GOODBURN

PRINCIPLES OF PLASTIC WELDING

The welding of plastics is not unlike the welding of metals. Both methods use a heat source, welding rod and similar types of finished welds, such as butt joints, fillet welds, lap joints, etc. Joints are bevelled and otherwise prepared in much the same manner and similarly evaluated for strength.

Due to differences in the physical characteristics of each material, however, there are notable differences between welding metal and welding thermoplastics. It is standard practice with hot gas welding to butt-weld with a chamfer of 60º to 70º on both edges of the sheet. With high-speed welding, it is advisable to increase the chamfer to 80º and the same applies to repairing cracks.

When welding metal the rod and parent material are made molten and puddled into a joint. Metals have a sharply defined melting point at which the metal becomes molten, or melt. Thermoplastics are poor conductors of heat and thus difficult to heat uniformly. Because of this the surface of a plastic rod or parent material will char or burn before the material below the surface becomes fully softened. The decomposition time at welding temperature is shorter than the time required to completely soften many thermoplastics for fusion welding. The plastic welder, therefore, must work within a much smaller temperature range than the metal welder.

Because plastic welding rod does not become completely molten and appears much the same before and after welding, to one accustomed to welding metal a plastic weld may appear incomplete. The explanation is simple, since only the outer surface of the rod has become molten and the inner core has remained hard, the welder is able to exert pressure on the rod forcing it into the joint to create a permanent bond. When heat is taken away the rod reverts to its original form. Thus, even though a strong permanent bond has been obtained between the welding rod and base material, the appearance of the welding rod is much the same as before the weld was made, except for molten flow patterns on either side of the bead.

Technically speaking, all thermoplastics can be welded. Their ability to be welded is governed only by the extent of their melting range; those with the widest melting range are easiest to weld and therefore in greatest demand among plastic fabricators. Two of the most popular thermo-plastics are polyvinyl chloride (PVC) and polypropylene.

Approximate Welding Temperatures

ABS	350ºC
Acrylic	350ºC
Hard PVC	220 - 300ºC
Hypalon	600ºC
Polycarbonate	350ºC
Polyethylene (Hard)	250 - 280ºC
Polyethylene (Soft)	270 - 300ºC
Polyisobutylene	600ºC
Polypropylene	300ºC
Polystyrol	250ºC
Polyvinylidene Fluoride	350ºC
Lucobit	600ºC

The temperatures are based on 20º ambient temperature. When the ambient temperature is 0ºC the welding temperature should be increased by 10% to 20%. Excessive increase of welding temperature will result in burning the weld and will not speed the welding process.

Tack Welding

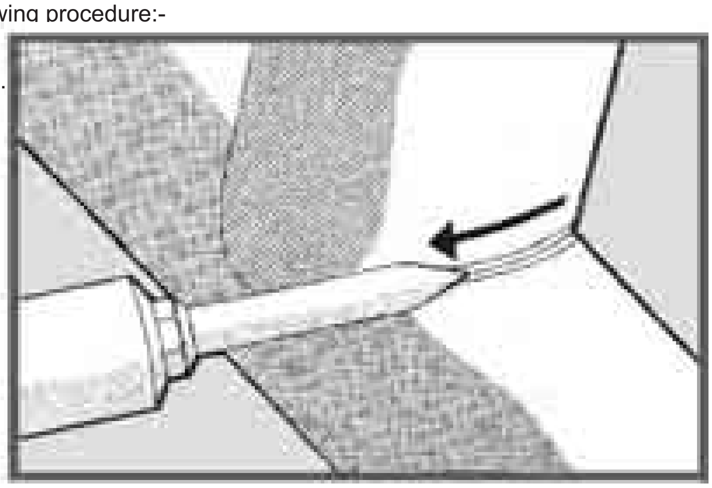
One disadvantage of welding polyethylene and PVC is that parts to be welded have to be tack welded to hold them into position. In many cases these tack welds are removed in stages prior to welding as work proceeds. Most welders, however, do not take the trouble to remove the tack welds and simply weld over them leaving humps along the weld line. As well as being untidy in appearance these humps may contain trapped air with a consequent lack of weld efficiency. Tacking with a special tacking nozzle enables the operator to produce a continuously tacking seam of unlimited length and to eliminate the danger of trapped air. Labour costs are reduced as it is no longer necessary to remove tack welds. Tacking is an important preliminary step.

Tack welding polyethylene, PVC and polypropylene involves the following procedure:-

1. The tacking nozzle should be attached to the torch.
2. Parts to be tacked should be held together with clamps or by hand.
3. The torch should be held in the right hand so that the nozzle is in contact with the material to be tacked. The torch, held at an angle of 45º, is then drawn along the seam with slight hand pressure at a speed of 30-40 inches (750-1000mm) per minute similar to the way one draws lines along the edge of a ruler with a pencil. Very large seams can be held temporarily held with half-inch (12mm) welds at five-inch (120mm) intervals to be covered subsequently with a full length tack weld.

Tack welds of this type have very little strength and are only made to assist the work of the welder.

Do not remove tacking tip until cool as the threads could strip or bind. Special nozzles are available which combine a swingback tacking shoe with slow or high speed nozzles and eliminate the need to change nozzles during welding.



Tack welding

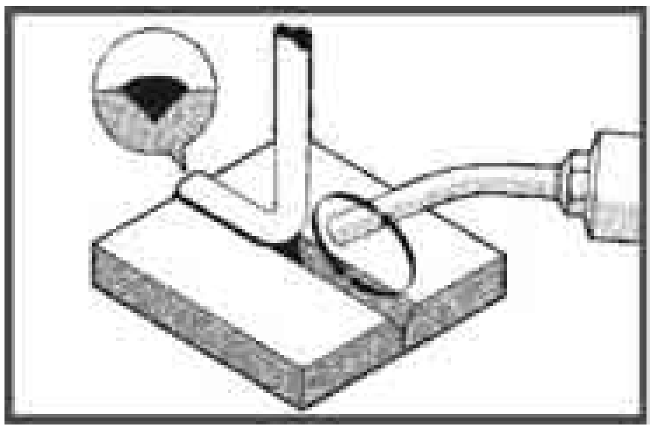
Low Speed Welding

In the welding of plastics, materials are fused together by a proper combination of heat and pressure. With the conventional low speed welding method, this combination is achieved by supplying pressure on the welding rod with one hand whilst at the same time applying heat to the rod and base material with hot air from the welding torch. Successful welds require that both pressure and heat be kept constant and in proper balance. Too much pressure on the rod tends to stretch the bead and produce unsatisfactory results. Too much heat will char, melt or distort the materials.

Starting the Weld

Holding the torch with the tip 1/4" - 3/4" (6 -20mm) from the material to be welded, preheat starting area on the base material and rod until it appears shiny and becomes tacky. Hold the welding rod at an angle of 90º (for polyethylene, polypropylene, fluorcarbons, etc., the angle should be 45º) to the base material and move it up and down slightly so that it barely touches the base material. When heated sufficiently, the rod will stick to the base material. To maintain the correct balance of heat, the torch should now be moved in a vertical fanning or weaving motion so as to heat both the rod and base material equally. At the same time the rod should be pressed into the material with a slight downward pressure (approximately 3lb - 1.5Kg). When a molten wave becomes evident where the rod meets the base material, the rod should bend and begin to move forward. Over-heated rod becomes rubbery and makes the application of even pressure virtually impossible. Overheated base material will char or melt causing an unsatisfactory bond.

When welding plastic a good start is essential, for it is in the starting point that welds most frequently fail. For this reason starting points on multiple bead welds should be staggered whenever possible.



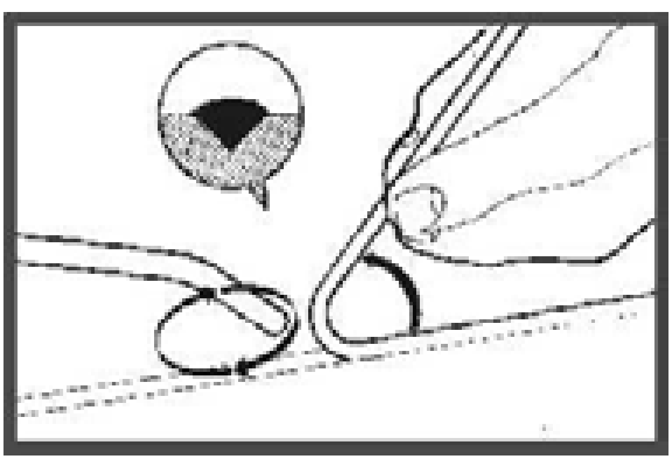
Low speed welding

Continuing the Weld

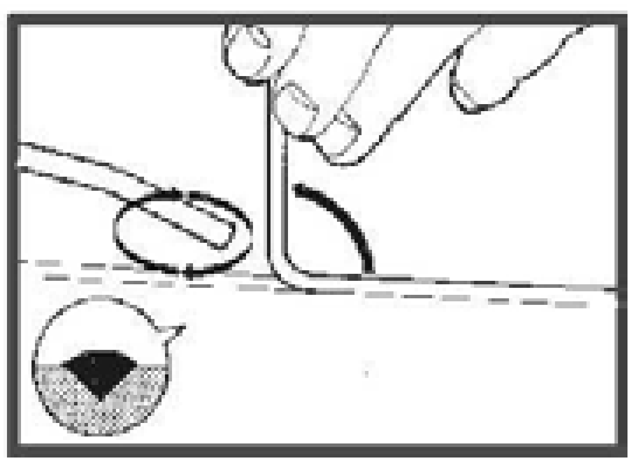
Once the weld has been started the torch should continue to fan from the rod to the base material with approximately two full oscillations per second. Because the welding rod has less bulk than the base material it heats more rapidly. To compensate for this difference the arc of the fanning motion should be concentrated on the base material approximately 60% of the time when using 3mm rod. The fanning motion should heat 1/2" (12mm) of the welding rod and 3/8" (10mm) forward of the rod on the base material. Average welding speed should be 6 to 8 inches (150-200mm) per minute.

Correct Angle of Welding Rod

When welding PVC the rod should be held at an angle of 90º to the base material. Although greater welding speed can be obtained by leaning the rod past the perpendicular (away from the direction of welding), the resultant stretching of the rod produces checks and cracks inthe finished weld upon cooling. In order to exert sufficient pressure on polyethylene or poly-propylene rod it must be fed into the weld bed at an angle of 45º to the direction of weld with the upper part of the rod looping away from the direction of the weld. For fillet welds the rod should be held in such a way that it bisects the angle between the two welded surfaces. In most cases this will be a 45º angle. It is essential to preheat all surfaces being joined. When welding flexible material the angle of the filler rod must be further reduced to obtain pressure on the weld. When this becomes impractical a roller should be used to apply pressure to the filler rod.



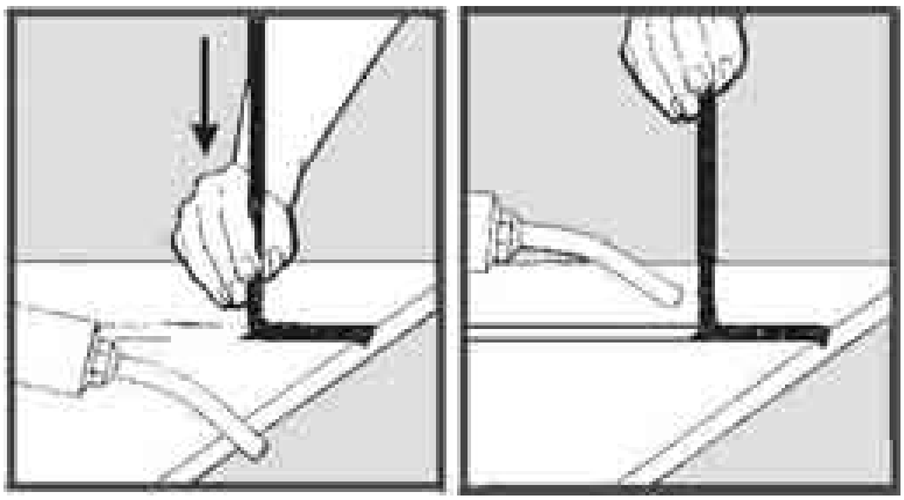
Rod angle for Polypropylene



Rod angle for PVC

Feeding the Rod

In the process of welding the rod will, of course, eventually be used up, making it necessary for the welding to renew his grip on the rod. Unless this is performed carefully, the sudden release of pressure may cause the rod to lift away from the weld bed, causing air to become trapped under the weld, resulting in a weak weld and often in complete weld failure. To ensure that this does not happen, turn the torch away from the work, maintaining pressure on the welding rod for a few seconds. Reposition fingers on the rod, then recommence welding. Do not hold the rod too far away from the point of weld, as welding contact may become difficult. Then resume normal pressure. When using the latter method, caution should be taken to turn the torch away from the working area, to eliminate danger of burning fingers.



Methods of re-positioning grip on rod

Finishing the Weld

When a weld is to be terminated, stop all forward motion and direct a quick application of heat directly at the intersection of the rod and the base material. Remove heat; maintain downward pressure on the rod for several seconds. Allow rod to cool for several seconds to prevent possibility of bead being pulled from its bed. Then, release downward pressure; twist rod with the fingers until it breaks. If a continuous weld is to be made, the deposited bead should be terminated by cutting at an angle of 30º with a sharp knife or cutting pliers after allowing rod to cool for several seconds under pressure. When joining one rod to another in a continuous weld, cut the new rod at a 60º angle. Heat the 60º angled surface of new rod and weld on angle of the old rod so that pieces joined together appear to be almost one piece. Never splice welds by overlapping side by side. When terminating a weld, as in the case of pipe welding, the weld should always be lapped on top (not beside) of itself for a distance of 3/8" to 1/2" (10 to 12mm).

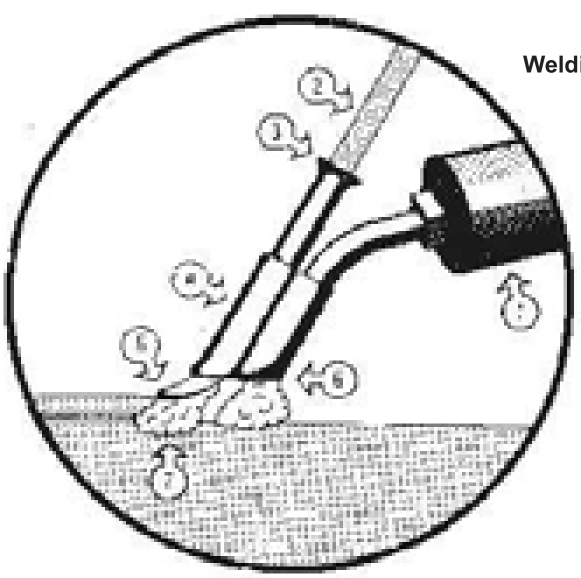
When welding PVC, a well finished weld will appear comparatively uniform with no brown or black discolouration. If insufficient heat has been applied the rod will appear in its original form and can easily be pulled away from the base material.

Small flow lines or waves on either side of the bead should be evident on a satisfactory weld. In the case of polyethylene and polypropylene, an overheated weld will produce a flat bead with oversized flow lines. Polyethylene and polypropylene do not char or discolour when overheated but become transparent much like hot candle wax.

When welding heavy sections of material, multiple beads are welded in the joint, one on top of the other. Caution must be exercised when running these multiple beads so that the whole mass does not become overheated and produce a bad weld.

High Speed Welding

High speed welding incorporates the basic methods utilised in slow speed welding. Its primary difference lies in the use of a specially designed high speed tip which enables the welder to produce more uniform welds and work at a much higher rate. As with low speed welding, constant heat and pressure must be maintained.



Welding Torch with Speed Welding Tip

1. Electric torch
2. Welding rod
3. Rod tube entry
4. Rod is pre-heated in tube
5. Shoe provides pressure
6. Orifice pre-heats area to be welded.
7. Hot air flow

Principle of High Speed Welding

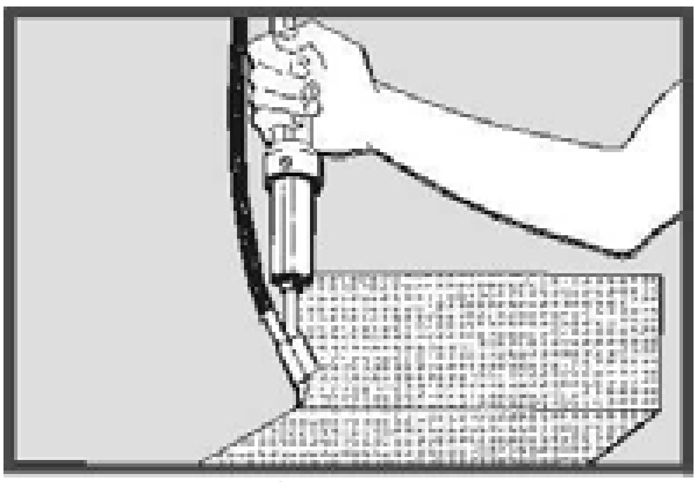
The increased rate of welding in high speed welding is made possible through preheating of both the welding rod and base material before the point of fusion. The rod is preheated as it passes through a tube in the speed welding tip. The base material is preheated by a stream of hot gas passing through a vent in the tip ahead of the fusion point. A pointed shoe on the end of the tip supplies pressure on the rod and eliminates the need for the operator to apply pressure. At the same time it smooths out the rod, creating a more uniform appearance in the finished weld. These high speed nozzles are available for various sections and sizes of welding rod, i.e. round, triangular, flat, etc. To ensure uninterrupted high speed welding, it is necessary to make certain that the welding/filler rods are slightly smaller in diameter than the guiding tube and also uniform in cross section to prevent sticking of the rod during welding and to ensure a maximum of welding speed.

Advantages of High Speed Welding

In high speed welding, the conventional two hand welding method is replaced by a faster and more uniform operation. Once started, the rod is fed automatically into the preheating tube as the welding rod is pulled along the joint. High speed tips are designed to provide the constant balance of heat and pressure necessary for a satisfactory weld. Average welding speeds are about 40" (1000mm) per minute.

Starting the Weld

With the high speed torch held like a dagger and the hose on the outside of the wrist, bring the tip over the starting point about 3" (75mm) from the material so the hot air will not affect the material. Insert the welding rod into the preheating tube and immediately place the pointed shoe of the tip on the material at the starting point. Hold the welder perpendicular to the material and push the rod through until it stops against the material at the starting point. If necessary, lift the torch slightly to allow the rod to pass under the shoe. Keeping a slight pressure on the rod with the left hand and only the weight of the torch on the shoe, pull the torch slowly towards you. The weld is now started.

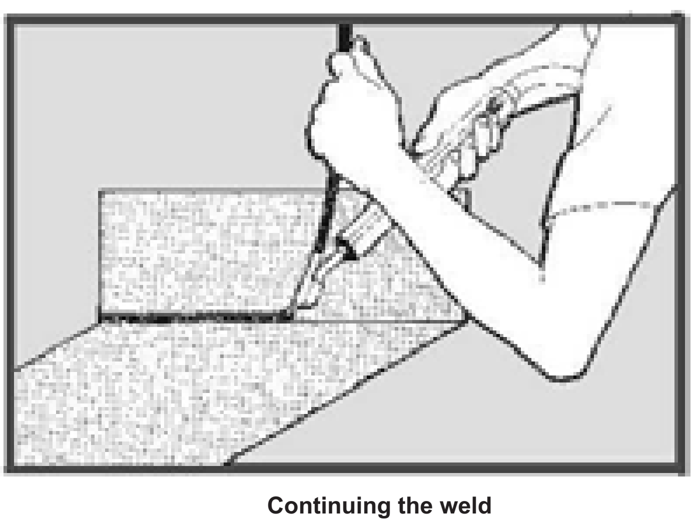


Starting the weld

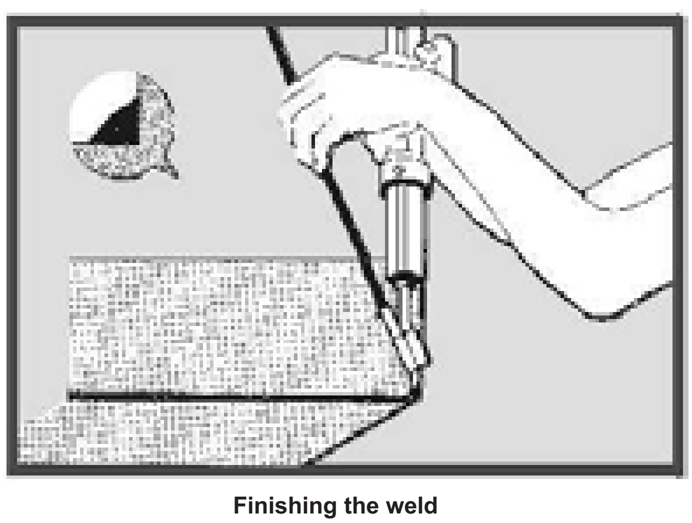
IMPORTANT: Once the rod is inserted in the preheating tube, the remaining steps in the process must follow in rapid sequence to prevent scorching or melting of the rod. Do not insert the rod in the tip until you are ready to start welding.

Continuing the Weld

In the first few millimetres of the travel, the rod should be helped along by pushing it into the tube with a slight pressure. Once the weld has been properly started, the torch should be brought to a 45º angle and the rod will feed automatically without further help. As the torch moves along, visual inspection will indicate the quality of weld being produced. When welding PVC, brown or charred edges of rod indicate a poor weld caused by welding too slowly. If the rod has been softened too much by overheating, it will stretch and break, or flatten out. When welding polyethylene or polypropylene too slowly the rod will flatten out and the transparent flow lines on each side of the bead will appear oversized. Absence of flow lines indicates insufficient pressure or a welding rate that is too fast.



Continuing the weld



Finishing the weld

The angle between the welder and the base material determines the welding rate. Since the preheater hole in the speed tip precedes the shoe, the angle of the welder to the material being welded determines how close the hole is to the base material and how much preheating is being done. It is for this reason the torch is held at 90º when starting the weld and at 45º thereafter. When a visual inspection of the weld indicates a welding rate which is too fast, the torch should be brought back to the 90º angle temporarily in order to slow down the welding rate, then gradually moved to the desired angle for proper welding speed. It is imp-ortant that the welder be held in such a way that the preheater hole and the shoe are always in line with the direction of the weld, so that only the material in front of the shoe is preheated. A heat pattern on the base material will indicate the area being preheated. The rod should always be laid in the centre of that pattern.

Finishing the Weld

It is important to remember that, once started, speed welding must be maintained at a fairly constant rate. The torch must not be held still. To stop welding before the rod is consumed, bring the torch back past the 90º angle and cut off the rod with the end of the shoe. Stopping the weld before the rod is consumed may also be accomplished by pulling the speed tip off the remaining rod. When cutting the rod with the shoe the remaining rod must be removed promptly from the preheater tube. Rod not removed promptly from the preheater tube will char or melt, clogging the tube and making it necessary for the tube to be cleaned. This may be accomplished by inserting a new rod into the tube.

A good speed weld in a 'V' joint will have a slightly higher crown that the normal hand weld and more uniformity. It should appear smooth and shiny with a slight bead on each side. For best results and faster welding speeds the shoe on the tip should be cleaned occasionally with a wire brush to remove any residue which might cling to it and create drag on the rod.

Work Limitations

The modern high speed plastic welding torch is designed primarily to meet the needs of production type welding. Since increased speeds must be maintained in order to procure good welds, the high speed welding torch is not suited for small intricate work. At first the position in which the torch is held may seem clumsy and difficult. However, practice and experience will soon enable the welder to make butt welds, 'V' welds, corner welds and lap joint welds successfully with a low speed tip. High speed welds can be made on circular as well as flat work and on all outside welding of hoods and ducts. Inside welds on tanks can be high speed welded unless the working space is too small to manipulate the torch.

Stretching and Distortion

Regardless of the skill and technique of a welder, some stretching of the welding rod will always occur. Unless such stretching exceeds 15%, strength and stability of the completed weld will be unaffected. As pointed out previously, excessive stretching occurs when the welding rod is leaned away from the direction of welding. In high speed welding, stretching is caused by too much pressure on the rod, or plastic residue on the shoe and in the preheating tube. When a thermoplastic rod is heated sufficiently to form a weld it becomes soft and tends to stretch. Upon cooling it contracts considerably. When this happens, stresses caused by stretching produce cracks and checks across the face of the weld. A simple method of determining the amount of stretch in a completed weld is to measure the length of the rod before and after welding. It has been stated that thermoplastics when heated tend to revert to their original shape. In multi-layer welds, deposited beads are, of course, reheated in the process of laying new beads one on another. For this reason, stretching in multi-layer welds must be held to a mininum since checks and cracks caused by stretching will show up as voids in the finished weld and cannot be detected by visual inspection. When making multi-layer welds, allow ample time for each weld pass to cool before proceeding with additional welds. To save time and give added strength to multi-layer welds, alternate welds from one side of the groove to the other.

In addition to stretching of the rod, welding also tends to cause distortion to the base material. This is particularly true when multi-layer single 'V' butt welds are being made.

As in metal welding, sudden heating and eventual cooling causes considerable expansion and contraction in the welded materials. Unlike metals, however, thermoplastics are notably poor conductors of heat and stresses created by alternate heating and cooling are confined to a much smaller area. This concentration of heat combined with an expansion co-efficient eight times that of steel creates great stresses in the welded plastic material.

Dressing and Repairing Welds

Contrary to metal welding procedures, it is not good practice to dress plastic welds, unless a flat surface is required. Weld strength is reduced as much as 25% when the crown is removed and frequently careless sanding or grinding will make notches in the weld, creating definite weaknesses. This is particularly true of the more notch-sensitive materials, such as PVC. If dressing is required on a completed weld it may be done with a file or rotary sander.

Welds which appear to be burned or charred or which lack cohesion with the base material should be removed and a new weld made. Welding over faulty welds does not remove the original weakness; a faulty weld should, therefore, be completely removed with a knife, rasp, router or sandpaper and the joint welded anew. Poor starts and cold welds can be removed easily by reheating and cutting with a knife.

Inspection, Testing and Evaluating Welds

The strength of a completed weld depends upon a combination of factors. In order of their importance these are as follows:-

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

The strength of butt welds is in accordance with the type of weld used. Dressing decreases strength of completed welds by approximately 25%. Welds equivalent to less than 75% of original material strength should be considered unsatisfactory.

Visual Inspection

Regardless of the material welded, a good weld will always show flow lines or waves on both sides of the deposited bead. These waves indicate the welding surface of the rod was heated sufficiently to allow material to flow and enough pressure was exerted on the rod to force the hot viscous material out of the weld bed, permitting bonding of the softened plastic parts.

Visual examination of multi-layer welds can be accomplished by cutting across the axis of the weld and polishing the cross-section. Close inspection will reveal any faults present, such as voids, scorching, notching, etc.

Non-Destructive Tests

Cracks, porosity and lack of bonding can be detected in welded containers by filling them with water and checking for leaks. Another common method is to apply air pressure to the inside of a capped container and immerse it in water. Bubbles of escaping air will indicate a leak. A pipe system can be checked by painting the joints with a soapy solution, then placing the capped system under air pressure. Bubbles will indicate slow leaks. To locate fine porosity in welds, a high frequency spark tester must be used. Operating at 10,000 to 55,000 volts, this instrument sends a shower of sparks over the surface of the plastic which has been grounded with a metal backing. Porosity is indicated by a straight line of sparks passing through the weld to the grounded metal. This method is used for testing plasticised and rigid tank linings. Air inclusions and voids in natural colour polyethylene and polypropylene welds can be detected by using a bright light held at an oblique angle to the work. The most effective non-destructive method of testing welds is the use of an X-ray or Fluoroscope machine which is capable of revealing voids and scorching in hidden welds on finished products.