IEEE Guide for Installation of Cable Using the Guided Boring Method

Sponsor

Insulated Conductors Committee
of the
IEEE Power Engineering Society

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IEEE Standards Board

Abstract: The method and equipment involved in proper and economical installation of insulated conductors and/or conduits using the guided boring method are covered. The method addresses installations of insulated cable, cable preinstalled in conduit (CIC), and conduit alone.
Keywords: boring, cable, cable preinstalled in conduit (CIC), conduit, guided boring, insulated cable

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Introduction

(This introduction is not a part of IEEE Std 1333-1994, IEEE Guide for Installation of Cable Using the Guided Boring Method.)

This guide was prepared by Working Group 11-28 of the Structures Subcommittee (No. 11) of the Insulated Conductors Committee of the IEEE Power Engineering Society. Members of this working group represent a cross-section of the affected parties including cable users, consulting engineers, and manufacturers. The purpose is to provide users of underground cable with guidelines and considerations pertaining to the installation of cable using the guided boring method.

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IEEE Guide for Installation of Cable Using the Guided Boring Method

1. Overview

This guide considers the method and equipment involved in proper and economical installation of insulated conductors and/or conduits using the guided boring method. This method may be used to install insulated cable, cable preinstalled in conduit (CIC), or conduit alone.

2. References

This guide shall be used in conjunction with the following references.

AEIC CS 5-94, Specifications for Cross-Linked Polyethylene Insulated Shielded Power Cables Rated 5 Through 46 kV, 10th ed.[1]

AEIC CS 6-87, Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 kV, 5th ed.

AEIC G5-90, Underground Extruded Power Cable Pulling Guide, 1st ed.

NEMA WC 7-1991 (ICEA S-66-524), Cross Linked Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.[2]

NEMA WC 8-1991 (ICEA S-68-516), Ethylene-Propylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

U.S. Code of Federal Regulations, Title 29 (29CFR), Occupational Safety and Health Administration (OSHA), Part 1910.269, Subpart R (Special industries—Electric power generation, transmission, and distribution), January 31, 1994.[3]

U.S. Code of Federal Regulations, Title 29 (29CFR), Occupational Safety and Health Administration (OSHA), Part 1926, Subparts P (trenches/excavations) and S (enclosed areas), July 1, 1994.

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[1]AEIC publications are available from the Association of Edison Illuminating Companies, 600 N. 18th Street, P. O. Box 2641, Birmingham, AL 35291-0992, USA.

[2]NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037, USA.

[3]OSHA publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, USA.

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3. General description

The horizontal guided boring method is usually used in existing built-up residential/commercial areas where conventional trenching methods would be too costly or disruptive. This method involves surface launching and boring a horizontal tunnel in the ground using a string of hollow metal rods [typically 10 ft (3 m) lengths]. Fluid (drilling mud), which should be compatible with the cable/conduit, is pumped through the rods to the boring head to assist in soil cutting, and for directing, cooling, and lubricating the drill head. After the guided boring head enters the exit pit, the drill string pulls it back along with a cable, CIC, or conduit through the tunnel to the entrance location. If enlargement of the tunnel is required, a reamer is attached to the boring end before pullback.

Guided boring is suitable for use in a wide variety of soils. Clay or loam soils are best suited for drilling. Sandy soils can be drilled, but usually require additional amounts of bentonite in the drilling mud. The mud is used to stabilize the tunnel and prevent its collapse. Harder soils such as hardpan, caliche, soft shale, and limestone can usually be drilled, but at a slower rate, and usually incur higher boring tool wear. Gravelly soils (greater than 25% rock) are not well suited for guided boring.

Depending on equipment capability and soil condition, these systems can drill holes (tunnels) 12–16 in (30.5–40.6 cm) in diameter, 2–40 ft (0.6–12 m) deep, and 400–600 ft (122–183 m) long. The accuracy of tracking the drill head location depth varies from approximately ±1 in (2.5 cm) at shallow depths to ±6–12 in (15.3–30.5 cm) at maximum depth.

Guided horizontal boring can also be accomplished with equipment and techniques that use little or no fluid. These methods are known as “dry” boring. They are generally used for small diameter installations and have the advantages of greater simplicity of equipment and setup. Cleanup of job site and equipment is easier since no fluid is involved. Dry boring directional systems require launch pits [e.g., 4 ft × 10 ft (1.2 m × 3 m)] and greater thrust, and are less effective in uncompactable soils such as caliche and dry clays. Depending on equipment capability and soil condition, dry boring systems can drill holes to 6 in (15.3 cm) in diameter and up to 150 ft (45.7 m) long. A dry boring system is typically less responsive to steering commands than fluid jet cutting.

The guided boring method can be used to install:

a) Cable
b) CIC
c) Plastic conduit
d) Metal conduit

3.1 Cable

On installations that have excessive bends, or that may contain hard or sharp surfaces (e.g., large rocks), damage may occur to the cable during the pull. For this reason, it is desirable to use jacketed cable. During the pulling process a “weak” link, which will break at a known tension, can optionally be inserted between the drill string and the cable. This will minimize cable damage due to excessive pulling tension. The location of the cable end during the pull is normally determined by counting the number of 10 ft (3 m) rods removed, (or observing a cable surface footage marker) so that if trouble occurs, an excavation can be made at the correct location.

3.2 Cable preinstalled in conduit (CIC)

The conduit used in CIC is continuously extruded polyethylene [typically high-density polyethylene (HDPE)]. The conduit is attached to a swivel with a pulling eye, which is connected to the reamer at the end

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of the drill string and pulled back. The conduit provides physical protection to the cable. It is necessary to ensure that the tensile strength of the conduit is sufficient to withstand the anticipated maximum pulling tension. During the pull, the cable may slip back in the conduit at the pull-out end. The installer should verify that sufficient cable has been pulled before completing the pull.

3.3 Plastic conduit

3.3.1 Continuously extruded conduit

Attachment and tension requirements for continuously extruded conduit (e.g., PE) are the same as for CIC (see 3.2).

3.3.2 Conduit requiring couplings

Where the use of couplings or joints results in locations weaker than the conduit, it is recommended that the conduit run be assembled aboveground and a steel cable or small diameter rod be inserted through the conduit length. By attachments on each end of the conduit run, the steel cable or rod is tensioned, resulting in the couplings being under compression. The assembly can then be installed in a normal manner.

A conduit system, which incorporates a jointing method with joints equal to or stronger than the conduit, would be treated the same as a continuously extruded conduit installation.

After the conduit is installed, and is known to be intact and not deformed, the electric cable can be pulled (or pushed) through in the conventional manner.

3.4 Metal conduit

Runs of metal conduit may also be installed using the guided boring method. Pipe can be welded or assembled with sleeve couplings (as long as the sleeve is only slightly greater in diameter than the pipe diameter).

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4. Equipment description

A typical boring installation is depicted in figure 1. A general description of the equipment used for installing cable/conduit using the guided boring method is given in 4.1 through 4.4.

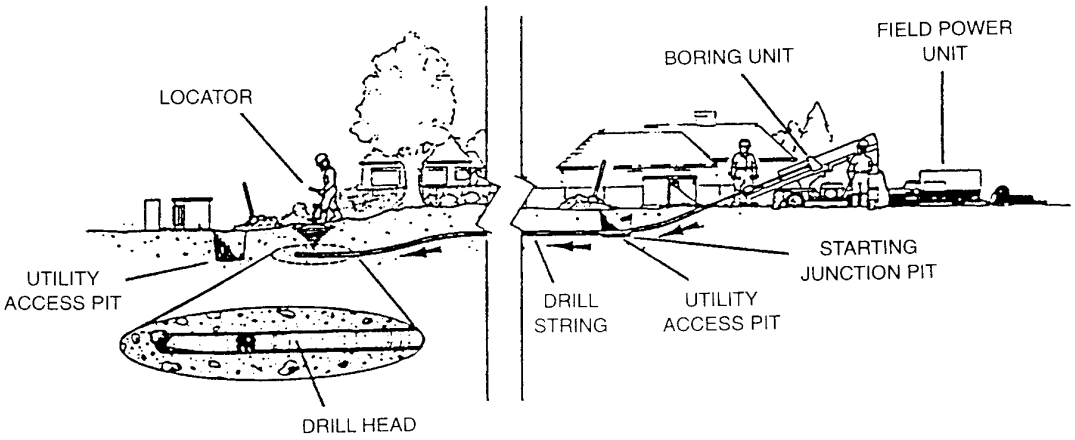


Figure 1—Typical boring installation

4.1 Boring unit (drill frame)

This piece of equipment contains the hydraulically or chain-driven carriage that rotates and provides thrust to the metal drill string. The drill frame also contains the control mechanism for advancing, retracting, rotating, and varying the flow of fluid to the rods. It may also contain the control to maneuver the carriage into the operating position and steering controls if it is motorized.

4.2 Field power unit (supply unit)

This unit usually contains a power unit and associated controls for the hydraulic systems. It also contains a tank for mixing and storing the drilling fluid and a means to pressurize the cutting/lubricating fluid. The drill unit may be transported on the supply unit, resulting in one unit that can be pulled by an appropriate vehicle (e.g., a pickup truck) or integrated onto the back of a truck. An umbilical system usually connects the supply unit to the drill frame.

4.3 Drill (boring) head and locator

Various head designs are used for boring and direction control (i.e., fluid jet, shaped head, etc.). The boring head may contain a transmitter that, in conjunction with a surface locator, determines the location and depth of the boring head, or it may contain a navigation system that transmits information to the operator. Different boring head designs may be used to accommodate various soil types. The head design should be capable of keeping the drill run within ±6 in (15.3 cm) of the desired drill path on both straight and curved runs.

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4.4 Required safety equipment

All personnel protective equipment and devices, as may be required by the various government or regulatory agencies, shall be worn/used in the manner for which they were intended, whenever the possibility of personal injury exists and where otherwise required due to environmental hazards.

During the boring operation, all equipment shall be effectively grounded and incorporate a system that protects operating personnel from electrical hazards (see 6.1.6). The safety system should consist, at a minimum, of the following components:

a) Proper grounding
b) Personnel protection
c) Audible strike alarm
d) Safety training

4.4.1 Proper grounding

Proper grounding shall include an earth ground (e.g., driven rods, effective neutral system), the resistance of which has been measured by a utility approved method. All equipment shall be connected to ground with a stranded copper conductor. All grounding equipment shall be sized to carry the largest fault current for a time period long enough to allow the line protection system to operate. After grounding equipment has carried fault current, all components of the grounding system should be immediately replaced, and later inspected and reconditioned, if necessary, before reuse. Additionally, all boring unit operators shall stand on wire mesh mats that are also connected to the ground to eliminate step and touch potential.

4.4.2 Personnel protection

Personnel protection shall be worn at all times by each crew member during the drilling and reaming operations. The boring machine operator and rod change person shall wear insulated boots and insulated gloves with leather protectors. The drill head locator operator shall wear insulated boots. If the locator equipment is electrically conductive, its operator shall also wear insulated gloves. All insulated boots and gloves shall be capable of withstanding the maximum voltage that could be impressed on them.

When digging pits, insulated (e.g., fiberglass) shovel handles shall be used and insulated boots shall be worn to protect against electric shock.

4.4.3 Audible strike alarm

At a minimum, the system shall be equipped with an audible alarm that can sense if contact is made with an energized electric cable. Proper operation of the system shall be confirmed prior to drilling each tunnel.

4.4.4 Safety training

All crew members shall have drilling safety training and training on the hazards of electric shock. Each crew shall ensure that all safety equipment is functional and proper procedures are being followed. All boring unit operators shall have had CPR and first aid training (refer to 29CFR, OSHA, Part 1910.269, Subpart R, dated January 31, 1994).

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4.5 Supplemental equipment

The following additional equipment may be useful—depending on local job requirements:

a) Backhoe
b) Air compressor
c) Jack hammer/pneumatic digging iron
d) Air excavator (air knife)
e) Dump/tank truck
f) Soil compactor

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5. Preliminary inspection

In order to attain the best safety and cost considerations, it is essential that a comprehensive preliminary job site inspection be made. The preliminary inspection requirements are:

a) Observation of field maps and circuit diagrams
b) Field survey
c) Surface marking of substructures
d) Material and equipment preparation
e) Job conditions

5.1 Observation of field maps and circuit diagrams

These observations will assist in identifying the location of substructures in the proposed boring route. The location of all energized electric cables or gas lines is of particular importance. Other sensitive substructures such as communication cables, sewer, or water lines should also be carefully marked.

5.2 Field survey

A careful analysis by survey personnel of the ground conditions in the route of the proposed bore is required. It is desirable to have some of the survey personnel consist of members of the crew that will perform the boring operation. In some cases it may be appropriate to take photographs or videotape of the job site to provide documentation of pre-existing conditions.

5.2.1 Review of job plan

The following information should be collected prior to the start of each run:

a) Cable or conduit size and type
b) Number of cables/conduits
c) Termination points (front- or rear-lot setup)
d) Length of run
e) Property and easement boundaries
f) Location of obstructions (such as storm drains)
g) Minimum burial depth and clearance from subsurface obstructions

5.2.2 Drill run

The most important aspect in any drill run is planning. Planning will ensure that the cable/conduit is installed properly (i.e., no overstressing or damage to the cable surface) in a safe, efficient, and professional manner.

When preparing for the drill run, equal consideration should be given to cable installation as is given to the layout of the drill run.

5.2.3 Cable handling

Every effort should be made to protect the cable against damage. The less the cable is handled, particularly off the reel, the less the likelihood of damage. When it is necessary to take slack cable off the reel, it should only be placed on grassy or smooth soil surfaces. If it must be placed on concrete or asphalt surfaces, a

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layer of some protective material—such as corrugated cardboard, polyethylene sheeting, or a similar material—should be placed under the cable. The cable should not be placed where it will be subject to damage from pedestrian or vehicular traffic.

5.2.4 Survey layout considerations

It is suggested that the final construction prints or a separate attached sheet contain a list of “remarks” concerning on-site conditions found by the survey crew. This will be beneficial to the field supervisor in planning for the job. Such remarks may include but are not limited to:

a) Best route for bore (this would include marking entry and exit pit locations)
b) Any impediments to proper location of equipment (e.g., trees, guard rails, fences, landscaping, etc.)
c) Location of valve boxes, manhole openings, splice boxes, etc., which can assist in the location and depth of substructures
d) Unusual traffic or pedestrian problems
e) Homeowner or business owner considerations
f) Soil conditions conducive to guided boring methods

5.3 Surface marking of substructures

5.3.1 One-call system

All substructures (i.e., water, sewer, gas, electric, and communication) should be surface identified. This can usually be accomplished with a one-call locating service that will contact the appropriate government agencies (city, county, etc.) and utility companies. In areas not serviced by a one-call system, it will be necessary to contact each agency or utility separately. The depths of the substructures are not usually identified and should be determined by the survey crew.

5.3.2 Profile drawings

After all available location and depth data is obtained, profile drawings should be made to plot the best course for boring.

5.4 Material and equipment preparation

Proper planning requires that all materials are available in the field at the job site and prepared for use before the project starts.

5.4.1 Material availability

Requisitions or bills of material for all of the material required for an installation should be carefully checked at the issuing warehouse to determine that they meet the engineering specifications for the job, are in usable condition, and are properly charged out to the job.

It is suggested that this be done as soon as material requirements are determined to allow time to correct discrepancies found or to reschedule the work starting date if sufficient usable material cannot be obtained. It is advisable to recheck the material just prior to the start of work to be certain that unforeseen usage has not depleted the supply.

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The earliest possible determination of material availability will also provide time to coordinate possible changes in the work plans of other personnel involved. Cable containing surface footage marking is desirable.

5.4.2 Material preparation

Cable required for an installation may be transported to the job site in its as-received condition and prepared in the field for pulling. This method depends principally on the size of the job, the availability of a suitable work area at the job site, traffic, and other construction conditions. This method presents the possibility of a job delay due to damaged cable or improper lengths or type of cable.

Preparation of required cable in the warehouse yard is frequently done. The principal advantages are:

a) Removal of the protective covering eliminates the problem of field disposal
b) Cable may be inspected for damage, proper length, and proper type
c) Installation of pulling attachments as required
d) Inspection or remake of end seals to prevent moisture from entering the cable
e) Placement of reels with yard equipment to permit easier loading on transportation equipment

In any method employed, the preparation of cable should be scheduled and completed to avoid delay to the installation crew.

5.4.3 Equipment preparation

Determination and scheduling of special tools and equipment required by the job should be made to ensure their availability for use when required.

5.5 Job conditions

A field inspection of the job situation prior to start of the work should be conducted as a precaution against changing conditions and to be sure that other preparation work has been completed as planned. Such an inspection may include:

a) Making a trip to the job site via the planned route for the construction equipment to ensure that the route presents no obstruction problems and allows for the shortest possible travel time
b) Making necessary contacts with municipal officials to verify that any local requirements will be satisfied
c) Reviewing the equipment setup plans to minimize damage to lawns, plantings, and other private property
d) Determining the type of work area protection required for any unusual traffic volume at certain times of the day
e) Determining if work should be done during certain hours
f) Ensuring that customer installations will be constructed to provide for service restoration in acceptable time intervals
g) Making necessary arrangements with the utility to make automatic reclosures inoperative and to have circuits taken out of service when applicable
h) Maintaining sufficient distance between the bore and substructures in the vicinity of the proposed bore path to comply with requirements of the owners of these substructures

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i) Where depth of critical substructures (e.g., gas mains, fiber optic cables, etc.) near the proposed path of the bore are not known, excavation and exposure of these substructures is required (other appropriate techniques to ensure that proper clearance distances are maintained may be used)

j) Making provisions to mark the route of the bore as it progresses (e.g., chalk or nonmetallic flags)

k) Notifying affected property owners of the proposed work

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6. Precautions

Prior to starting the bore, all personnel should be familiar with and practice good safety procedures. The following operations should be given special emphasis:

a) General safety precautions
b) Guarding and protecting work areas
c) Testing enclosure atmosphere (e.g., manhole)
d) Excavating and shoring pits

6.1 General safety precautions

6.1.1 Personnel briefing

All personnel involved in the boring operation should be familiar with the operation of the equipment and construction apparatus that is to be used. Prior to beginning work, a briefing of all involved personnel shall be held to set the plan of operation, the type of equipment and the grounding devices to be used, the safety procedures and operating procedures to be followed, and any other appropriate matter.

6.1.2 Care of equipment

Good housekeeping should be practiced. Material and tools should be arranged so that they will not interfere with job operation or pedestrian or vehicular traffic.

6.1.3 Communications

Adequate communication shall be established and maintained between the boring machine operator and the crew member using the drill head locator. Radio communications should be used over distances greater than 50 ft (15.2 m), or when out of line-of-sight. If communication is lost, boring shall be halted until communication is reestablished.

6.1.4 Conformance to utility requirements

All safety practices should be understood and in compliance with the requirements of the utility for whom the work is being performed.

6.1.5 Hazards

Hazardous conditions shall be controlled or eliminated.

6.1.6 Safety equipment

All safety devices and equipment shall be in proper operating order and shall be used (e.g., grounding, grounding mat, insulated protective apparel, etc.). See 4.4.

6.2 Guarding and protecting work area

Since most utilities and/or municipalities have traffic safety rules for guarding and protecting work areas on streets and sidewalks, this guide will recommend minimum requirements for proper safety practices. A general listing of required safety practices is given in 6.2.1 through 6.4.

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6.2.1 Placement of vehicles

Equipment (e.g., trucks, etc.) should be placed in a protective position for civilian and working personnel near or around the work area, if required. Vehicular traffic flow should be maintained.

6.2.2 Traffic control

Sufficient warning lights and traffic cones should be used to guide and protect vehicular traffic. Flagpersons should be deployed where necessary to direct traffic around the work area.

6.2.3 Placement of barricades

The work area should be barricaded to alert pedestrian or vehicular traffic. Pedestrians should not be allowed near operating machinery. Barrier tape should be used between barricades or cones. Protection from equipment that has the possibility of becoming energized is of particular importance. Guards or barricades should be placed around excavations to warn errant pedestrians and workers.

6.3 Testing enclosure atmosphere

If the bore entrance or exit locations are in enclosures where explosive gas could accumulate (e.g., manholes) it will be necessary to test the enclosures prior to entry.

Prior to entering such an enclosure, it shall be tested for combustible gases and oxygen deficiency with proper detection equipment. If testing indicates the presence of a dangerous atmosphere, it should be ventilated until testing confirms that the enclosure is safe to enter.

Regardless of whether an enclosure is or has been cleared of a harmful atmosphere, proper safety procedures warrant continuous ventilation and repeated detection testing while personnel are working in or around the enclosure (refer to 29CFR, OSHA, Part 1926, Subpart S, dated July 1, 1994). State and utility requirements should also be observed.

CAUTION

Never assume an enclosure is safe to enter
until its atmosphere has been tested.

6.4 Shoring

Depending on depth and soil type, some pits may require shoring. Shoring material should be on site for use in pits and in trenches if required (refer to 29CFR, OSHA, Part 1926, Subpart P, dated July 1, 1994). State and utility requirements should also be observed.

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7. Drilling the run

Straightness of drill run is a major factor in both correctly operating the drill and installing the cable. Some areas of emphasis are given in 7.1 through 7.6.

7.1 Planning

Planning the run prior to starting operation will allow the operator to make a large radius sweep around an obstruction (starting from as far back as possible) rather than an abrupt correction at the point of an obstruction.

7.2 Start of bore

The launch should be smooth, on-line, and contain no waves. Unnecessary bends or turns within the run reduce the effective thrust (thus steering ability) and increase the tension on the cable during pullback.

7.3 Obstructions

When large rocks or other unforeseen obstructions are encountered, a path around the obstruction should be determined or the obstruction should be removed.

7.4 Depth and spacing requirements

Utility requirements for minimum/maximum depth and spacing from other substructures should be followed when boring the run.

7.5 Pits

Entrance and exit pits serve two major functions. They act as a basin to contain spoils and provide access to the tools and reamers when making connections.

Pits should be large enough to allow the wrenches to turn the coupling nuts and deep enough to allow access to the bottom of the drill head or reamer [usually 3 ft × 3 ft × 4 ft (0.9 m × 0.9 m × 1.2 m) deep].

Reliefs should be cut away at any point where the cable may contact an edge including around the bore opening. This will greatly reduce cable drag and prevent high sidewall loads.

7.6 Drilling fluid control

It may be necessary to control (or remove) excess runoff of boring fluid. This may be accomplished by erecting barriers, etc.

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8. Cable preparation

8.1 Reel and reel trailers

The reel trailers should be placed on a level surface. The trailer wheels should be chocked to prevent movement during pullback. The reel should be examined for damage and any protruding staples, nails, or bolts should be removed from the inside of the reel flanges.

8.2 Cable

8.2.1 Inspection

The cable should be inspected for cuts or nicks in the jacket. Cable with observed flaws or irregularities should not be installed without approval from the utility, or the flaws should be repaired or removed prior to installation. Footage marks at the flaw location should be recorded for possible future reference (e.g., on “as-built” drawings or equipment enclosure).

8.2.2 Cable sealing

When cable will be installed with a basket grip, the cable end should be waterproofed by covering it with an effective seal (e.g., electrical tape, cable cap, etc.).

8.2.3 Cable attachments

a) *Conductor pulling eye.* Sufficient insulation should be stripped back from conductor to allow placement of the pulling eye. The pulling eye should be secured (e.g., tighten screws or swage) to the conductor.

b) *Cable basket grip.* The cable basket grip should be installed by installing the basket over the sealed cable end. Slack should be worked from the grip and tightened on the cable. Binder tape should be applied at the open end of the grip to prevent the grip from loosening.

8.3 Attaching cable to drill string

8.3.1 Swivel

The swivel should be inspected to ensure that it turns freely in both directions and is rated correctly for the planned installation.

The swivel should be attached to the reamer. The connector should be inspected to ensure that it is sound.

8.3.2 Breakaway link

In order to prevent damage to a cable due to excessive tension during pullback, a “breakaway” (weak) link (or mechanical fuse) may be installed between the swivel and cable grip.

Table 1 gives typical values of maximum allowable cable pulling tensions for various cable conductor sizes; these values may be used when utility standard values are not available. The proper size link may be selected from this table.

When using a basket grip attachment, it may be necessary to contact the cable manufacturer for allowable pulling tension.

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Table 1—Maximum cable conductor pulling tension

Conductor size AWG (mm^2)	Tension, lb (kg)	
	1 cable	2 or 3 cables
#2 (34) Cu[a] and HDAl[b]	530 (240)	1060 (481)
#2 (34) 3/4 HDAl (or less)	400 (181)	800 (363)
#1/0 (54) Cu and HDAl	845 (383)	1690 (767)
#1/0 (54) 3/4 HDAl (or less)	630 (286)	1260 (572)
#3/0 (85) Cu and HDAl	1340 (608)	2680 (1216)
#3/0 (85) 3/4 HDAl (or less)	1000 (454)	2000 (907)
#4/0 (107) Cu and HDAl	1700 (771)	3400 (1542)
#4/0 (107) 3/4 HDAl (or less)	1270 (576)	2540 (1152)

[a]Cu = Copper
[b]HDAl = Hard drawn aluminum

Table 1 contains the maximum cable conductor pulling tensions for the “breakaway” link. Other size conductors may be calculated using the following formula and constants:

$$T_{max} = CTC \times CA \times N$$

where

T_{max} is maximum pulling tension, in pounds

CTC is conductor tension constant

Use 0.008 for Cu and HDAl
0.006 for 3/4 HDAl
0.004 for 1/2 HDAl

CA is cross-section of one conductor, in circular mils

N is multiplier for number of conductors

Use 1 for one cable
2 for two or three cables

8.4 Reamers

Reamers should be selected for the soil type being drilled. It is important to supply adequate lubrication for the cable installation while reaming. The importance of lubrication and fluid cutting pressure should be considered for each job.

Correct sizing of the reamers will provide clearance for cables and basket grips, and for spoils flow during installation, and will prevent jamming of the cable during installation. As a guide, the minimum acceptable size reamer for a given installation should be approximately 1.5 times the greatest diameter (e.g., over cable grip).

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9. Installation

9.1 Cable/conduit pulling

The cable/conduit should be pulled back without delay in order to minimize the possibility of tunnel collapse. The pull back should be performed in a steady controlled manner. Multiple starts and stops should be avoided. A greater force (higher tension) is required to start a cable moving than to keep it moving.

Calculations used to pull cable in a duct can also be used for installing cable in a tunnel.

9.1.1 Communication

Constant communication should be maintained with exit pit personnel who are feeding in the cable during pullback. “Cable start” and “cable stop” messages should be used throughout the run.

9.1.2 Cable feed-in requirements

Attachment at the exit pit (cable feed-in end) should be made with care. Crew members should pull the cable/conduit from the reel(s) to maintain slack (i.e., zero tension), and feed the cable/conduit into the pit as the cable/conduit is installed. While feeding the cable/conduit, care should be taken to ensure that the cable(s) or conduit(s) are not over bent, do not catch or snag, do not scrape on the ground, and feed smoothly into the tunnel. The use of a flexible cable feeding tube will control the flow of cable from the reel(s) into the bore. The cable/conduit should have no twists or kinks. Crew members should look for any cuts, nicks, etc. in the cable jacket. Any drag where the cable/conduit enters the pit is amplified through any turns or waves in the borehole. Footage marks should be noted to track the amount of cable installed.

9.1.3 Breakaway link separation—Options/procedures

The separation of the “breakaway” link indicates that the maximum allowable tension has been reached. The individual monitoring the cable feed end should carefully watch to see if the cable stops when the drill continues its pullback. This is the only way that a broken link can be detected. One of the following options should be pursued if the link breaks:

a) Replace the separated link and continue the pullback.
b) Remove the cable from the tunnel.
c) Abandon the cable.

9.1.3.1 Replace separated link and continue the pullback

This option will allow continuation of pullback only if the tension on the cable was caused by a source that can be located and removed prior to the resumption of pullback (i.e., the cable or basket grip was snagged, or the tunnel collapsed near an open pit).

The procedure is as follows:

a) Locate cable end.
    1) Use footage marks on cable (note footage at start) or count the number of drill rods removed.
    2) Listen for jets or reamer.
b) Excavate reamer and cable end.
c) Replace the link.
d) Identify and remove the obstruction.
e) Continue the pullback.

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9.1.3.2 Remove the cable from the tunnel

When the cable is to be removed from the tunnel, the following procedure may be used:

a) Withdraw the cable from the tunnel (pull from the exit pit or reel end).
b) Inspect the cable jacket for damage.
c) Redrill the tunnel back to the exit pit.
d) Change the reamer size and/or jet conditions to create a larger tunnel.
e) Reattach the cable.
f) Restart the pullback.

9.1.3.3 Abandon the cable

If the cable cannot be advanced or retracted:

a) The cable may be spliced at that point. This requires locating the cable end and digging a new exit pit. The pullback should be restarted from that point. Cables may later be spliced together. [See 9.2 step a) below.]

   In the event that a decision is made to utilize a length of cable that cannot be advanced (to complete the pull) or retracted (to start over), it is strongly recommended that such a cable be tested, to note its electrical integrity, before finalizing the decision. At a minimum, such testing would involve an insulation resistance measurement between the conductor/metallic shield and ground.

b) If it is decided not to splice (e.g., damage to cable), the cable should be abandoned and an adjacent run should be drilled.

9.2 Completing the installation

a) If there is any indication that the cable may have been damaged during the cable pullback, consideration should be given to testing the cable to determine if damage has occurred (e.g., insulation test between metallic shield and ground).

b) Sufficient slack should be pulled into the cable pit to ensure that an adequate length is available to attach (or splice) to associated equipment. If CIC is installed, the cable end should be located to verify that an adequate length of cable has been pulled.

c) The cable should be cut at least 3 ft from the end of the cable grip or eye.

d) The cable ends should be waterproofed.

e) The cable ends should be grounded (if necessary).

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10. Post-installation activities

10.1 Cleanup

All fluids (e.g., bentonite) should be removed from pits and disposed of properly. All excavations should be backfilled and properly compacted. The surface should be restored to its original condition.

10.2 Record as-built conditions

Any permanent changes made should be recorded (e.g., location of any pull boxes, presence and location of any repair splices, description of the new cable/conduit, actual cable route, depth, etc.).

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