7. Select proper air pressure as shown on page 25. The points to remember are:
   - to *Increase* heat, *Reduce* air pressure
   - to *Reduce* heat, *Increase* air pressure

   The welder is now ready to use, provided that the tip or high-speed tool has reached proper operating temperature.

It is best to have a small stand (See Below) in which to place the welder when it is hot. The stand will protect the welder from falling off the bench and also protect other equipment from the hot air stream.

Metal Welder Stand

After completion of welding:

Disconnect electricity before a welder is shut off. Allow the air stream to cool off the heating element and the barrel. The heating elements may burn out unnecessarily if the air is shut off first.

Changing heating elements:

There are two basic types of locking devices that hold the handle and the barrel together.

On models with a spring-loaded pin:

Locate the pin at the junction of the barrel and the handle. Place welder fiat on bench, with spring-loaded pin in upward position. Push in pin with the point of a screw driver. The barrel is spring-loaded and releases itself. Insert new heating element into socket located in the handle. Slide the barrel over locking pin until it snaps back into the hole.

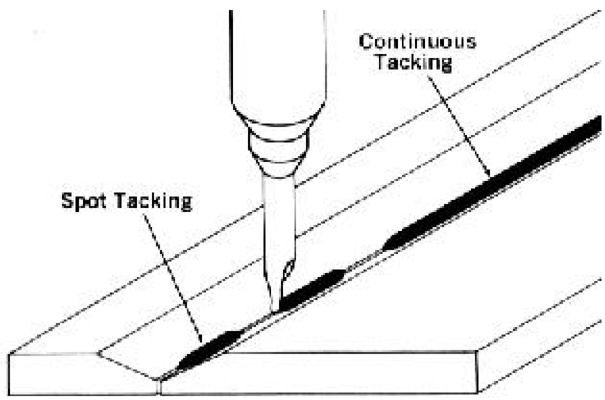
On models with spanner nut:

Hold welder at the handle and push the front of barrel against edge of a work bench. Take spanner wrench and turn spanner nut clockwise (the nut has a right-handed thread). Keep holding the welder against work bench until the nut is removed. The spring-loaded barrel will then release itself. Insert new heating element into socket, located in the handle.
Follow reverse procedure for the assembly.

CAUTION: Do not place barrel in a vise or any other device for the purpose of holding the barrel as this could indent the barrel, causing permanent damage.

Welding Operations

a) **Tack Welding:**



The purpose of tack welding is to hold pieces in place prior to welding. Tack welds have negligible tensile strength. They are simply a superficial fusion of the pieces and cannot be compared with the tensile strength achieved by welding with a rod or a flat strip.

Tack welds help to eliminate the use of clamps, jigs, or additional man power, commonly needed to hold

Tack welding Overview:

1. Screw a tacker tip into the threaded end of the barrel. Wait for about 1 to 2 minutes until the tip has reached its proper temperature.

Tacking Tip

2. Hold welder firmly in hand at an angle of about 80 degrees. The point of the tip should touch the material at the joint.

3. Initial tacks are made by drawing tacker tip quickly at intervals along the joint. Tacks should be about ½-inch to 1-inch long. Welder can then be drawn along entire joint for continuous tacking.

The basic material is now tack welded and ready for further welding.

The tack weld should not show any browned or burned spots. This would indicate that there may have been too much heat, or the tack was not made quickly enough, or a combination of both.

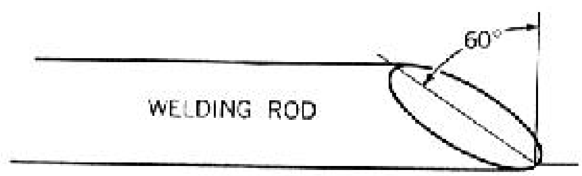
If the work pieces do not stay together properly, it is possible that no fusion took place due to insufficient heat, too quick a tack or a combination of both. Where the hand tacker tool is not available, tack welding can be performed by using a 3/32 inch welding rod and a round tip. The method is identical to hand welding (see next paragraph). Extensive jigging and additional manpower are usually required.

b) ***Hand Welding:***

The purpose of hand welding is to join two or more pieces permanently together using a rod or a strip as filler. Hand welding is recommended where difficult areas such as corners, short runs, and small radii are to he welded. In welding thermoplastics, fusion of rod and the base materials is achieved by the proper combination of heat and pressure.

The welder has to use both hands — one hand holds the welding gun, while the other hand holds the welding rod. Certain thermoplastic materials may produce obnoxious odors or even poisonous fumes when being welded. Precaution notices issued by the material supplier should be followed. If in doubt, weld in a well-ventilated area and avoid excessive inhaling of any fumes. Common welding goggles or helmets are not required.

Cutting pliers or a knife must be available to the welder to angle-cut the welding rod. The welding rod should be cut at an angle of approximately 60^0F before starting. One of these tools is also necessary for cutting the rod after welding.



Since PVC is the most widely used material in construction, the following instructions are based on this material. In addition, PVC is slightly more difficult to weld than other thermoplastics. It offers, however, possibilities of visual inspection during the welding operation, since PVC will decompose if not treated properly. The techniques for welding for other materials are almost identical.

The step-by-step procedure for hand welding rigid PVC with round rod:

1. Install a heating element that produces from 450^0F to 500^0F, and a round tip. Set the air pressure according to the recommendations by the manufacturer of the welder. Temperatures above 500^0F are for high-speed welding and not recommended for the beginner.

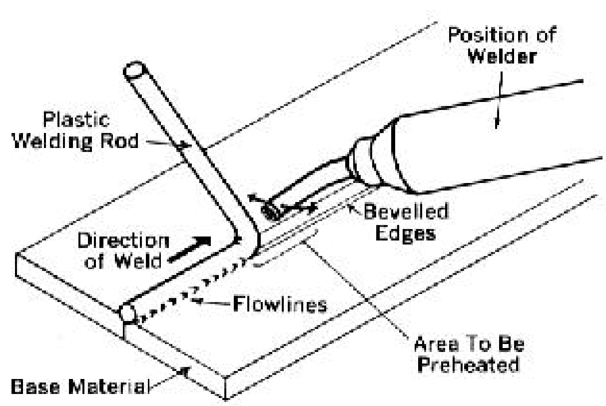
To determine the right amount of heat required for welding, hold the welder about 1/4 inch above a flat piece of PVC so that the hot-air stream is directed to that piece. Now speak the following: “one and two and three and four.” At that time, a slightly brown tinge should be visible.

2. Obtain a flat piece of PVC, about six inches long, two inches wide, and at least 3/32 inch thick. Clamp this piece securely to the workbench. Make sure that the surface of the plastic piece is clean.

3. Obtain a 1/8 inch diameter PVC welding rod and cut its end at a 60^0 angle.

4. Hold the welder in one hand and the welding rod in the other hand. Direct the end of the round tip to a point at least 1/2 inch away from the point where the weld should be started. Immediately begin a fanning motion. The hot-air stream should heat the area to be welded.

5. Move the welding rod up and down to touch the surface of the preheated base material until it becomes tacky. Hold welding rod vertically and apply pressure. Continue to supply heat by fanning motion so that about 60% of the heat is directed toward the base material and 40% to the mating surface of the welding rod.



6. It should take only a few seconds after the heating process begins for the welding rod to stick firmly to the base material. Now angle the rod slightly in the direction of the weld. Continue to supply heat in a fanning motion, so that the end of the welding-gun tip is aimed in line with the direction of the weld.

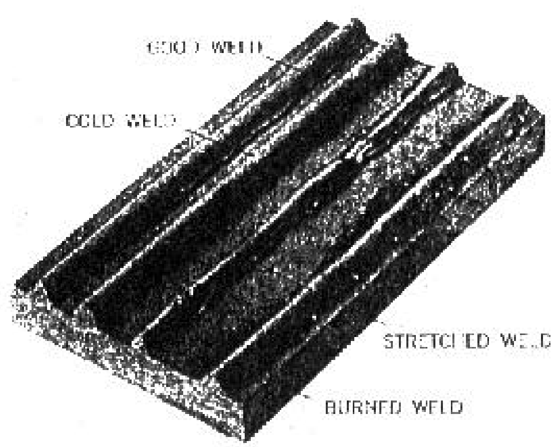
7. Bring rod back to a slight slant after about ¼ to ½ inch of the rod is joined to the base material. Do not Do not lean the rod toward either side of the weld bed.

8. Exert only as much pressure on the rod as is necessary to cause the two surfaces to fuse together. If too much pressure is exerted on the rod, it will stretch excessively. Subsequent welding against the stretched section will cause it to crack, because of the internal stresses created by the stretching.

9. Check for the appearance of flow lines along the sides of the rod, as well as the appearance of a small wave of semi-molten material in front of the bottom surface of the rod, as it flows into the softened base

base material. Insufficient heat on the rod will cause it to merely lie in the softened trough of base material without having fused to it. Both of these conditions, of course, mean an unsatisfactory weld. NOTE: A slight yellowing of the rod and base material is caused by slight overheating. This, however, is desirable during welding practice, to assure the beginner of having at least enough heat. It helps to eliminate the possibility of making cold welds. Once satisfactory welder manipulation is achieved, the beginner should gradually eliminate the yellowish tinge, but maintain the flow lines. Eventually, the beginner should produce cold welds intentionally in order to recognize them as such. They have no flow lines and minimum fusion takes place. This procedure should be repeated and alternated until the welder can rapidly from a cold weld or a hot weld to a good weld.

10. You can stop the weld at any point merely by withdrawing the welder from the welding area. The rod can then he twisted but not pulled off, while still soft, or cut with cutting pliers or a knife.



11. After the first satisfactory weld bead is laid and has cooled sufficiently for additional welding, lay a second and third bead against the original bead. Cooling may be accelerated by use of a wet sponge or a jet of cool air.

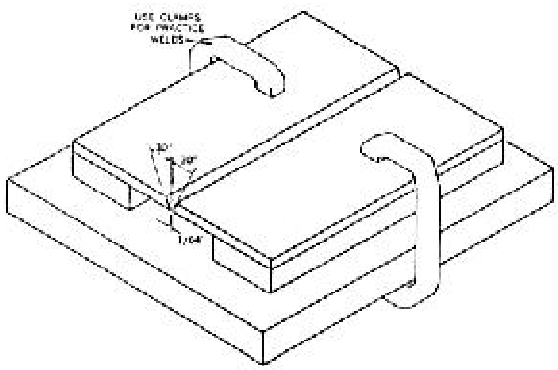
12. Direct the rod at an angle of about 45 degrees into the angle formed between the side of the first bead and the surface of the base material. Always allow cooling time between welds. This exercise should be repeated until you can lay consistently good welds.

The strength of the bead can be evaluated by trying to pick the rod off of the base material with a pair of pliers, while the weld is still hot. If it is a good weld, the rod will stretch and may break, but it will not part from the base material. If the rod lifts readily from the base material, there may have been insufficient heat, or too much heat. You should be able to tell which by checking appearance of the material.

13. After laying several satisfactory weld beads with 1/8 inch rod, different sizes of welding rods should be used in repeating the whole procedure. This will help in becoming familiar with the heat and weld time required to properly bond varying diameter rod. This may he tedious, but it is of primary importance.

Once you have mastered straight passes on a flat surface, you are ready to progress to the welding together of two pieces of material.

1. Take two pieces of material about the same size as the flat piece you used for practicing straight weld, and bevel one long edge on each, at an angle of about 30 degrees, with a 1/32 inch flat a the edge, using a sandpaper wheel, a file, or a block plane.



2. Place both beveled pieces on a shim above the bench top so that the area to be welded is suspended above the bench. Leave a root gap of about 1/64 inch between the two edges, to allow the material to flow through for a stronger bond. This will help you become familiar with proper temperature and pressure. The semi-molten material should flow through to the bottom side of the work. Penetration of the rod requires adjustment of temperature or pressure.

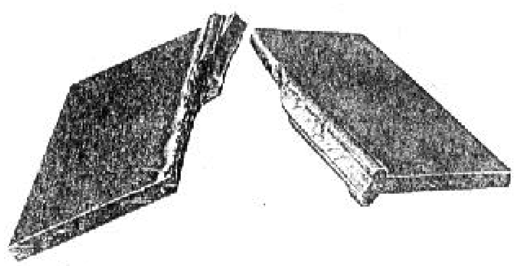
3. Use the same starting technique as described for flat welds. Lay a bead in the joint, allowing the softened undersurface of the 1/8 inch rod to flow into the weld root.

4. Repeat the same procedure with additional beveled pieces until good root passes are accomplished. Then proceed to run filler passes. It is essential for good welds that the weld bed be completely filled, with overlaps on the top beveled edges.

In order to determine the strength of these practice welds, the following test can be made:

Clamp one side of the cooled test piece into the jaws of a vise, with the weld-bead facing outward, about 3/16 inch and parallel to the top of the jaws. Cover with a loose cloth to prevent injury due to flying pieces. A blow with a hammer on the weld side will usually break off the top piece. If the weld is a good one, each broken piece will retain some portion of the welding rod, with the break occurring through the body of the rod. In an exceptionally good weld, the break will occur through the base material. This indicates a weld strength of 100%,

or close to it, of the strength of the base material. If the weld was overheated at any point, the pieces will usually separate at that point, and the browned portion will be readily visible, indicating the typical poor adhesion of overheated areas. If the rod or base material was under-heated, the break will also occur where the unheating occurred. NOTE: If there were no overlaps at the top of the beveled edges, the weld would normally break along the plane of the bevel. This demonstrates the necessity for filling welds.

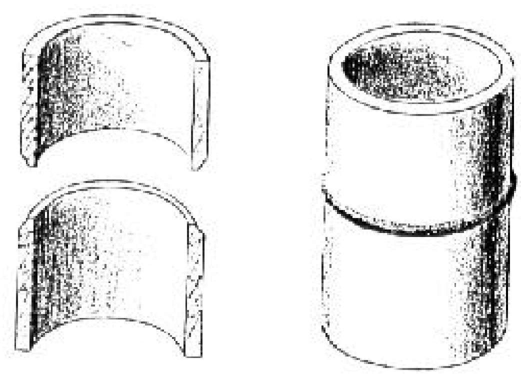


These exercises should he repeated until you can consistently achieve welds of adequate strength and good appearance. For most structural fabrication, a weld strength of not less than 75% of the strength of the base material is acceptable, although for certain critical fabrications, effort should he made to achieve as close to 100% as possible.

The techniques described above are for flat-surface work. Welding round material is essentially identical in all phases.

The one primary difference is this: In welding flat pieces, the arm moves the welder in the forward direction only; in welding round shapes, the welder has to go forward and follow in the direction of the round shape at the same time. This, of course, requires considerable additional practice. Suggested practice technique is using 2-inch diameter pipe, cut 1 inch long, with a bevel on one exterior end.

Welding around is then practiced by tacking and welding to a base sheet. For additional practice, it is recommended that the inside of the pipe be welded to the base plate. This aids in better manipulation with the rod and the welder. From here, the welder proceeds to practice the conventional butt welds with two sections of beveled pipe. Both sections should line up to a centerline. A flat on the bevel is essential. The same technique applies for round-duct butt welding.



It is best to start a weld as far to one side as possible so that it can be made with as few interruptions as possible if a complete circumferential weld cannot be made.

High-speed hand welding with round rod

The step-by-step procedure for high-speed hand welding of rigid PVC with round rod is as follows:

1. Obtain a flat piece of PVC, preferably 18 to 24 inches long, two inches wide, and at least 3/32 inch thick, and clamp it to the work bench or table.

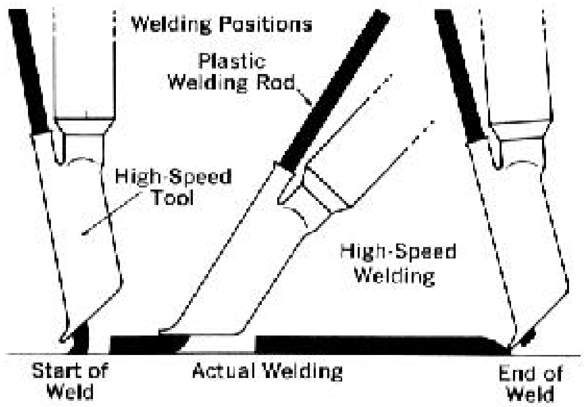
2. Select the high-speed tool designed for use with the diameter of welding rod to he used. The cold rod should fit the tool loosely. Prepare the rod by cutting one end at a 60^0 angle.

3. Conned the welder to a source of either compressed air or inert gas. Turn on air to desired pressure. Connect electricity (115 volts A.C.) and allow the unit to warm up.

4. Hold the welder upright in the hand, as illustrated.

5. Hold the shoe of the high-speed tool about one-half to three-quarters of an inch above the surface of

6. Quickly insert the beveled welding rod into the pre-heating tube, and push it into the softened base material until the rod bends slightly backwards.



7. Decrease the angle of the welder to about sixty degrees In thin direction of the weld, and push on the top surface of the protruding section of rod until it starts to adhere to the surface of the material.

8. Continue to exert pressure with the shoe, and start pulling the welder in the direction of the weld. At the same time, help the rod into the pre-heating tube by exerting light pressure by hand.

9. Continue to pull the welder along in the direction of the weld. Always press on the top surface of the rod with the shoe. The weld should proceed at the maximum speed that fusion of the rod to the base material allows.

10. Once the weld is properly started there can be no hesitation. Continue to pull the welder along in the direction of the weld, and the rod will feed through, being pulled by its adhesion to the base material. If necessary, because of slight overheating due to hesitation, the rod should he helped through the tube. The speed of the weld can be increased by depressing the angle of the welder even lower, to about forty-five degrees, The maximum possible speed can be attained in this manner. The portion of the rod emerging from the end of the pre-heating tube, below the shoe, will show flow-lines similar to those visible in hand welding. The crown, however, will be higher. If the welder is not moved quickly enough, the rod may soften excessively and bunch up in the pre-heating tube, sometimes charring or burning. This condition can be seen readily, because the emerging end of the rod will soften, flatten out, stretch, and

will usually break. A rod in this condition is impossible to control and will make a poor weld. When this occurs, the welder should be quickly withdrawn, and the rod cut with pliers or twisted off a the last point where good adhesion or bonding occurred. If the rod is not removed quickly enough, some residue will usually be left in the pre-heating tube. This may be removed by pushing a cold rod back and forth through the tube until it is cleared.

As in hand welding, absence of flow lines indicates a ‘‘cold’’ and unsatisfactory weld.

11. Observe the emerging rod constantly, so that corrective action can be taken immediately, as soon as unsatisfactory conditions are evident.

12. If the rod is stretching, the weld is going too slowly and the rod is overheating. When this occurs, withdraw the welder, cut off the rod, and make a new start before the point where the rod started to stretch excessively. If flow lines do not occur, the weld is going too fast, and adequate bonding is not taking place. In this case, recovery can sometimes he made by bringing the welder back up to an angle of ninety degrees, and continuing at that angle for a few inches, gradually bringing it back down to the sixty-degree angle. Any poorly welded section must be completely removed and rewelded before proceeding. The rate at which the weld proceeds is governed by the temperature, the consistency of the rod, and the angle of the welder.

13. Make sure that the pre-heating orifice in the high-speed tool is aligned exactly in the direction of the weld, so that the pre-heated rod will bond into the center of the pre-heated base material.

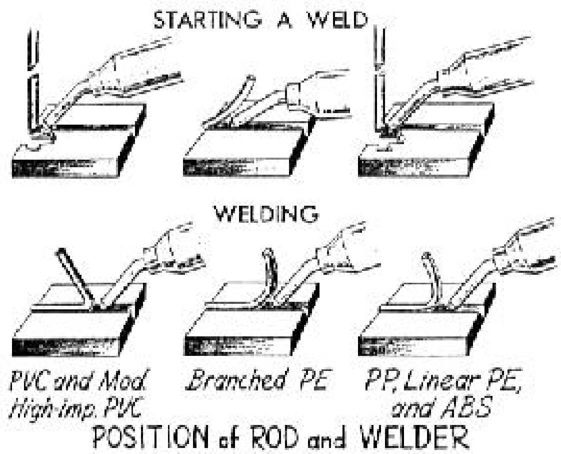
14. To stop a high-speed weld:

Withdraw the welder quickly until all welding rod is out of the tube, or bring the welder quickly to the ninety-degree angle, so that the sharpened edge of the shoe will bear on the softened top surface of the rod. Press down toward the base material. This will cut the rod. Quickly remove rod from the tube.

15. A good single ‘V” speed weld will have a slightly higher crown than a hand weld, and will have a much more uniform and smoother appearance than a hand weld, and the flow-lines will usually be somewhat less prominent.

remove residue.

The same techniques should be applied to all other types of welds. Small-radius welds should not be made with a high-speed tool because of the speed and difficulty in controlling the weld. The techniques mentioned here are for welding PVC. High-speed hand welding of polyethylene and polypropylene is slightly different as it requires more heat.



High-speed hand welding of flexible PVC with a plastic strip

A flexible plastic strip is used instead of a round rod primarily for tank linings arid similar applications. Plastic strips come in different shapes such as the flat strip or the corner “V’’ strip, and they are generally supplied in roll form. Unlike the rod, where several passes are usually required, only one pass is necessary with a strip.

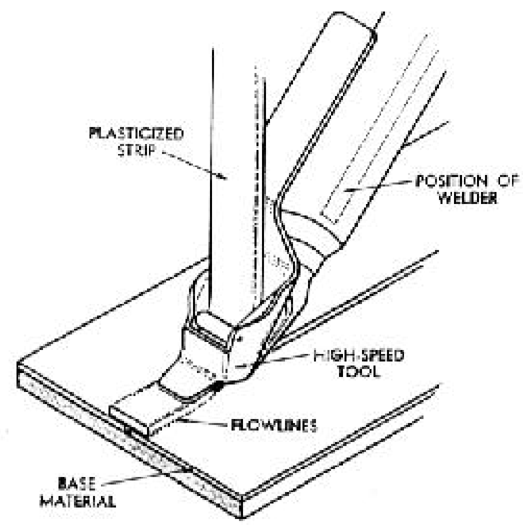
The technique of welding with a strip is similar to that of welding with round rod, with the following exceptions:

1. The strip must be pre-cut into the length required, with an addition of about one to two inches for trimming.

2. Start the weld by tamping with the broad shoe of the especially designed high-speed tool on the top of the first inch of strip, in the direction of the weld. Do not drag the welder for the first inch, until the first inch

of the plastic strip adheres firmly to the base material. The welder should be held at an angle of about 80^0, and some pressure by hand should be applied to hold the top of the strip down.

3. Guide the strip by hand and continue the weld at sufficient speed. Flow lines should form on both sides of the strip. If the proper speed is not maintained, the strip will soften and stretch because of excessive heat. This condition can he corrected by a quick tamping motion with the shoe, as used to start the weld. Proceed then in the direction of the weld.



4. To stop a weld, simply remove the welder and allow the remaining strip to pull through the high-speed tool.

If a strip weld is to be made from corner to corner, such as the bottom of a tank, the weld should be started in one corner and proceed only halfway across. Then start in the other corner and overlap the scarfed end of the first weld. Since mitering will not ensure a perfect bond, and each strip butts to the other, additional flat strip overlays are necessary. A flat tip pre-heats the area while the flat strip, held in a gloved hand, is pressed firmly into the corner. All high corners can be heated and pushed down with the blunt end of a knife,

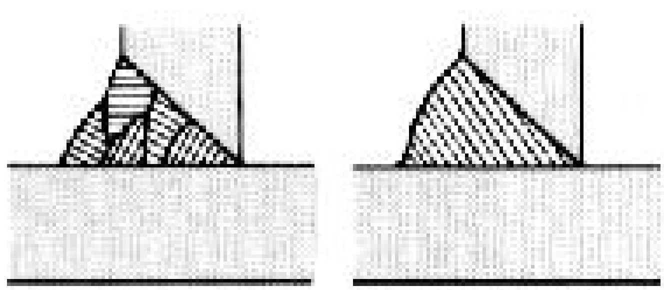
All other weld ends can he heated by a flat tip and pressed down flat with a blunt end of a knife handle in order to make a good seal and also to improve the appearance of the welded strip joint.

It is possible to hand-weld strip by using a flat tip in the welder, but the high-speed tool will provide a considerable increase in speed. The strip has to be held by hand. The hand should be protected from the hot air by a heavy glove. For more details on strip welding see “Lining of a Plasticized tank’, page 103.

Welding flat strip with a round tip is not recommended due to uneven heat distribution. Linear polyethylene and polypropylene in gauges from to 1/16 to 3/32 inch can be welded successfully by hand, using a flat tip or a high-speed tool.

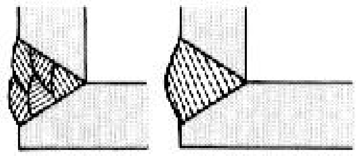
TYPES OF ROUND-ROD WELDS

Inside Corner Welds



Tack weld the pieces into position, either with tacking rod, laid in 1 inch beads spaced along the length of the joint, or by use of the tacker tip, in which case the two pieces will he tacked together along the entire length. Start several inches from the corner, as it is nearly impossible to start a weld satisfactorily in the confines of the corner. Lay the root bead at the junction of the sides and bottom, running it continuously past the corner on a horizontal plane. When the vertical weld is run, make sure it overlaps the horizontal weld, giving maximum strength to the joint, and forming a positive seal. In making tanks, it is preferable to form the corners, and weld on the flats. Where this is not feasible, the inside corner weld is the preferred technique. Because welds in tanks are subjected to considerable pressure, the fusion of the rod and base material must be complete.

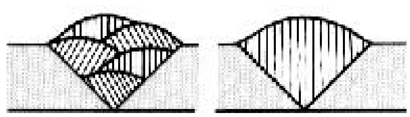
Outside Corner Welds



Round Rod Triangular Rod

Tack weld the pieces into position, either with tacking rod, laid in 1 inch beads spaced along the length of the joint, or by use of the tacker tip, in which case the two pieces will be tacked together along the entire length. If the material is 1/8 inch thick, a 5/32 inch diameter rod will fill the corner. If a 3/16 inch material is used, lay the first bad with a 1/8 inch rod, allow to cool. Then the second and third beads should be laid with 5/32 inch rod.

Single “V” Butt Welds



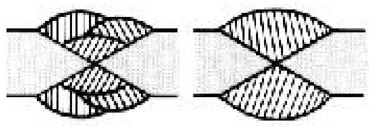
Round Rod Triangular Rod

The single “V” butt weld is used in joining sheets, where only one side of the sheet to be welded is accessible.

The edges of the sheet to be welded are beveled to an included angle of 60^0. A root gap of approximately 1/32 to 1/64 of an inch is left between the joining sheets to insure full weld penetration. In making a single “V” butt weld, the first pass is made a the bottom of the weld-bed, after tacking. Passes are then made along the edge of first one sheet and then the other so that the weld is built up evenly. If the back area of a single “V” butt weld is accessible, a single bead on the back will provide additional strength for this type of weld. When using 1/8 inch material, one 3/16 inch rod will usually fill the “V” and overlap the edges. For 3/16 inch material, the first bead should be laid with 1/8 inch rod, and for a good overlap, two additional beads, of 5/32 inch rod, will give maximum strength.

Note: A single “V” weld, reinforced with a 1/8 inch rod pass on the other side will be usually stronger than a double “V” butt weld.

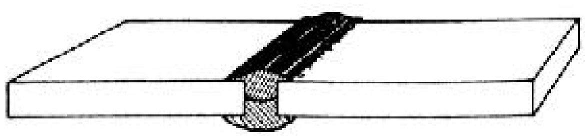
Double "V" Butt Welds



The double 'V" butt weld shown in the sketch is the second strongest type of weld for joining two pieces of sheet plastic. It is used principally in work that can be welded from both sides of the sheet.

In preparation for the weld, the sheets are beveled to a 60^0 included angle on both sides of one edge of each sheet. This beveling may be accomplished by a planing, filing, sanding, or sawing operation. To insure complete penetration of the weld, a root gap of approximately 1/32 to 1/64 of an inch is maintained between the two sheets prior to tacking. All beveled edges should be overlapped.

Square Butt Welds

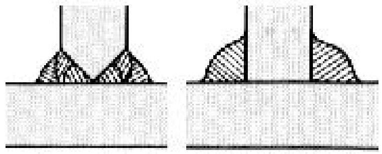


Square butt welds are used on light-gauge sheets through 3/32 inch. No preparation of the edges is required other than cleaning. A root gap of 1/64 of an inch is used to allow for full penetration of the weld.

In welding two plastic sheets by the butt-weld method, the sheets must be held together on a flat surface by some type of clamping device or by being weighted down. Two passes are recommended in making a square butt weld – the top pass and a pass on the under side.

The square butt weld is an acceptable weld for all ordinary loads. It is simple to make and is used where cost is the principal consideration. In making a square butt weld, care should be taken to be sure there is complete fusion of the edges of the sheets.

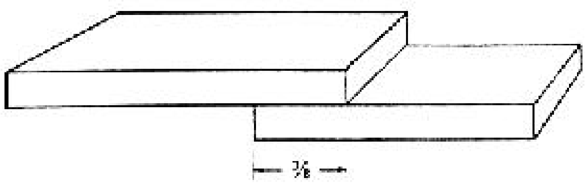
Fillets and Corner Welds



Fillets and corner welds are used where it is desired to attach two sheets of plastic at 90^0 to each other. Beveling is the same as for ''V' butt welds, except that only one sheet need be beveled. To produce the best welds possible, it is advisable to bevel and weld both the inside and the outside of the sheet.

The piece abutting the base material should be beveled, or undercut, as illustrated, for maximum strength. This beveled section will require more rod, which will also add to the strong of the joint.

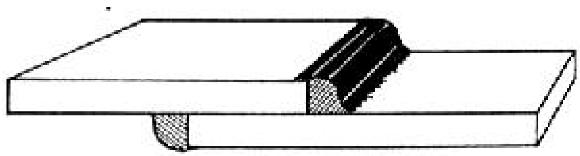
Lap Welds



Lap welds are recommended for thin sheets of plastic – 1/16 inch or less. The principal requirement in making a lap weld is to be sure the faces of the sheets forming the lap are thoroughly clean before joining them together in a lap weld. The lap of one sheet over the other should be at least 3/8 of an inch to insure a good lap-weld bond. No welding rod is used. The overlapping areas are fused together by using a flat tip with following pressure.

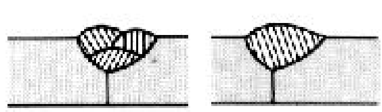
The *rosette weld* is a modification of the lap weld. It is used primarily for joining two layers of plastic. In preparation for this weld, alternate holes are drilled in each sheet and the welding takes place inside these holes. The diameter of each hole, and the spacing between holes, is at least three times the thickness of the plastic sheet. Using welding rod whose diameter is slightly less than the thickness of the stock, the operator makes a spiral weld that secures the bottom sheet to the one that is lapping over it; the spiral weld is continued until the hole is filled and both sheets are joined. The procedure is repeated for each hole.

Over-lap fillet welds



Two sheets are joined in the angles at which they overlap, in addition to being lap welded as mentioned before.

Edge Welds



Edge welds are used to obtain maximum cross-section. An edge weld is a form of scarf joint, made by chamfering the edges of the sheets at an angle of 30^0 degrees, butting the chamfered edges, and welding.

Faulty Welds

Faulty welds are the result of the following errors that sometimes occur in plastic welding.

1. Overheating
2. Underheating
3. Improper root-penetration
4. Air-inclusion in the weld
5. Stretching of filler rod
6. Incorrect handling of welder
   a. Wrong angle
   b. Too slow or too fast travel
   c. Lack of fanning motion

   d. Heat too close or too far away from work
   e. Heat source not centered on weld bed
7. Incorrect gas used for heat source
8. Improper or no bevel preparation

As stated before, a good plastic weld requires the following:

1. Thorough root-penetration
2. Proper balance between the heat used on the weld and the pressure exerted on the welding rod
3. Correct handling of welder
4. Correct sheet preparation

To insure complete root-penetration, the welder must make certain that the proper gap is maintained at the weld root, on both single ‘V’ and double “V’ butt joints.

Overheating of the weld is a common fault with the novice plastic welder. By paying close attention to the color of the weld, the welder can tell whether overheating is occurring. When PVC is overheated, it will begin to discolor from a yellowish tinge to a brown, and eventually will char. When PP or PE is overheated, it will become transparent and eventually flow away like hot wax from a candle. ABS will show decomposition craters.

Underheating of the welding rod, the base material, or both, will also result in a poor weld.

Whatever the cause, a poor weld bead should always be removed from the weld bed and a new weld made. Under no circumstances should a new pass be laid over a burnt weld or one not properly bonded.

The novice welder has a tendency to push the welding rod rapidly into the weld before the heat from the welding gun has brought it up to the proper temperature. This results in a stretched-rod pass, which creates locked-up stresses in the weld. The release of these stresses by subsequent passes or by service-impact loads, will result in weld cracks or separation.

length of the pass. The latter should not be more than 10% greater than the length of rod used.

Correct handling of the welding gun is of utmost importance. Fanning motion of the round tip for hand welding should be continuous and at the correct distance from the work, for proper heating of rod and base material. The travel of the welder across the weld bed should be fast and with a decisive motion, with no hesitancy once the weld has been started.

WELDING GASES

In hot-gas welding of polyethylene and other readily oxidizable plastics, an inert gas such as nitrogen is used as the heat-transfer medium. The water-pumped grade of nitrogen is recommended. Compressed air is completely satisfactory for carrying heat to PVC.

PLASTIC WELDING ROD

The simplest type of plastic welding rod or filler rod is a strip cut from a sheet of the plastic to be welded.

The most common type of welding rod furnished commercially is extruded round rod available in various standard diameters. It is available in lengths of approximately 60 inches. It is also available in triangular or oval shapes, for specific applications. The welding rod should be of a size to permit a minimum number of passes for any material thickness. An overlap of the beveled edges by the welding rod is essential to produce a good weld.

The welding rod should be cut to a length to suit the actual welding requirements. A few inches extra length for final trim should be allowed.

Flexible welding rod is usually coiled, and cut to requirements.

HEATED-TOOL WELDING

Heated- tool welding is a evolution from the art of heat -sealing thin plastic film. It consists of the use of a heated tool or fixture to bring the plastic to the fusion temperature.
Heat is applied directly to the surface of both plastic pieces to be joined. The plastic is kept in contact with

the heat source until there is sufficient flow of molten material to form a good weld bond. When the plastic has reached the proper flow temperature and there is indication of a good flow-pattern and softening of the plastic, it is removed from the heated surface and is quickly joined with another plastic piece or sheet that has been simultaneously prepared. The two are firmly secured together in the desired position or shape and held until the plastic has cooled, thus forming a firm welded joint.

A slight pressure should be maintained between the joining surfaces. The pressure range necessary to make a good bond is between 5 and 15 pounds per square inch of surface. In most applications it can be applied by hand. For production-type work, jigs are used to apply the pressure.

Heated-tool welding can be accomplished in a number of ways. The use of electrical strip, bar, or hot-plate resistance-coil heaters are the methods most common in the industry. In some applications, gas or steam is used as the heating medium. Even a soldering iron can be used to make a heated-tool weld under certain conditions. The material generally used for the surfaces of hot-plate, bar, or strip heaters is aluminum or nickel-plate. Steel or copper, when hot, has a tendency to decompose plastic and should not be used, especially with polypropylene. Aluminum is used to a great extent in the manufacture of hot-plates, and with very satisfactory results.

The technique for making a good heated-tool weld depends on the proper temperature of the heater and the time-lapse between removal of the heated plastic from the hot-plate awl the joining of the two pieces.

The facilities for making heated-tool welds should be so set up that the time-interval between removal from the hot-plate and the clamping or holding operation is kept to an absolute minimum. The strength of the weld decreases as the removal-time increases. The optimum time is in the range of a few seconds from the heated state to joining.

The temperature required to insure good flow or molten plastic for heated-tool welding is high. Indicating pyrometers for accurate reading and control of temperature are found in the more up-to-date heated-tool installations. The temperature range in heated-tool welding is in the vicinity of 400 ^{0}F to 650 ^{0}F depending on the weld size. Correct temperatures can be determined from a practice run on the last plastic to be welded. There should be sufficient flow for proper fusion after about 10 seconds of heating.

Another important application of heated-tool welding is the joining of plastic sheets to form larger areas type heaters and suitable jigs for holding, moving, and maintaining pressure on the sheets during bonding. A weld of this type has the same strength value as the plastic sheet itself. The heated-tool welding method is most applicable to the polyolefins discussed in this handbook.

INDUCTION WELDING

Induction welding of plastic, as the name implies, is fusion of two pieces of plastic by electrically induced heat.

The heat of fusion is obtained by causing a high-frequency electric current to flow in a metallic insert such as a wire screen, a coil of wire, a die-stamped metal foil, and/or metallic conducting particles intermixed with the base resins near the face of the plastics to be joined together.

The localized heat caused by the flow of the electric current through the metal insert is sufficient to bring the surrounding area to fusion temperature. Pressure is then applied to the two pieces of plastic, bonding them together.

Induction welding is one of the fastest and most versatile methods of joining plastics together, and it results in an acceptable bond.

The disadvantages of induction welding are: the metal insert remains in the finished product; the cost of induction-welding equipment is high and the weld is not as strong as that obtained with other methods of heating.

Although the weld-strength of induction welding is not as high as that obtained by other plastic welding methods, it is satisfactory for many applications. Using a wire screen insert, a weld-strength of 50% of the strength of the plastic itself may be realized.

FRICTION WELDING

FRICTION WELDING together until friction, generated by spinning motion, develops sufficient heat for fusion of the two surfaces. Pressure has to be applied at the same time.

The technique of spin welding involves rotation of one thermoplastic piece against the other one which is held stationary.

The principle advantages of spin welding are the speed at which it can be accomplished and the simplicity of the technique. Standard equipment found in process shops, such as lathes and drill presses, is easily adapted to spin welding.

Because of the fact that thermoplastics are poor heat conductors, frictional heat required for spin welding is produced almost immediately while the temperature of the material immediately below the surface of the weld remains unchanged.

Spin welding results in good joint strength and appearance.

The principle disadvantages of spin welding are its limitations to circular areas. This, however, can be corrected by making the circular weld part of a non-circular article. Another disadvantage is squeezing or flashing out of soft material beyond the weld area before the weld has been completed. This can be corrected by designing the weld so that excess flashing is directed to the internal area of the item being welded.

In order to avoid overheating and to maintain proper pressure, the spin-weld cycle should be only long enough to insure complete fusion. The shorter cycle of welding operation reduces the flash and the resultant internal stresses. The internal stresses affect the tensile and impact properties of the welded article.

Spin welding is used extensively in the process industries for the frictional welding of instrument knobs, bottle sections, tool handles, container caps, pipe, pipe fittings and other similar applications.

Friction welding is also adaptable to welding discs on plastic sheets for repairing and for sealing thermoplastic containers for liquids.

WELD INSPECTION

The procedure for testing of hot-gas welds in plastic material has be established by American Society of Testing Materials, and the Societies of Plastic Industries, and by self regulation of plastic fabricators.

Inspection and testing of plastic welds are divided into three general categories.

(a) Destructive
(b) Non-destructive
(c) Chemical

The strength of a plastic weld is dependent on a combination of these six (6) factors.

1. Strength of base material
2. Temperature and type of welding gas
3. Pressure on welding rod during weld
4. Type of weld
5. Preparation of material before weld
6. Skill of welder

Destructive Testing

Tensile- Strength Test

A section of the unit weld is cut out as a test specimen, and tested in accordance with American Society of Testing Materials and Society of Plastic Industries testing procedures; see Section 7, Testing.

Non-destructive Testing

Visual Inspection

It is essential that the weld be properly inspected and evaluated before the part having the weld joint is put into actual service.

A plastic weld can be partially evaluated for strength and bond by visual examination of the weld bead. Incomplete weld penetration can produce a weld that appears sound from visual inspection but can be actually defective.

A good weld will have flow lines or little wave-like lines along each side of the deposited weld rod and will show no signs of decomposition. If these flow lines are present, continuous, and uniform, it is visual evidence of a good weld. The continuity of these flow lines indicates there was sufficient heat on weld rod to create flow and correct pressure on rod, by welder, to force the hot viscous material out of the weld bed, bonding the plastic parts together.

It is difficult to detect air inclusion or cracks in localized sections of the weld joint. An ordinary inspection light held obliquely to the weld angle will show air inclusions *farily* well, provided, of course, the plastic is not pigmented. The light-inspection method is limited in scope to clear or translucent plastics.

Spark-Coil Testing

One of the best methods of plastic-weld inspection is the use of a high-frequency, high-voltage spark tester that will show pores and cracks, in a weld that are not visible by any other inspection method.

The spark-coil tester sends a line of sparks through the cross section if the weld is porous or cracked. Porosity is indicated by a straight line of sparks passing through the weld to the metal ground.

The voltage rating of the coil may vary from 5,000 to 30,000 volts depending on the thickness of the plastic ground liner and the magnitude of porosity required by the inspection specifications.

The usual spark-coil tester used in plastic-weld inspection is in the 10,000- to 15,000-volt range, the average being 8,000 volts. Care should be used not to apply voltage that could *create porosity* by inducing decomposition.

In using a spark-coil tester, the pencil tip of the instrument is run along the weld area. If sparks appear, there is porosity in the weld. In testing welds on units with no metallic parts, a ground must be provided for the spark-coil tester. This is accomplished by use of metal foil, or electrical conducting paint to create the ground connection.

Radiography

Radiography is perhaps the most efficient method of plastic weld inspection because it shows defects in a plastic weld that are not readily discernible by any other inspection method. It gives a complete, detailed picture of the weld joint, and a permanent record of the weld. The one disadvantage of radiographic weld inspection is cost. Inspection of welds on a large unit or assembly by radiography would be expensive. However, this expense can be justified when the unit is to handle dangerous chemical materials where weld failure would be disastrous.

Chemical Test

Immersion of a PVC-weld test-specimen in acetone for two to four hours is a chemical method of plastic-weld inspection. Faulty welds will separate from the base material, and strains and stresses in the weld will be indicated by swelling of the material. Another chemical inspection of plastic welds is by the dye-penetrant method. A dye penetrant is painted or sprayed on a weld. A poor weld will be disclosed by the penetrant seeping through and discoloring the weld.

In cases where it is known that the temperature and chemical action on a plastic will approach the chemical limits of the material, weld specimens should always be tested chemically. Butt welds and corner welds should be immersed in the chemical intended to be used, put under stress, and the proposed temperatures maintained. If stress cracking occurs, or a weld separation is evident, the material is unsatisfactory for this service.