

Other Conduit Types

CONDUIT BENDING and FABRICATION



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Although the great majority of conduit used today is steel, there are other types of approved and available metallic and nonmetallic conduit. Steel rigid conduit is widely available and recognized as acceptable for raceway systems in most applications. However, rigid conduit may also be manufactured from stainless steel, brass, and silicon-bronze. Aluminum conduit is allowed in some applications.

PVC-coated steel conduit is used in corrosive environments. In order to protect the PVC coating, special tools are required. Standard clamping, cutting, and threading tools can damage the PVC coating. Modified tools are available to minimize the damage.

Nonmetallic PVC conduit has increased in use since its introduction in the early 1960s. PVC conduit is often used for underground installations and grounding electrode conductor raceways. Because PVC conduit is made of plastic, it has several advantages over metallic raceways. Voltage loss due to electromagnetic induction is nonexistent. PVC is impervious to the elements and does not easily corrode. It is much lighter in weight than rigid and is much easier to cut. Sections of PVC conduit are solvent-welded together and do not require threading.

OBJECTIVES

1. List common types of metallic conduit.
2. Describe the differences between standard clamping, cutting and threading, and bending tools, and tools used with PVC-coated conduit.
3. Describe how sections of PVC conduit are joined together.
4. Describe how to bend PVC conduit.
5. List the different types of PVC heaters.
6. Explain why it is necessary to rotate PVC conduit while it is in a heater.



METALLIC CONDUIT

In addition to the conventional types of conduit, there are several other types of metallic conduit available. The most common of these is aluminum conduit. Metallic conduit can also be made from stainless steel, silicon-bronze, and brass. Several types of PVC-coated steel conduit are also available.

Tech Tip

Thread/joint lubricants may be used with aluminum conduit to prevent seizing and galling and to reduce wear and breakage of mating parts.

Aluminum Conduit

Aluminum conduit is extremely lightweight compared to steel conduit. See Figure 7-1. It provides an excellent ground path and it can be bent with virtually no springback. The disadvantages of aluminum conduit include less physical protection for conductors because aluminum is softer than steel.

Aluminum conduit is typically used where weight is a concern, such as when the conduit needs to be installed above a finished ceiling. In addition, aluminum conduit has much lower impedance than steel conduit and therefore makes a better equipment grounding conductor.

Conduit Weight			
Size	Galvanized Rigid Conduit*	EMT*	Aluminum*
1/2"	82	30	28
1"	161	67	55
2"	350	148	119
4"	1030	393	350

*weight in lb. per 100'

Figure 7-1. Aluminum is the lightest metallic conduit.

Aluminum is easy to cross-thread when installing a coupling or fitting. Also, aluminum conduit does not shield wiring from outside electromagnetic interference (EMI) as well as steel conduit. In industrial installations where critical digital and analog control conductors require extensive shielding from high-power noise, such as from motors or heaters, the conduit is normally made of steel or other ferrous (iron-based) metal.

Aluminum conduit is available with wall thicknesses corresponding to rigid and EMT steel conduit. Threaded aluminum conduit is readily available in 10' lengths, including the coupling, in trade sizes from 1/2" to 6". Plastic thread protector caps are color coded to help with identification. The cap colors are the same as for conventional rigid conduit—blue for even inch sizes, black for 1/2" sizes, and red for 1/4" sizes. See Figure 7-2.

Aluminum Thread Protector Caps		
Color	Sizes	Examples
Blue	Inch sizes	1", 2", 3", 4", 5", 6"
Black	1/2" sizes	1/2", 1 1/2", 2 1/2", 3 1/2"
Red	1/4" sizes	3/4", 1 1/4"

Figure 7-2. Plastic thread protector caps are color coded to help with identification.

Other Metallic Conduit

Rigid conduit can be manufactured from a variety of metals other than steel. Depending on the requirements, the designer may specify stainless steel, silicon-bronze, or brass conduit. Stainless steel conduit is corrosion resistant, but extremely hard and very difficult to bend, cut, and thread. Also, stainless steel conduit has quite a bit of springback. In addition, stainless steel conduit must be threaded slowly with plenty of cutting oil.

Silicon-bronze alloys may also be chosen for improved corrosion resistance. Brass conduit, while considerably softer than stainless, also has quite a bit of springback. With brass conduit, it is not unusual to have to bend 105° to end up with a 90° bend.

Tech Fact

Aluminum conduit is often used when the wiring in the conduit is carrying high-frequency (400 Hz) alternating current, such as in military, data processing, and radar installations, where steel raceways would be subject to inductive heating.

PVC-COATED CONDUIT

PVC-coated conduit is often specified for use in corrosive industrial environments. PVC-coated conduit is usually installed as a system where all of the raceway components (couplings, fittings, enclosures, straps, and hangers) are coated with PVC. PVC-coated conduit is commonly called robroy, after Robroy Industries, a manufacturer of PVC-coated conduit.

Conduit Sizes

Most often, the PVC coating is applied to standard rigid conduit, although the coating can also be applied to IMC and EMT. Threaded PVC-coated rigid conduit is readily available in 10' lengths, including the coupling, in trade sizes from 1/2" to 6". Plastic thread protector caps are color coded to help with identification. The cap colors are the same as for conventional rigid conduit—blue for even inch sizes, black for 1/2" sizes, and red for 1/4" sizes.

PVC Coating

The PVC coating on the outside of the conduit is 40 mils (0.040") thick. This coating increases the outside diameter of the conduit by 80 mils. The PVC coating is applied over three types of conduit. These three types of conduit are bare steel, galvanized steel, or zinc-coated steel. **See Figure 7-3.**

The outer coating comes in a variety of colors. The most common coating is gray. The conduit manufacturer's specifications should be consulted when selecting the correct coating for the installation. The inside of the conduit has a 2-mil urethane coating.

Coating Repair. PVC-coated conduit is used in corrosive environments. Cutting the threads exposes the steel conduit, and bare steel is vulnerable to corrosion. Therefore, after the threads are cut, they must be thoroughly degreased, cleaned, and dried. Any standard degreasing spray or liquid can be used. After the threads are cleaned, a touch-up compound must be applied to

the threads. This restores the corrosion protection to the threads.

The PVC coating can become damaged despite attempts to keep it intact. Any areas with exposed metal should be repaired as soon as possible. Patching material may be supplied with the original conduit order. A corrosion inhibitor should be used to paint over any exposed areas. Several coats may be necessary. Coatings for this purpose are listed under UL (Underwriters Laboratories®) category "FOIZ".

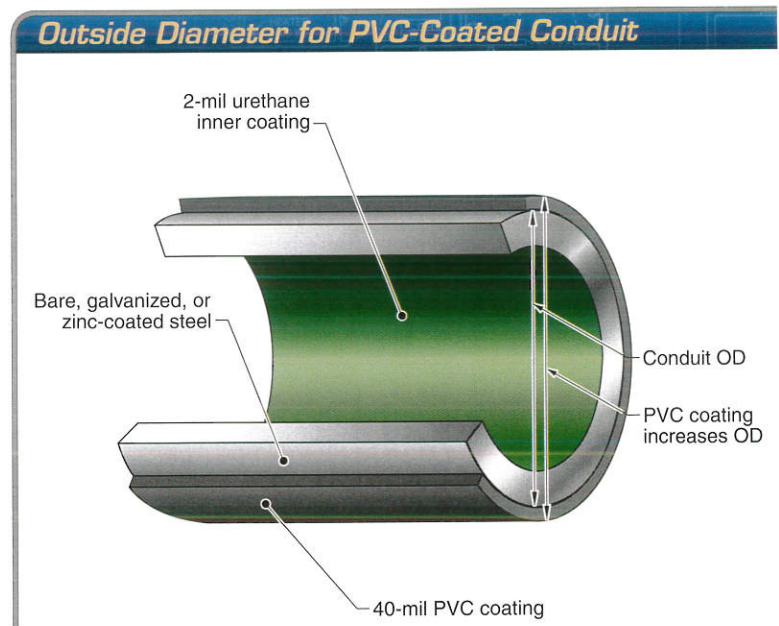


Figure 7-3. The PVC coating increases the outside diameter of the conduit.

Tools

Bending PVC-coated conduit requires different tools and techniques than when bending rigid conduit. The main difference between PVC-coated conduit and other types of metallic conduit is that the PVC coating must be protected from damage. This means that the bending and handling tools need to be modified or special tools need to be used that do not damage the coating. These tools include clamping tools, cutting and threading tools, and bending tools.

Clamping Tools. Clamping tools, such as pipe vises and wrenches, must not have teeth that can damage the PVC coating. A common modification is to replace the jaws of a pipe vise with a three-sided adapter that spreads the clamping force over a larger area. See Figure 7-4.

If a pipe vise cannot be used, a half-shell clamp can hold the coated conduit. This clamp also spreads the force over a larger area. A half-shell clamp can either be purchased or can be made from a section of rigid conduit.

To make a half-shell clamp, two sections of rigid conduit are used, each about 6" long in the next larger trade size. The two sections of rigid conduit are cut lengthwise with a band saw, with the cuts placed slightly off center. The larger halves are discarded, and the smaller halves are kept to use as the half-shells. The two halves should not touch each other when clamped around the PVC-coated conduit. A half-shell clamp can also be used with a chain vise.

Cutting and Threading Tools. PVC-coated conduit can be cut with any conventional cutting tools, such as a rolling cutter or a saw. As with any other type

of conduit, the cut end must be reamed before use.

PVC-coated conduit can be threaded with standard threading tools. However, the outside diameter of PVC-coated conduit is larger than standard conduit of the same trade size because of the thickness of the PVC coating. Therefore, the PVC coating on the end must be pencil-cut (bevel cut) before threading. See Figure 7-5. This allows the die teeth to engage the conduit.

The PVC coating needs to be cut in a way that allows the threading die to remove the coating in small pieces during the threading operation. This will prevent long strips of the PVC coating from fouling the die. A thread protector cap is used to determine the length of the threads, and a cut is made around the circumference at that point. Longitudinal cuts in the coating are made from that point to the end of the conduit where the threads will be cut.

Tech Fact

Care should be taken when using degreasing solvents and solvent cements. Proper PPE is needed, and the MSDS requirements must be followed.

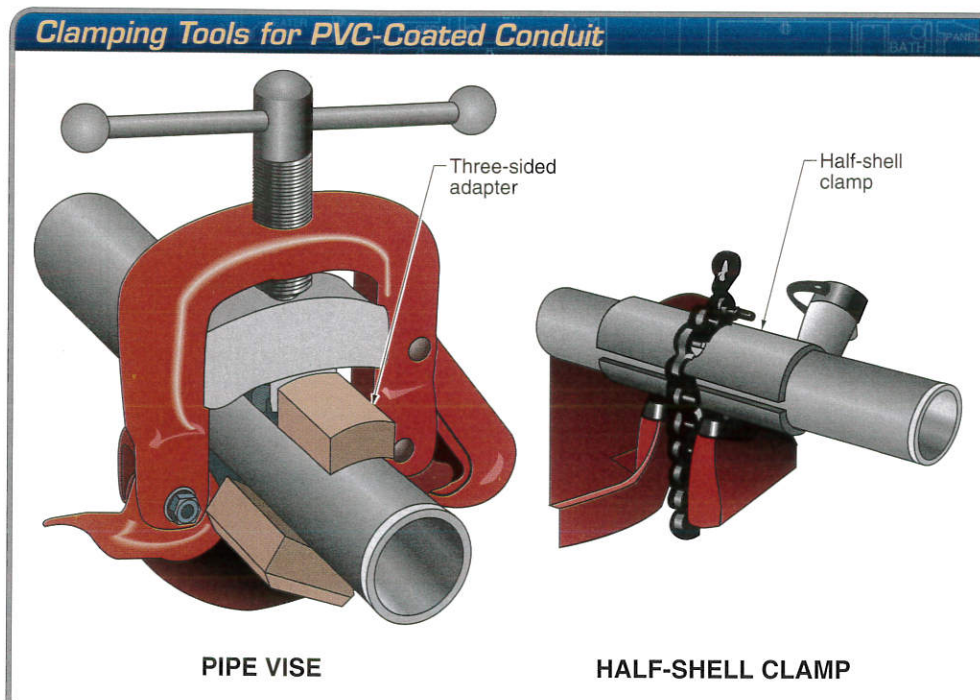


Figure 7-4. PVC-coated conduit requires special clamping tools to prevent damage to the coating.

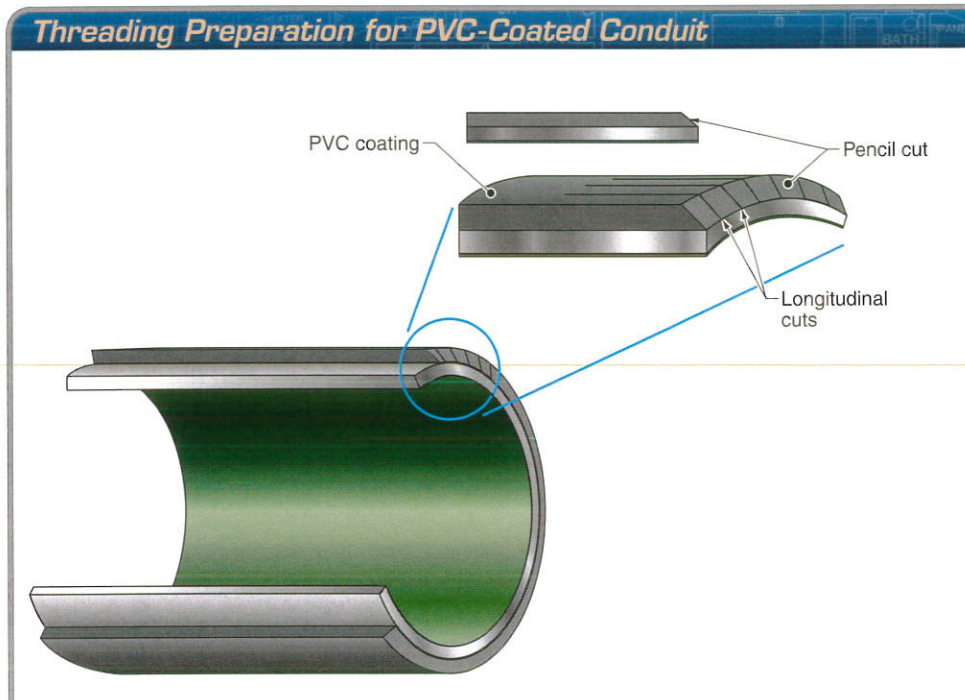


Figure 7-5. The PVC coating must be prepared before threading.

Bending Tools. Because of the coating, the outside diameter of PVC-coated conduit is slightly larger than standard conduit. Therefore, it cannot be bent with standard bending shoes without damaging the coating.

PVC-coated conduit must be bent on special shoes designed to bend this particular type of conduit. See Figure 7-6. For hand bending, some manufacturers recommend using the next-larger-size bender. Existing shoes should not be modified to accommodate the coating. Shoes are manufactured to fine tolerances and any field modification will ruin the shoe.

Couplings and Fittings

Sleeves are present on couplings and fittings for PVC-coated conduit. These sleeves are used at all joints to protect the joint from corrosion. The installation of couplings and fittings can be a little difficult in cold weather. It is much easier to place the sleeve when it has been warmed before installation. An easy way to warm the sleeves is to immerse them in warm water until they are soft and pliable.

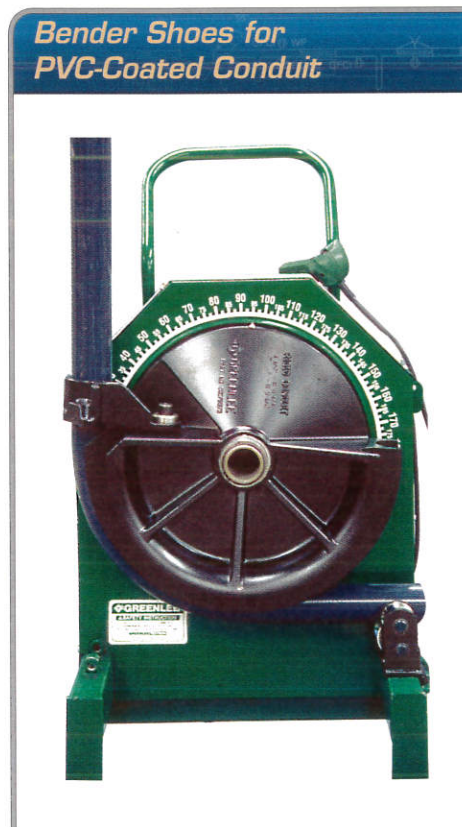


Figure 7-6. Special bender shoes are required when bending PVC-coated conduit.

Strap wrenches or pipe wrenches with specially equipped wide jaws should be used to install these couplings and fittings. See Figure 7-7. Slip-joint pliers or standard pipe wrenches should not be used to install PVC-coated conduit or fittings. Threadless fittings must not be used with PVC-coated rigid conduit or IMC.

Tech Tip

Only fresh solvent cement should be used on joints. If solvent has started to gel or get stringy, a joint can fail and require costly repairs. The cement should be applied evenly over the outside of the conduit, and a thin coat should be applied on the inside of the fitting.

Modified Tools for PVC-Coated Conduit

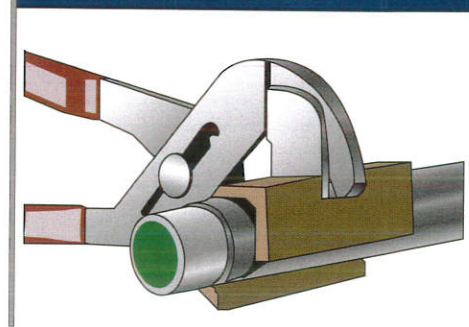


Figure 7-7. Standard tools must be specially equipped for handling PVC-coated couplings and fittings.

PVC CONDUIT

Nonmetallic PVC conduit is a very different raceway than the other raceways discussed so far. Because PVC conduit is made of plastic, it has any number of advantages over ferrous raceways. Voltage loss due to electromagnetic induction is nonexistent. PVC is impervious to the elements and does not easily corrode. It is lighter in weight than rigid, and much easier to cut. Sections of PVC conduit are solvent-welded together and do not require threading.

PVC Conduit Sizes

PVC is available in a number of wall thicknesses. These are designated in schedules. Schedule 20 has a very thin wall and is used in underground installations when encased in concrete. Schedule 40 is the standard wall thickness and is used both aboveground and belowground. Schedule 80 has a very heavy wall and is often used in direct burial situations under heavy traffic areas such as roads, streets, and parking lots.

Joining PVC Conduit

All schedules of PVC conduit are fabricated and installed by the same methods, despite the differences in wall thickness. Sections are connected together with a solvent-welding technique. The solvent is a powerful chemical and must be used in a well-ventilated area. The material safety data sheet (MSDS) and all precautionary labels must be read and understood before using the solvent.

There are several types of UL-listed solvent cements on the market for different temperature ranges and conduit sizes. See Figure 7-8. The labels must be read carefully. If a warm-weather solvent is used in cold weather, the solvent will not dry properly and may attack the conductor insulation. If a cold-weather solvent is used in warm weather, the cement will cure before the joint can be assembled.

PVC Solvent



Figure 7-8. Sections of PVC conduit are connected with a solvent-welding technique.

Mating surfaces should be dry and clean before applying the solvent. Both pieces being joined should be coated with the solvent. The solvent works by dissolving the PVC on the surface of the conduit and fittings where they will be placed in contact with each other. After the connection is

made, the joint needs to be rotated a quarter turn to make sure all the mating surfaces are in complete contact.

Depending on the temperature, the joint may set up in just a few seconds or a minute. As the solvent dries, the two objects are fused (welded) together. This produces an extremely strong joint. Once the joint has cured, it cannot be taken apart.

PVC can be cut in any number of ways. As with metallic conduit, PVC conduit should be reamed to remove any burrs or rough edges. If the conduit is of a relatively small diameter, a ratchet cutter can be used to make quick, clean cuts. **See Figure 7-9.** For larger-diameter PVC conduit, handsaws are available that produce clean and easy cuts. Regardless of the cutting method, the joint must be cut square and any burrs must be removed.

PVC can also be cut with a good quality braided mason's string. This saves the electrician time when attempting to cut conduit in a trench. The mason's string is placed around the conduit and the string is pulled back and forth with both hands.

Bending PVC Conduit

Bending PVC conduit is a somewhat challenging task. PVC conduit is very rigid and cannot be bent at room temperature. The conduit must be heated before it will bend. However, PVC retains heat for some time. This can cause serious injury if proper care is not taken.

After the conduit reaches bending temperature, it can be bent around a template. **See Figure 7-10.** A bending template can be as simple as a piece of EMT bent to specifications or as complex as a sheet of plywood with blocks secured to it to define the proper bend. Simple bends in PVC conduit can also be made by hand without a template. Care must be taken to ensure that the conduit does not kink or distort as it is being bent.

Once the conduit has been heated and formed into the proper bend, it must be held in the new shape until it cools. Water can be applied with rags or a sponge to speed up the cooling. This helps accelerate the entire bending procedure. If water is not used, it may take some time for the conduit to cool.



Figure 7-9. A ratchet cutter can be used to cut small-diameter PVC conduit. A mason's string makes it easy to cut larger sizes of PVC conduit in the field.

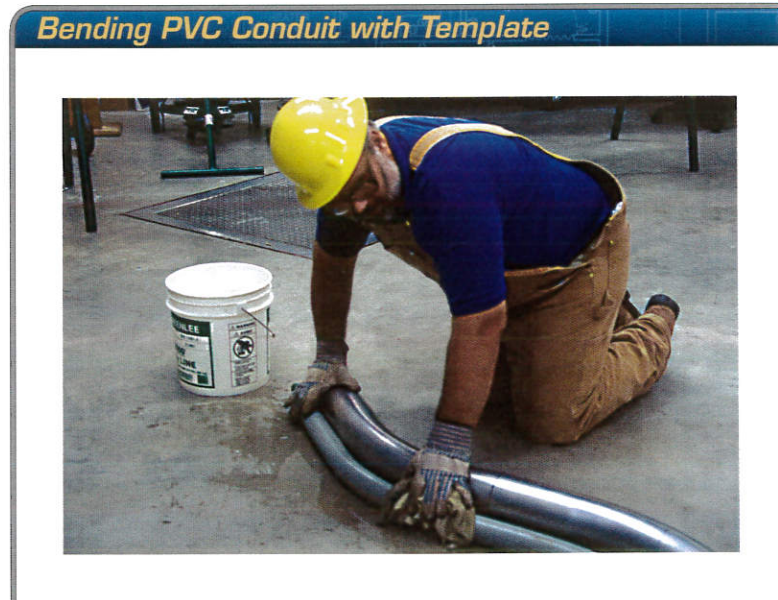


Figure 7-10. PVC conduit can be bent around a template. Water is often used to cool the conduit after it is formed to the correct shape.

Smaller-diameter PVC conduit can be easily bent to any angle using this process. Larger-diameter PVC conduit is more difficult to bend because an extremely large bend radius is required. Standard factory-made sweep elbows are available to replace a field bend. The use of elbows makes it unnecessary to bend the conduit and can speed up a job.

Tech Tip

PVC conduit should be checked for a dry fit before beginning. A loose fit may not cement together correctly. The conduit should not bottom out in the socket.

PVC Heaters

There are a number of tools available to heat PVC. They all have advantages and disadvantages. The most common heaters are hot boxes. Heating blankets or pads that wrap around the conduit and plug into an outlet can also be used. Gas torches can be used with a special nozzle to create a wide, diffuse flame to evenly distribute the heat. Glycol heaters have also been used but are seldom employed anymore.

Pipe plugs may be placed in the ends of the conduit to help the heating process along. Pipe plugs keep the hot air inside the conduit rather than allowing it to escape out the ends. The air trapped inside the conduit also helps keep the conduit from kinking or collapsing while it is being bent. This helps meet the NEC[®] requirement that rigid nonmetallic conduit not be damaged, nor its diameter reduced when making bends. See **Figure 7-11**.

PVC Pipe Plugs



Figure 7-11. Pipe plugs are used to keep heated air within the conduit and speed up the bending process.

Hot Boxes. A *hot box* is a PVC heating tool containing an electric heating element within an enclosure that holds the heat. See **Figure 7-12**. Hot boxes range from relatively small units designed to bend 1/2" conduit to larger units for bending 4" conduit. A small hot box may use 110 V, while a large hot box may need 220 V.

The key to using a hot box is to keep the conduit turning in the enclosure. If the pipe is not rotated, the side toward the heating element will overheat and blister. Rotation keeps the heat uniformly distributed over the entire bending area of the conduit. Some models have an electric roller system that turns the conduit automatically.

Hot boxes are reliable, easy-to-use machines. Their main disadvantage is that they require a power supply. Electric power may not be readily available when installing a large underground conduit system far from the electric utility.

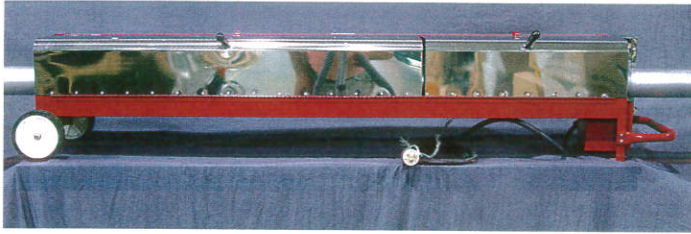
Torches. If electric power is not available, there are a number of torches available for heating PVC. These torches need to have an extremely wide flame to evenly distribute the heat and must be identified as suitable for the purpose. The key to using these torches to heat PVC is to keep the flame moving over the entire area to be bent. This ensures that the entire section will be heated properly and the conduit will not blister.

Glycol Heaters. Glycol heaters have not been available from manufacturers for some time but are still occasionally used in the field. These heaters used an electric or LP gas heating unit to heat glycol and pump it through a blanket placed around the conduit. Glycol holds heat extremely well, and if the glycol escapes the system, it can cause severe burns. If a glycol heater is being used on a job site, the electrician must understand the operational procedure before using it.

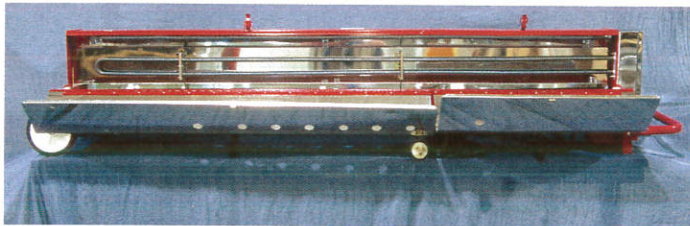
Tech Fact

Work quickly when joining PVC joints together. Assemble the joints immediately and hold them in place for about a minute until they begin to set. Wipe off any excess cement.

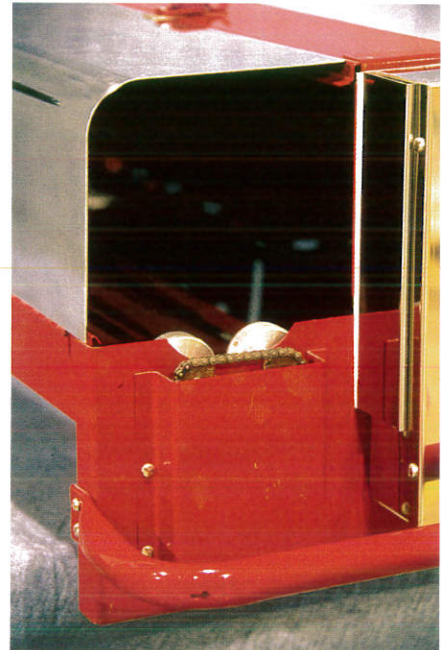
Hot Boxes



HOT BOX



HEATING COILS



ELECTRIC ROLLERS

Figure 7-12. A hot box can be used to heat PVC conduit for bending. A heating coil provides the heat, and an electric roller rotates the conduit for even heating.



SUMMARY

- In addition to the conventional types of conduit, metallic conduit is available in aluminum, stainless steel, silicon-bronze, and brass.
- PVC-coated conduit is often specified for use in corrosive industrial environments.
- For PVC-coated conduit, a common tool modification is to replace the jaws of a pipe vise with a three-sided adapter that spreads the clamping force over a larger area.
- If the PVC coating becomes damaged, it must be repaired with touch-up compound or special paint.
- Sections of PVC conduit are joined together.
- PVC conduit must be heated before bending.
- A hot box contains an electric heating element within an enclosure.

