HDPE CONDUIT JOINING GUIDELINES

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105 Decker Court • Suite 825 • Irving, Texas 75062 • 469.499.1044 • www.plasticpipe.org

Foreword

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The purpose of this technical note is to provide guidance on joining of HDPE conduit for broadband and power applications.

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For further information, contact:

The Plastics Pipe Institute
105 Decker Court
Suite 825
Irving, Texas, 75062
469.499.1044
www.plasticpipe.org

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1.0 INTRODUCTION AND OVERVIEW

There are multiple joining methods that can be used for joining or terminating HDPE conduit. Joining methods can be broken into three very broad categories:

- Mechanical
- Heat fusion
- Adhesive bonding

This guide provides an overview of each joining category by joining method. The guide also identifies key design attributes to be considered when choosing a joining method for specific applications. Joining for this document refers to coupling the ends of two lengths of a conduit for extending the raceway. It could be joining the ends of two HDPE conduit lengths or the end length of HDPE conduit to a length of other conduit material such as PVC, FRP, galvanized steel, etc. Termination refers to joining a length of conduit to appurtenances such as enclosures, meters, building entrances, and other devices.

1.1. Mechanical Coupling Overview

Mechanical fittings are the most often used coupler types for joining or terminating HDPE conduit. Mechanical fittings are usually attached to the outside surface of the conduit ends so as not to reduce the conduit’s inside diameter, allowing the cable to pass freely through the joined section as it is being installed.

Multiple mechanical coupler designs are available for joining or terminating HDPE conduit. For this guide’s purposes, the following characteristics broadly describe commonly used mechanical coupler designs:

- Compression – in this design the gasket is utilized as a mechanism for both sealing and gripping.
- Self-threading – the coupler has internal threads used for gripping, but it typically has no mechanism for sealing.
- Push-fit – usually a combination of gasket for sealing and internal metallic locking ring for gripping.
- Elastomeric Sleeved – internal elastomeric layer for sealing and gripping with an external rigid housing for providing axial and circumferential strength.
- Hybrid – Combines internal gasketing with tool actuated clamps for engaging locking rings.

Each mechanical coupling type is discussed in more detail in Section 5.0 on mechanical couplers.

1.2. Heat Fusion Overview

A less often used but important joining method, is heat fusion. The most often used heat fusion methods are butt fusion and electrofusion for joining conduit. Socket fusion is another heat fusion method typically used for smaller conduit diameters. Socket fusion is more frequently used for joining pressure rated water tubing or gas tubing.

Heat fusion joining methods for conduit are recommended where very high tensile loads are expected to occur during installation, for example when conduit is to be pulled-in using the Horizontal Directional Drilling (HDD) method.

Heat fusion joining methods are covered in more detail in Section 6.0.

1.3. Adhesive Bonding Overview

Joining conduit by adhesive bonding is the third joining method. Joining HDPE conduit requires special preparation of the conduit ends and couplers for bonding. Adhesive types are typically two-part formulations that create a curing reaction after mixing the two ingredients together. They do not require the addition of water, air, or outside energy sources, such as Ultraviolet (UV), Electron Beam (EB), or heat. Once the two parts are mixed the reaction begins, making application time sensitive.

Joining details for adhesive bonding are provided in Section 7.0.

2.0 TERMINOLOGY:

- Conduit – A plastic raceway used to protect either power, telecommunications, or control cables.
- Coupler/Coupling – A fitting used to join a conduit to another conduit or to a termination point.
- Fitting – A component used to join, terminate, branch, or change direction of the raceway.
- FRP conduit – Also known as composite conduit, a rigid conduit of fiber reinforced plastic material used most often in bridge locations requiring greater strength or highly corrosive environments.[1]
- HDPE – High density polyethylene is a durable plastic material used in the manufacture of conduit.[1]
- Joining – coupling the ends of two lengths of a conduit for extending the raceway or the end of an HDPE conduit to a length of conduit made from other materials.
- Joint – The location at which two pieces of pipe or a pipe and a fitting are connected together.[2]
- PVC conduit – A conduit made from polyvinyl chloride.

3.0 SAFETY CONSIDERATIONS

This Technical Note does not address safety considerations associated with joining. Joining may involve hot plastics, chemicals, or significant forces. It is the responsibility of the user to ensure manufacturer's instructions and industry norms are followed. Jobsite safety requirements should be fully understood and observed.

4.0 GENERAL CONSIDERATIONS

The need for joining and terminating HDPE conduit is a given, but the nuances in terms of performance may vary greatly depending on the method of joining. In addition, there are wide ranging performance requirements that may be placed on conduit joints and terminations. There are three critical stages pertaining to joining performance requirements. They include:

- Stresses placed on coupled joints and terminations during conduit installation.
- Stresses placed on the coupled joints and terminations during cable installation.
- Stresses placed on coupled joints and terminations in-service.

Not all stages are equal in terms of types and magnitudes of stresses the joined locations will need to withstand. Installation stresses imparted during conduit construction or cable installation are often the most demanding. For example, tensile loads placed on a joint during installation via horizontal directional drilling or bending moments placed on a joint during plowing will influence the type of coupling method most appropriate. Compare manufacturer recommendations with the maximum safe pulling strengths for HDPE conduit, available in PPI TN-63. Resultant expansion or contraction forces or elongation stresses that may occur during installation will influence the timing for final coupling and termination of the conduit.

The in-service environment surrounding the location of each assembly plays a key role in the stresses that can be anticipated. For example, long above ground spans where the conduit will be subjected to wide temperature variations (such as bridge crossings), the joining method will need to be designed to compensate for temperature related expansion / contraction forces that will occur.

The requirements of the cable installation method are important considerations when selecting the correct coupler option. For example, the joint between the conduit and riser (sweep) up to the puller must withstand the significant cable pulling forces developed when heavy cables are pulled into place.

A different concern applies when installing fiber optic cable using the air-assisted cable pushing installation method, i.e., jetting of cables. Maximizing cable installation lengths requires the velocity of airflow to be maintained. For this reason, selecting a coupler capable of holding short term pressure without air loss is very important to achieving the desired cable installation lengths.

A more comprehensive list of considerations for coupling or terminating HDPE conduit during installation or in-service is provided in the following sections.

5.0 MECHANICAL COUPLERS

Achieving desired coupling or termination performance is a combination of workmanship and coupler design.

There are a few basic workmanship steps to follow that are critical to assuring joint integrity. They revolve around properly preparing the conduit ends prior to assembly into the coupler. The following steps should always be done in preparation for assembly:

- The ends of the conduit should be cut cleanly and perpendicular to the axis of the conduit.
- The outside edge of the conduit end should be beveled or chamfered to ease insertion into the coupler and prevent damage to the gasket.
- The inside edge of the conduit end should be beveled or chamfered to provide a smooth transition and internal alignment so there is no sharp edge that might catch and damage the cable during installation.

As outlined in 1.1, there are multiple types of mechanical coupling designs that provide varying levels of sealing and gripping strengths. For proper coupler selection, it is important to understand and differentiate between those types of stresses which will be placed on a joint during installation versus in-service. It is also important to consider the location and what types of stresses will be placed on a joint during cable installation. Here are a few high-level considerations:

- Mechanical couplers should never be placed in a bend. To assure proper alignment of the conduit ends, they should only be placed in the straight sections of the installation.
- Mechanical couplers placed at the base of a riser location, where the cable is to be pulled into place, must be designed to provide greater gripping strength than the force of pulling the cable will exert on the joint at that location. If the joint has insufficient strength, the joint may be pulled apart during cable installation causing lost time, possible cable damage and increased cost to make the repair.
- If plans call for the cable to be pushed/jetted into the conduit after installation, then the couplers must not leak allowing loss of air pressure. To optimize cable placing distances and efficiency during the push/jetting cable installation method the couplers must be capable of holding the necessary air pressure for the duration of the cable installation.

- Enough conduit slack should be pulled into any type of underground access point such as a handhole or manhole to allow for making a single joint. Traditionally rigid conduits are cut just inside the structures wall, but for HDPE conduit this does not leave enough length for either joining with a mechanical coupling or will require two couplers to piece in a length of conduit if it is necessary to bridge the structure. Due to HDPE conduit's flexibility, it is not necessary to end it at the inside wall because the HDPE conduit can be trained for racking it against the furthest wall in a manhole and then joined. This is especially important if the access point is a feed or pass-through location where the cable does not need to be accessed. Not having the conduit continuous through this type of location is inefficient and adds unnecessarily to installation costs.

Five types of mechanical couplers are:

1. Compression
2. Self-Threading
3. Push-fit
4. Elastomeric Sleeved
5. Hybrid

The following subsections describe each type of mechanical coupler in more detail and highlight critical performance considerations distinct to each coupler type.

Always follow the fitting manufacturer's installation instructions.

5.1. Compression

Compression couplers, as shown in Figure 1, are designed to couple and seal around the OD of each end of the conduit being joined. This coupler type is comprised of three main components, main body threaded on both ends, two gaskets for sealing, two end pieces (nuts) that are threaded internally for connecting to the main body. The coupler manufacturer should provide the specific torque requirements for tightening of the end nuts, as well as the short-term pressure rating and gripping strength for each diameter once properly assembled.

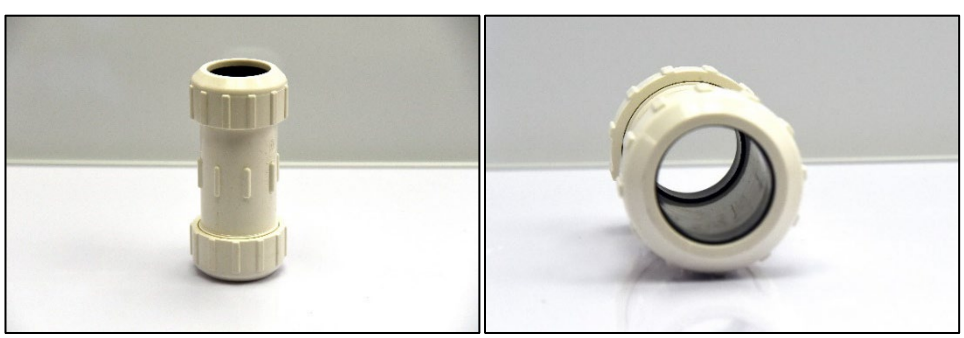

Figure 1: Example of compression coupling (Courtesy of Petroflex NA)

5.2. Self-Threading

Self-Threading coupler designs, as shown in Figure 2, are generally made from materials, like metal or composites, which are stronger than the conduit material. The couplers are one piece with internal opposing threads allowing the coupler to self-thread onto the conduit ends by rotating it in one direction. The internal threaded region is slightly tapered to accommodate the conduit's outside diameter tolerance range. There may be minor variations to thread designs offered by different manufacturers for improving ease of installation and gripping strength. Generally, there is no gasketing in these types of coupler designs. These types of couplers are not air or watertight and **are not suggested for use where the cable is to be installed via the push/air assist method.** They do provide excellent holding strength and can be used for plowed-in applications.

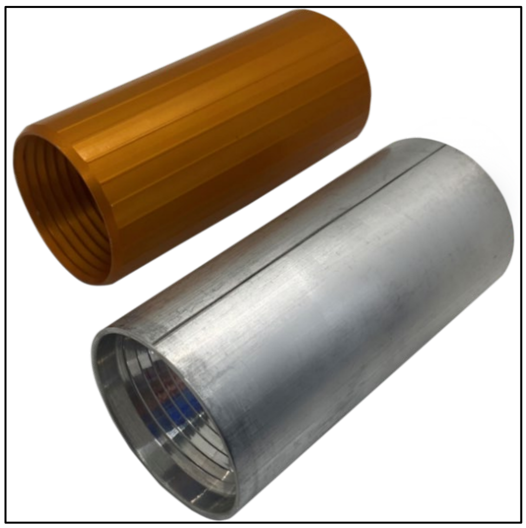

Figure 2: Self-threading conduit coupling (Courtesy of Dura-Line LLC)

5.3. Push-fit

Push-fit type couplers are push-to-connect and usually do not require any special tools for assembly. The couplers consist of three main components, an external rigid housing, internal elastomeric seal and a metal or composite plastic lock ring. Couplers may be of an opaque solid design or may incorporate a clear center section for providing visibility to show the conduit ends have been seated all the way to the center stop, as shown in Figure 3.

This style of coupler is generally available for connecting conduits of 2" or less in diameter and may be material specific. For example, they may only be functional for joining HDPE conduit to HDPE conduit but not for transitioning from HDPE conduit to PVC conduit. Consult with the manufacturer to determine if there are specific types of conduit materials onto which a given coupler can be applied.

Figure 3: Push-fit conduit coupling (Courtesy of Dura-Line LLC)

5.4. Elastomeric Sleeved

Elastomeric sleeved design, as shown in Figure 4, consists of an externally rigid shell lined with an internal elastomeric liner. The internally applied elastomeric material is bonded to the rigid shell so both components work in concert. The elastic liner is molded with a center stop combined with a series of internal flutes that serve to seal and grip the conduit end's outer circumference. Multiple circumferential internally spaced flutes have a tapered design to make insertion easier while increasing gripping strength. This style of coupler can usually be pushed on but will create somewhat more resistance to pull out. They are not recommended for locations that may experience significant tensile loads after assembly.

Figure 4: Example of Elastomeric Sleeved Coupling (Courtesy of Petroflex NA)

5.5. Hybrid Mechanical

Hybrid mechanical couplers are designed to optimize both sealing and gripping strength. These designs generally consist of multiple components including a high strength external sleeve combined with an internal elastomeric O-ring seal, either high strength composite plastic or metallic locking rings and external hose clamps for actuating the internal lock rings. This coupler design provides excellent gripping strength and superior pressure resistance.

6.0 HEAT FUSION JOINING

6.1. Background

Heat fusion is the process of heating and melting the HDPE surfaces to be joined, bringing those surfaces into contact, and allowing them to cool under controlled pressure to create a monolithic and continuous structure. The joint can be between two lengths of HDPE conduit or between a length of HDPE conduit and an HDPE fitting.

For conduit, two main processes are used: butt fusion and electrofusion. Butt fusion uses standard equipment to face the ends to be joined, heat them, and bring them into contact during the cooling process. Electrofusion uses an HDPE coupler, with an integral heating wire, and specialized equipment for that coupling that will handle the heating process for the coupling. Butt fused and electrofused joints are shown in Figure 5 and Figure 6, respectively.

Heat fusion, whether by butt fusion or electrofusion, gives a very strong joint for demanding applications, including HDD installation. A properly fused joint is typically considered to be as strong or stronger than the conduit itself.

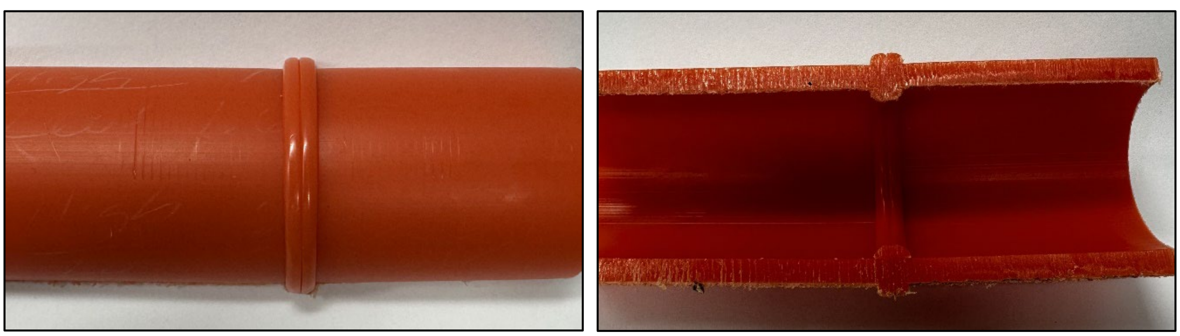

Figure 5: Example of Butt Fusion Joint Between 2 Lengths of HDPE Conduit (Left: Exterior view, Right: Cross-sectional view) (Courtesy of McElroy Manufacturing Inc.)

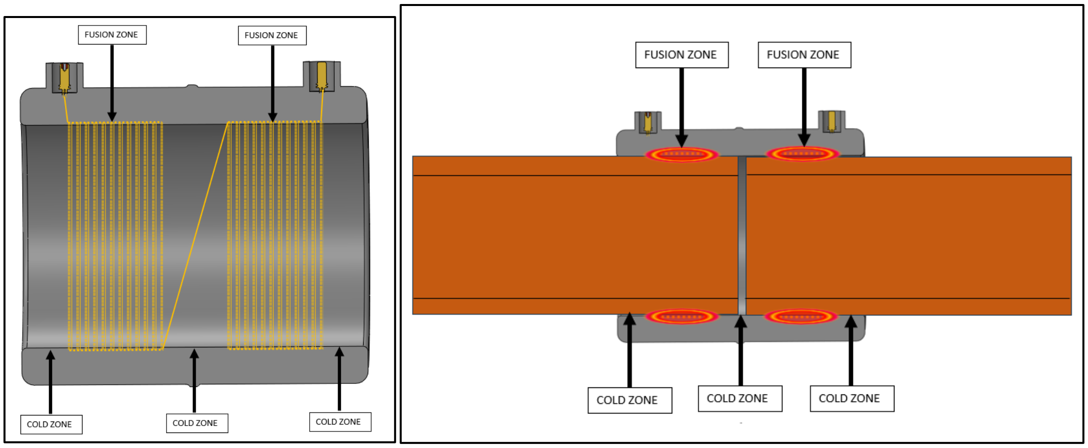

Figure 6: Cross-sectional view of Electrofusion fitting (left) and Conduit Joint with Electrofusion Coupling (Right), illustrating Fusion Zones. (Courtesy of Georg Fischer Central Plastics)

6.2. Butt Fusion Procedure Details

The generally accepted industry fusion procedure is in ASTM F2620 *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*[3]. This procedure is designed for pressure rated gas or water pipe, but the basic procedure is equally relevant for HDPE conduit materials.

ASTM F2620 lays out a detailed process needed for butt fusion, the basic steps of which are summarized below:

1. Set up the machine properly and confirm it is operating within manufacturer specifications.
2. Clean the pipe ends with a lint free cloth.
3. Face the pipe using the facing tool.
4. Align the pipe and adjust the machine pressure.
5. Verify the heater temperature, bring the pipe ends to the heater plate to heat the pipe faces until the appropriate melt bead size has been achieved.
6. Remove the heater plate, bring the pipe faces together until they touch and apply pressure pushing the melted ends of the pipes together. This step creates the fusion joint between pipes.
7. Allow the joint area to cool without disturbance.
8. Inspect the joint for the melt bead shape and uniformity.

ASTM F2620 should be followed carefully to achieve a good joint.

6.2.1. Butt Fusion Limitations

- Size - There are size limitations for butt fusion of conduit due to alignment and bead issues that may obstruct the internal diameter of the conduit. The generally accepted industry lower limit for butt fusion is 0.75” nominal outside diameter conduit. Butt fusion is generally not recommended on microducts, although individual manufacturers may have specific guidance for their products. Always follow manufacturer guidance when available. For more information on fusion beads see Section 6.4.3.

- Unlike wall thickness, cold temperatures, coiled conduit - ASTM F2620 provides specific guidance on the butt fusion of unlike wall thickness, fusing at cold temperature and inclement weather and fusing of coiled pipe. Contact the conduit or fitting manufacturing for additional information when fusing under these conditions.

6.3. Electrofusion Joining Procedure Details

Electrofusion should be performed in accordance with manufacturer recommendations.[4]

The basic steps of an electrofusion procedure are summarized below:

1. Cut square and debur the ends of the conduit to be joined.
2. Clean the outside surface of the ends of the conduits and inner or contact surfaces of the fitting to be joined.
3. Mark the conduit outside surface to the penetration depth of the fitting socket.
4. Using the appropriate tool, peel the conduit surfaces from the end to the marks.
5. Without contaminating the surfaces, insert the conduit ends fully into the fitting sockets.
6. Install the fitting clamp to hold the conduits and fitting rigidly during entire fusion and cooling process.
7. Attach leads, input the fitting type into the fusion process machine and activate. Allow the machine to complete its cycle, including the prescribed cooling time, prior to removing the clamp.

6.4. Fusion Considerations

The following subsections provide additional considerations when butt fusing or electrofusing.

6.4.1. Internal Ribs

Fusing products that have internal ribs is possible and typically requires no change in procedure.

6.4.2. External Ribs

Fusion of conduit with external ribs is generally not recommended because of the difficulty of aligning the conduit and properly clamping it during a butt fusion procedure.

If butt or electrofusion fusion of external ribbed products is desired, the ribs should first be removed in the joint area beyond where the clamps are applied to the conduit prior to going through the standard fusion process.

6.4.3. Fusion Beads

Conduit that is butt fused will have an internal bead and external bead, both similar in size and shape. It is the roll-back of some of the molten material that forms the fusion bead, see Figure 5. Fusion beads are not generated in properly made electrofusion joints.

ASTM F2620 provides guidance on the appropriate shape of the external bead.

- External Bead - The external bead can be removed without compromising the integrity of the joint. Specialized tools for external bead removal are recommended.

- Internal Bead - The internal butt fusion bead generally will not interfere with installation of cables because it is typically small relative to the inside diameter of the conduit. There are de-beading tools that can be used to remove the bead inside the conduit, if desired. These tools are limited to removing beads within 40 feet of the end of the conduit because the tools are designed for 40 feet sticks.

6.4.4. Lubricated Conduit

Some conduit products use a pre-lubricated inner layer to reduce friction. These generally are applied to the inner surface or by co-extruding a thin inner layer containing lubricants. The most common materials used are polydimethylsiloxane (PDMS) or fluoropolymer additives including polytetrafluoroethylene (PTFE).

- Butt Fusion - When butt fusing conduit with an applied lubricant or coextruded inner lubricant layer, it is important to remove any surface lubricant on the inner surface near the joining ends and conduit ends. Special care should be taken to ensure the facer and heater are clean of any lubricant before each fusion.

Note: Consult with conduit manufacturer for special requirements when fusing conduit with coextruded lubricated layer.

- Electrofusion - Electrofusion joining of conduit with internal lubrication is unaffected by lubrication layer. Ensure the outer surface is clean of any lubricant per the normal electrofusion joint preparation process.

6.5. Heat Fusion Joint Inspection

Evaluating the quality of a heat fusion joint without destructive testing is essentially limited to a visual inspection and a review of the fusion records. For this reason, proper operator training and suitable equipment is required to obtain a good butt fusion or electrofusion joint. A written procedure should be established for the method and should be followed rigorously in the field.

ASTM F3190[5] provides guidance on fusion operator qualification. Certification of operators for gas and water installation is a common requirement, but it may not be normal practice for conduit installation.

For butt fusion, ASTM F2620 provides guidance on visual inspection of the joint, based on pipe alignment and the bead size and shape.

For electrofusion, follow the manufacturers recommendation for visual inspection. ASTM F1055 provides guidance on destructive testing of joints.

7.0 ADHESIVE JOINING

Using an adhesive bonding system is an effective alternative to mechanical bonding and heat fusion joining. These systems use a socket coupling and can be used to join HDPE conduit to HDPE conduit or other conduit materials (e.g., PVC, steel, composite). These systems create an adhesive bond for a high-strength, airtight, watertight joint. Joints can be strong and airtight, making them suitable for most conduit installation methods, including cable fiber blowing techniques.

Always select an adhesive bonding system that is specifically designed and tested for HDPE conduit and the anticipated conduit installation and operating conditions. As adhesive bonding products differ, always follow the product manufacturer's installation instructions. The following sections provide a general overview of installation and other considerations.

7.1. Installation Practice

Adhesive bonding to HDPE is inherently challenging so proper surface preparation and adhesive application is essential to achieve the desired joint strength.

Note: The success of this process is highly dependent upon proper preparation of the conduit sections, operator training and following the manufacturer's recommendations. The manufacturer's instructions take precedence over the instruction here-in.

A close fit coupling is typically used to join HDPE conduit to HDPE conduit or other conduit materials (e.g., PVC, steel, composite). PVC couplings are typically used.

Preparation:

1. Cut the conduit end square to the conduit, i.e., 90° angle to the conduit axis. For conduit larger than 3 inches in diameter, add a small 45° taper to the lead edge to help with later insertion into the fitting.
2. The conduit end should be wiped with a clean cloth. The depth of the coupling socket should be marked on the HDPE conduit. Using a sanding strip of 80 grit, HDPE conduit surface should be roughened by sanding around the entire conduit up to the depth mark. Finally wipe the conduit surface using 98% isopropanol, or suitable recommended cleaner, to remove any oils.
3. Apply the same treatment of sanding, followed by wiping with a suitable cleaner, to the socket inside surface.
4. All surfaces must be dry before progressing with the application of the adhesive.

Adhesives systems are typically 2-part epoxy resins that require proper mixing before application. Applicators, e.g., caulking guns, with specialized disposable mixing heads, are typically available from the manufacturer that ensure both proper mixing and easy application (see Figure 7). Always use the methods and tools recommended by the adhesive product manufacturer.

Apply the recommended quantity and distribution of adhesive around the conduit, and, if required, within the fitting socket. For conduit over 3 inches in diameter, it may be necessary to spread the adhesive evenly over the joining surface. Always inspect for adequate quantity and uniformity of adhesive application.

Follow manufacturer's details on application and spreading of the adhesive, and the conduit insertion procedure.

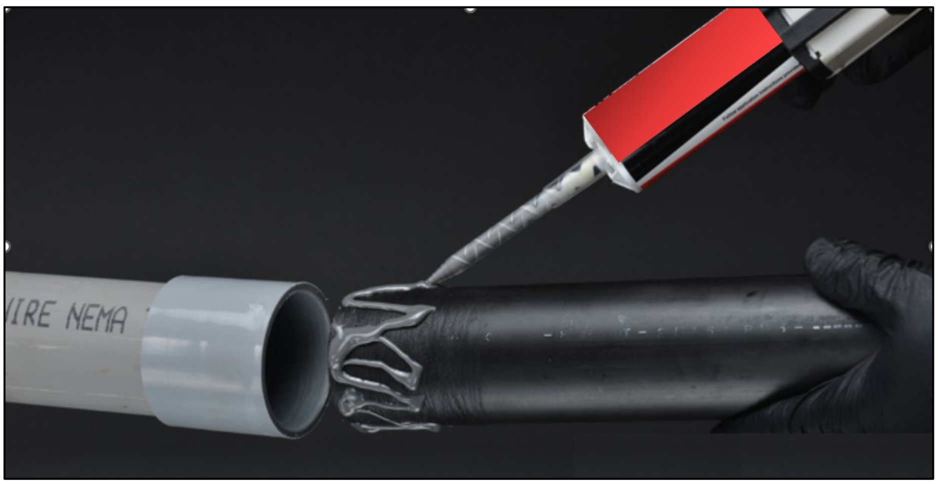

Figure 7: Example of Adhesive Bonding Application (Courtesy of Polywater USA)

7.2. <u>Curing Time for Handling & Installation</u>

Adhesives require time to cure to achieve sufficient strength for handling and to achieve full strength for installation purposes. The time to reach these levels of cure will be dependent on the particular adhesive bonding product and will be significantly impacted by ambient temperatures. Follow the manufacturer’s guidance before handling and installing conduit or cable.

7.3. Additional Considerations

The installer should confirm if the adhesive system is suitable for outdoor use, including exposure to humidity, water, and temperature fluctuations. Adhesive should be applied above the minimum temperature specified by the adhesive manufacturer. Working time and cure time are directly impacted by the ambient temperature, both will be shorter with increasing temperature and longer with decreasing temperature. Materials (adhesive, pipe, coupling/connector) can be heated or cooled to facilitate installation.

Axial joint strengths similar to that of the HDPE conduit are possible but dependent on the particular system and proper joint fabrication. Compare manufacturer recommendations with the maximum safe pulling strengths for HDPE conduit, as available in PPI TN-63.

REFERENCES

[1] PPI Handbook of PE Pipe – Chapter 14 on Duct and Conduit, Plastics Pipe Institute, USA, 2021.

[2] ASTM F412-19 Standard Terminology Relating to Plastic Piping Systems, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States

[3] ASTM F2620 - Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States. Refer to latest edition.

[4] PPITR-49 – Generic Electrofusion User Guide for Field Joining of Polyethylene Gas Piping for additional information, Plastics Pipe Institute, USA

[5] ASTM F3190 Standard Practice for Heat Fusion Equipment (HFE) Operator Qualification on Polyethylene (PE) and Polyamide (PA) Pipe and Fittings. ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States. Refer to latest edition