast, maxi-HDD technology is capable of accurately boring holes thousands of ft in length, and placing pipes of 48 in. or greater at depths up to 200 ft. Maxi-HDD machines may weigh as much as 30 tons (or greater) and are appropriate for placing pipes under large rivers or other major obstacles.

The ASTM F1962 provides recommended procedures for the placement of HDPE pipe using maxi-HDD. The ASTM document provides overall guidelines, addressing preliminary site investigation, safety and environmental considerations, regulations and damage prevention, bore path layout and design, implementation, and inspection and site cleanup. One of the significant contributions of ASTM F1962 is the provision of a rational, analytical method for selecting the polyethylene pipe strength based on the estimated installation and postinstallation (operational) loads on the polyethylene pipe. The ASTM F1962 therefore provides a means of determining project feasibility, as well as initial design information.

While the ASTM F1962 guidelines are convenient and practical to apply by experienced engineers for a maxi-HDD operation, the corresponding equations and procedures represent relatively complicated formulas (and an extensive tedious methodology) when considering smaller, lower-cost operations associated with typical mini-HDD applications, including placing a new water or sewer distribution line.

Some mini-HDD installations may be considered to be relatively critical or approach

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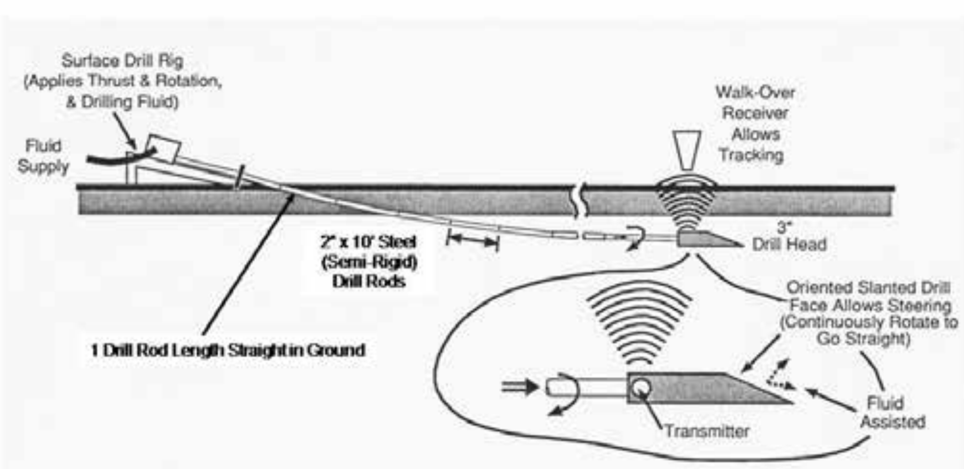

Figure 1. Typical Mini-Horizontal Directional Drilling Equipment and Pilot Boring Process

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limits with respect to the capability of the available drill rig and/or the strength of the product pipe being installed, and for which a relatively convenient, although possibly less precise, design procedure would be desirable.

Any construction procedure must address basic safety rules, avoid damage to existing facilities, adhere to applicable government regulations, and consider environmental issues. The MAB-7 was therefore developed to serve as an inclusive document, providing practices for placement of HDPE (PE4710) pipe for municipal applications using mini-HDD.

In particular, MAB-7 includes easy-to-understand guidelines for proper drill rig positioning, consistent with meeting required placement depths and drill rod capabilities, as well as for estimating the relevant forces and effects present during installation, allowing proper selection of the pipe strength.

Description

The MAB-7 contains 10 main chapters, or sections, as briefly described, supplemented by several appendices.

Scope, Related Industry Standards, and Terminology (Sections 1, 2, and 3)

The MAB-7 addresses planning, design, drill rig setup, and installation practices for the placement of polyethylene pipe using mini-HDD equipment. The primary focus is on commonly used HDPE pipe with a material designation code of PE4710. Depending on the diameter, polyethylene pipe may be supplied in continuous lengths on reel or discrete segments, which would typically be fused together in the field.

Preliminary Site Investigation (Section 4)

The general feasibility of utilizing mini-HDD technology for placing the proposed pipeline(s) must be determined prior to any proposed construction activities. Such a preliminary investigation is required to gain an understanding of the local characteristics in order to help ensure a cost-effective, efficient, and above all, safe operation. Of particular importance, and as addressed in other sections of the guidelines, is the awareness of existing utilities in the vicinity of the proposed pipeline and the need to maintain minimum specified clearances during the construction process.

Safety and Environmental Considerations (Section 5)

Safety is a primary concern during any activity, including construction utilizing mini-HDD equipment and procedures. Potential safety issues fall into two general categories: those directly related to the setup and operation of the mini-HDD equipment; and those associated with the proper location, identification, and marking procedures intended to avoid contacting and damaging existing utilities. Section 5 of MAB-7 addresses the first category, providing practices to avoid or minimize equipment-related risks during mini-HDD operations.

Employees must be trained to prevent injuries to themselves and others during the operation of the equipment and be prepared to mitigate the effects of accidents. Electric power and gas-line strikes are specifically addressed. Although not considered to be hazardous materials, the proper handling and disposal of drilling fluid is also discussed to avoid possible environmental issues.

Regulations and Damage Prevention (Section 6)

Section 6 of MAB-7 addresses the second category of potential safety issues, focusing on procedures to eliminate or reduce hazards associated with damaging existing utilities, including during the initial boring or back-reaming operations.

Recommended practices include:

- "Call before you dig" (811).
- Properly locating and marking existing utilities, as well as exposing such utilities at anticipated crossings with the bore path.
- Avoiding mechanized digging within the required tolerance zone.
- Use of subsurface utility engineering, as described in the Construction Institute/American Society of Civil Engineers (CI/ASCE) 38, "Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data."

Pipe Design and Selection Considerations (Section 7) and Bore Path Planning and Drill Rig Setup (Section 8)

Sections 7 and 8 contain particularly useful information, provided in a convenient format, as discussed in greater detail.

Implementation (Section 9)

It's beyond the scope of the MAB-7 guidelines to provide detailed operational procedures for the various mini-HDD and auxiliary equipment, which are generally available from the manufacturers or other sources. Proper procedures, however, are described for pilot boring, tracking, steering, reaming, and pullback operations, as well as pipe handling/connection and recordkeeping.

Completion (Section 10)

Following installation of the pipe, it's necessary to confirm the viability of the new facility, provide a permanent record of the actual placement location, and ensure final site cleanup. The integrity of the pipes should be appropriately verified, depending on the application and the owner's specifications. Any mud or debris that may have entered the pipe must be expelled and the pipeline flushed, and the system then pressurized and checked for leakage.

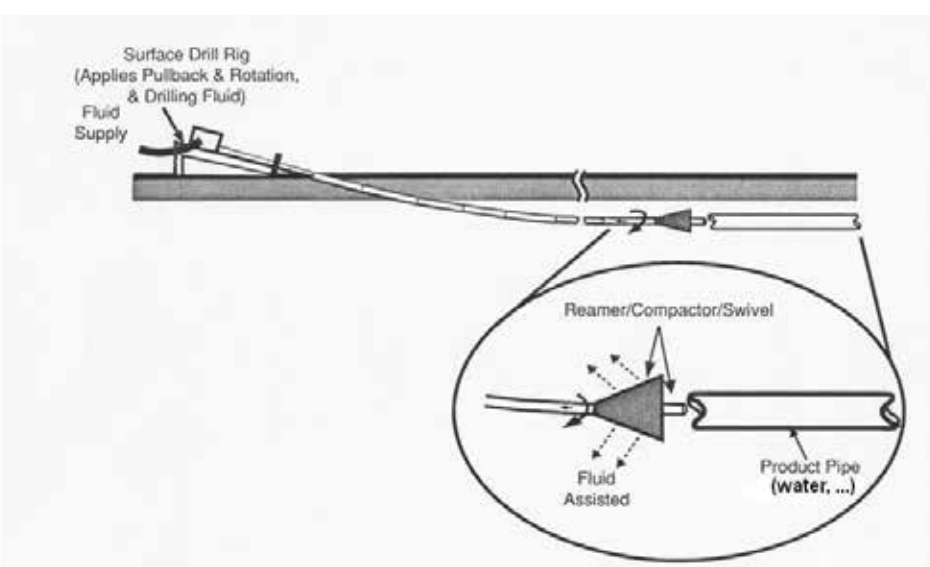

Figure 2. Typical Mini-Horizontal Directional Drilling Back-Reaming and Pipe Pullback Process

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Table 1. Safe Pull Tension (lb), High-Density Polyethylene (PE4710) Pipe, 1-Hour Iron Pipe Size

Nominal Size	Pipe Diameter-to-Thickness Ratio (DR)				
	7	9	11	13.5	17
2-in.	3,038	2,450	---	---	---
3-in.	6,597	5,321	---	---	---
4-in.	10,906	8,796	7,361	6,109	4,931
6-in.	23,638	19,066	15,954	13,240	10,687
8-in.	40,064	32,315	27,040	22,441	18,114
10-in.	62,237	50,200	42,006	34,861	28,140
12-in.	87,549	70,616	59,090	49,039	39,584

Table 2. Safe Pull Tension (lb), High-Density Polyethylene (PE4710) Pipe, 1-Hour Ductile Iron Pipe Size

Nominal Size	Pipe Diameter-to-Thickness Ratio (DR)				
	7	9	11	13.5	17
3-in.	8,445	6,812	---	---	---
4-in.	12,408	10,008	8,375	6,950	5,610
6-in.	25,641	20,681	17,306	14,362	11,593
8-in.	44,109	35,578	29,771	24,707	19,943
10-in.	66,356	53,522	44,786	37,168	30,002
12-in.	93,838	75,689	63,335	52,562	42,428

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Appendices (A - F)

The 10 main sections outlined are intended to provide user-friendly guidelines for the installation of HDPE (PE4710) pipe in municipal applications using mini-HDD. These sections are supported by six appendices that provide examples of the application of the information described in Sections 7 and 8, as well as the theoretical basis for their development.

Pipe Design and Selection Considerations (Section 7)

The MAB-7 contains a convenient calculation method for the selection of the HDPE (PE4710) pipe strength. The procedure is presented in an easy-to-understand format, appropriate for users with various backgrounds. The procedure provides a means of selecting the pipe strength to avoid collapse due to hydrostatic pressure at the desired placement depth, as well as to withstand the required pulling loads during installation.

Minimum Wall Thickness Based on Depth

The pipe strength is directly related to the wall thickness, as specified by its dimension ratio (DR), which is defined as the pipe outer diameter by the wall thickness. The MAB-7 guidelines indicate that essentially all the commonly used wall thicknesses for PE4710 pipe, with the possible exception of DR 17 pipe, would be sufficiently strong for depths to approximately 15 ft, the typical limit for mini-HDD installations.

A DR 17 pipe should generally be limited to less than a 10-ft depth, although 15 ft may also be acceptable in some cases.

For depths greater than 15 ft, thin-walled pipe, or special situations, the adequacy of the product for the application should be verified using the supplementary information provided in the document. In some cases, such as thin-walled pipe and/or relatively large depths, special practices or precautions not typically employed during mini-HDD installations may be required. For example, filling the pipe with water during pullback simultaneously reduces the net external hydrostatic pressure during (and following) installation and the buoyant weight of the pipe, resulting in reduced pull loads.

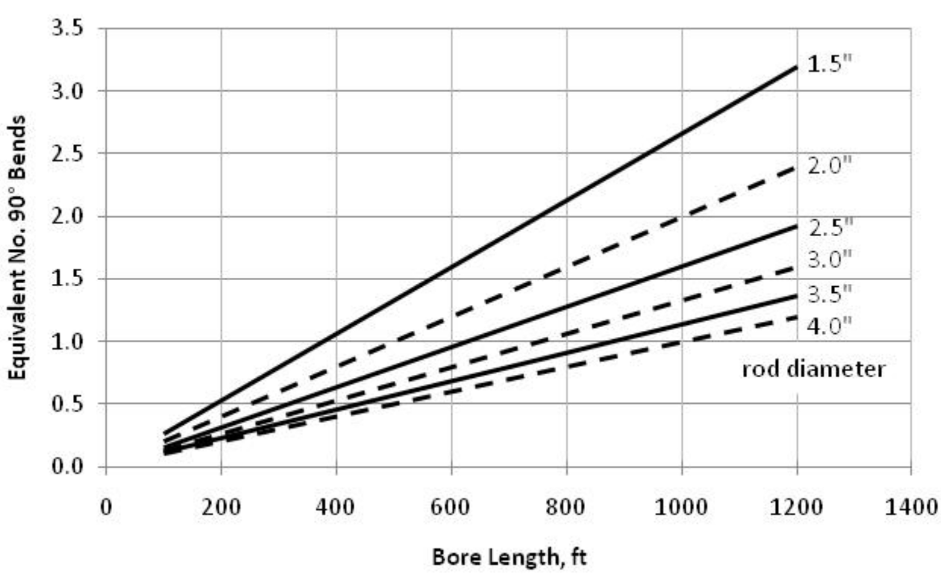

Figure 3. Unplanned Curvature (n_2)

Minimum Wall Thickness Based on Pulling Load

Table 1 provides the "safe pull tension" for HDPE (PE4710) pipe as a function of pipe (nominal) diameter and wall thickness (DR value) for IPS pipe sizes, while Table 2 provides the strengths for DIPS pipe sizes. These values are intended to account for the cumulative load duration on the pipe, and avoid nonrecoverable viscoelastic deformation. The indicated strengths are based on the minimal required wall thickness, as opposed to that of the actual manufactured product, and therefore underestimate the average safe pull tension by approximately 6 percent.

The following simplified equation has been developed for the purpose of estimating the pull load during mini-HDD installations of polyethylene pipe:

Tension (lb) = [Bore Length (ft) x Buoyant Weight (lb/ft) x (1/3)] x $(1.6)^n$

The buoyant weight may be conveniently determined as follows:

Buoyant Weight (lb/ft) = ½ [Pipe Outer Diameter (in.)]^2 – Pipe Weight (lb/ft)

The term "n" is equal to the number (including fractions) of effective 90-degree bends due to cumulative route curvature where $n = n_1 + n_2$. The quantity n_1 is the number of planned (deliberate) 90-degree route bends, and n_2 is the number of effective route bends resulting from typical path corrections and route curvature during the pilot boring operation for which the following guideline is suggested:

n_2 = [Bore Length (ft)/500 ft] x [2-in./ Rod Diameter (in.)]

The quantity n_2 is shown in Figure 3 for various rod diameters.

For a specified pipe diameter, the procedure for selecting an appropriate pipe strength (DR value) consists of comparing the estimated pull load to the strengths in Table 1 or 2. This procedure is similar to, but much less complicated than, that incorporated in ASTM F1962 for the more-sophisticated maxi-HDD installations. The present mini-HDD calculations will generally result in considerably shorter placement distances than those corresponding to the design methodology provided in ASTM F1962, which may result in possible pullback distances of several thousands of ft.

Mini-HDD installations suffer relative to those performed using typical maxi-HDD technology due to the lesser degree of control (e.g., greater cumulative route curvature) and the desire to forego the use of antibuoyancy techniques, such as inserting water into the pipe during pullback to reduce buoyant weight and significantly reduce required pull loads.

In general, the preceding formulas and methodology are recommended for estimating pull loads for mini-HDD installations. Other methods for determining pulling loads are typically based on well-controlled maxi-HDD installations and are not representative of actual mini-HDD applications with respect to anticipated pull loads.

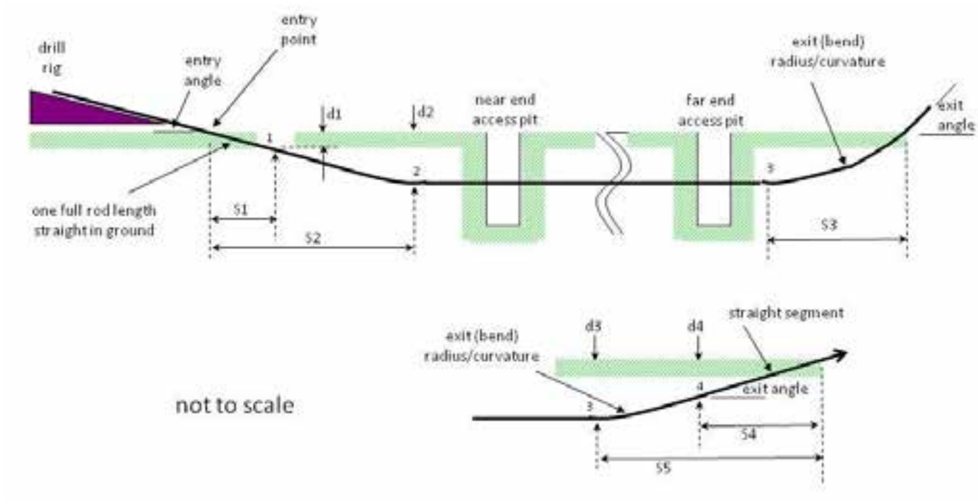

Figure 4. Drill Rig Setup and Related Distances

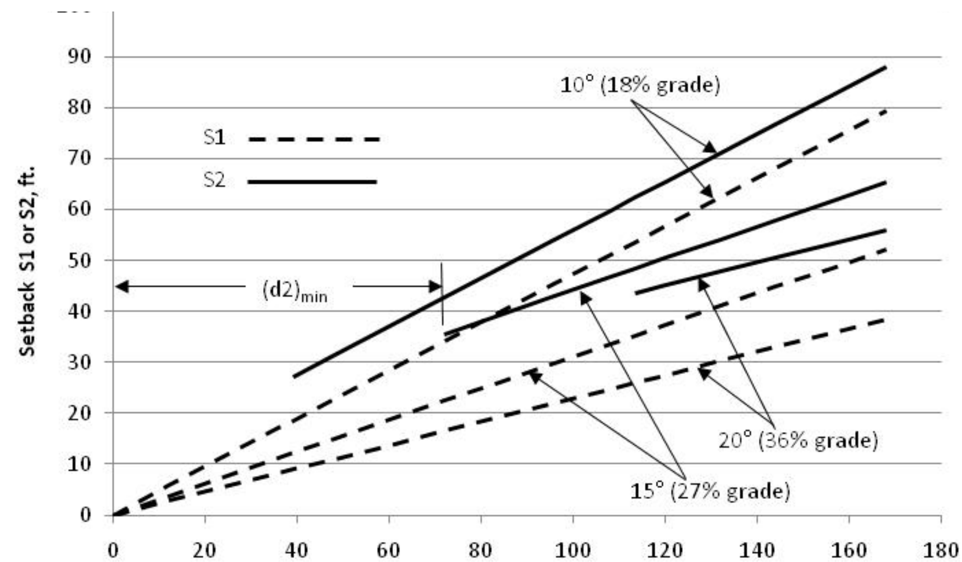

Figure 5. Drill Rig Minimum Setback Distance
Drill Rods: 10 Ft Long, 100-Ft Radius of Curvature

Bore Path Planning and Drill Rig Setup (Section 8)

In comparison to maxi-HDD installations, for which the design of the bore path is typically performed by experienced engineers or organizations, the mini-HDD contractor is generally responsible for cost-effectively accomplishing this task. Thus, MAB-7 provides user-friendly drill rig setup and bore path planning information that is consistent with meeting the requirements of the project owner, including geographic constraints and placement depth. The ability to satisfy the overall requirements depends on the bending characteristics of the steel drill rods and the drill rig setup parameters.

Figure 4 illustrates a typical mini-HDD bore vertical profile trajectory, including occasional pits along the route. These pits may be required for pipe splicing, completing lateral connections, or to expose existing utilities. The pits may also be useful for collecting drilling fluid from the boring or reaming operations. The bending capability and length of the drill rods, and their entry angle to ground surface, will determine the minimum depth achievable at the beginning of the bore path.

In order to achieve a specified depth at a particular point toward the beginning of a pilot bore operation, the front of the drill rig must be located at an appropriate distance rearward from the point of interest. Knowledge of such minimum setback requirements is important with respect to verifying that there is sufficient space available to properly perform the mini-HDD operation. For example, point 1 (Figure 4) is located directly along the entry path of the drill rod, where the resulting bore path is inclined at the entry angle and for which the setback distance corresponding to reaching the depth (d1) is designated as S1. The S1

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represents the minimal setback distance for achieving a specified depth, independent of the orientation of the bore path, which is not level at that point.

Beyond point 1, the drill rods are steered, such that the bore path trajectory becomes level at point 2, corresponding to a depth (d2) and S2. For the same depth of interest, S2 is significantly greater than S1. The greater distance is required to allow the drill rods to establish an upward curvature consistent with achieving a horizontal orientation.

The S2 depends on both the entry angle and rod characteristics. Due to the limited bending capability of the rods, as well as the recommendation that the first drill rod be placed in the ground without any curvature or steering (see Figure 1), there is a minimum depth, designated as $(d2)_{min}$, at which the trajectory is able to become level.

The S1 and S2 are a function of the depth (d1 or d2), respectively (Figure 5), for a representative 10-ft-long drill rod, with a minimum bend radius of curvature of 100 ft. $(d2)_{min}$ identified by the minimum depth plotted for the S2 curves. As an example, for an entry angle of 15 degrees, a depth (d1) of 72 in. will be achieved at a setback distance S1 of approximately 22 ft. In comparison, an S2 of at least 35 ft is required to reach the same depth (d2) at a level trajectory.

Figure 5 also indicates that this entry angle and drill rod combination is not consistent with achieving a level trajectory at depths shallower than approximately 72 in. If it's necessary to become level at a shallower depth, a lower-entry angle and/or drill rod with a smaller allowable bend radius would be required.

Information regarding other significant dimensions, including the required horizontal distance to rise to the surface and for drill rods for different characteristics, is also provided in a similar format.

Summary

The MAB-7, "MAB Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of HDPE (PE4710) Pipe in Municipal Applications," has recently been published by the MAB of PPI, representing a comprehensive set of information supporting the placement of HDPE (PE4710) pipe by mini-HDD equipment for potable water and sewer applications. The new document, previously available as Technical Report TR-46, is intended to provide information analogous to that provided in ASTM F1962 for maxi-HDD projects, but at a level appropriate for the less complex mini-HDD technology and typical project characteristics.

Although the MAB-7 guidelines are primarily described with respect to mini-HDD operations, guidelines for the use of midi-HDD machines and associated practices may be obtained from the present MAB-7 document, and/or ASTM F1962, depending on the particular application and the judgment of the contractor or engineer.

References

- ASTM F1962, "Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings." American Society for Testing and Materials.
- CI/ASCE 38, "Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data." American Society of Civil Engineers.