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Welder's Guide to Contact Capacitor Discharge Stud Welding

October 1994 Revision 1

Contents

OTHER INFORMATION:
"Welding Handbook," Eighth Edition, Volume 2. O'Brien, R.L., Editor, ©1991. Chapter 9 " Stud Welding", American Welding Society.

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What is CD Welding?

A technical definition might read something like: Capacitor Discharge welding is a controlled short circuit where charged electrolytic capacitors (devices that store energy like a battery) short out through a small tip on the end of the stud. A direct short of this nature allows a very high current flow (up to 3,600 amps). This current flow generates enough heat to melt the base metal and the stud to complete the weld.

Steps in Contact CD Welding

1. **Check and install chuck (collet)** Select the proper diameter chuck for the size stud to be welded. Inspect the inside of the chuck for wear. If you notice grooves, pits or rings the chuck should be replaced. Test fit the stud into the chuck, it should be snug. If the stud goes in easily or can be jiggled around it is time to replace the chuck. A significant portion of the stud (at least 1½ times the diameter) should be able to be inserted into the chuck. If not adjust the set screw inside the chuck. Place the chuck into the weld tool and tap into place.

2. **Adjust voltage and turn on power supply** Adjust the voltage setting to match the size stud you plan to weld (see table 1). Turn on the power supply. When turned on, the capacitors inside the power supply charge up to the specified level. These capacitors are HUGE and store a lot of electrical energy.

   NOTE: If the set level is too high and must be turned down, the capacitors must be discharged to the lower setting. This can be accomplished by turning the unit off.

3. **Load stud into weld tool.**

4. **Adjust plunge** There should be approximately 1/8 of an inch of stud (including the flange) sticking passed the end of the spark shield (or other nose piece). If not, loosen the leg set screw(s) and adjust the leg(s) so 1/8" of stud is past the end of the weld tool. This is called setting the plunge.

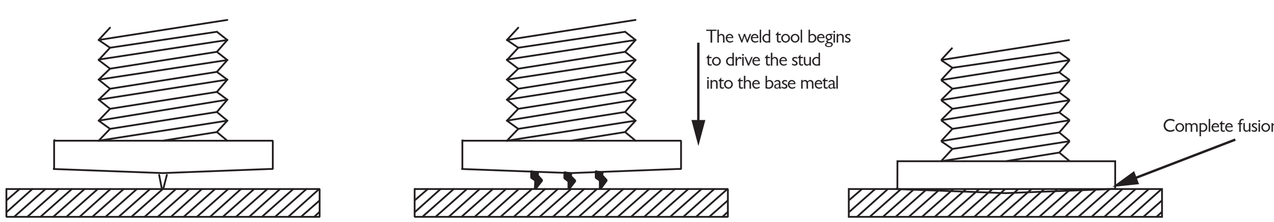
4. **Position stud** The weld tool is positioned against the base metal. Note the stud is connected to the negative terminal on the power supply and the base metal is "grounded" to the positive terminal (Stud welding is a positive ground system). An electrical path is created through the tip of the stud.

4. **Initiate Weld** The weld tool trigger is pulled. This creates the electrical short circuit and releases, or discharges, all the stored energy in the capacitors.

5. **Weld Arc is Formed** The tip or nib on the stud is too small to handle the system current (up to 3,600 amps in some cases). As this tip vaporizes (similar in function to a fuse) it creates an electrical path which establishes an arc.

6. **Stud Plunges into Weld Pool** The arc melts the bottom of the stud and a portion of the base metal. At the same time the spring pressure in the weld tool drives the stud into the molten pool of metal.

7. **Weld Complete** The molten metal cools and completes the weld cycle all in less than .012 seconds.



CD Stud is positioned against work.

The Trigger is pulled, the timing tip vaporizes and an arc is formed. This arc melts the bottom of the stud and top of the base metal.

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Adjusting the Settings on a CD Welder

There are only a few key factors to be adjusted for reliable CD welding: 1. Voltage; 2. Plunge (also known as the amount of stud sticking out passed the end of the weld tool); 3. Type of spring; and 4. Cables. This guide will look at each item.

Adjusting Voltage

Think of voltage as controlling the size or intensity of the arc. Increasing voltage increases the arc intensity while decreasing the voltage reduces the arc.

The voltage will vary directly with the stud diameter. See table 1 as a guide line for setting up voltages on a typical CD stud welding machine.

Adjusting Plunge/Type of Spring

The spring pressure, which is controlled by the type of spring and the amount of plunge, controls the duration of the weld. This controls weld time. The more plunge (more stud sticking passed the end of the weld tool) the greater the spring pressure when compressed. The greater the spring pressure the faster the stud is driven into the weld pool extinguishing the arc.

If the plunge is too fast, there may not have been enough metal melted to achieve a good weld.

If the plunge is too slow, the melted metal may cool prior to the stud being pushed into the molten pool. If the metal has cooled a good bond will not form. This frequently happens with non-ferrous metals such as aluminum or brass.

Adjusting Cables

The cable set should always be uncoiled. Any loops in the ground or welding cables can dramatically effect the welding results.

Table 1

Stud Size	Stud Material	Base Material	Plunge	Spring	Voltage*
#6	Carbon Steel	Carbon Steel	1/8”	Light	65-95
	Stainless Steel	Stainless Steel	1/8”	Light/Med	65-95
	Aluminum	Aluminum	1/8”	Med/Heavy	65-95
#8	Carbon Steel	Carbon Steel	1/8”	Light	80-110
	Stainless Steel	Stainless Steel	1/8”	Light/Med	80-110
	Aluminum	Aluminum	1/8”	Med/Heavy	80-110
#10	Carbon Steel	Carbon Steel	1/8”	Light	90-125
	Stainless Steel	Stainless Steel	1/8”	Light/Med	90-125
	Aluminum	Aluminum	1/8”	Med/Heavy	90-125
1/4”	Carbon Steel	Carbon Steel	1/8”	Light	110-160
	Stainless Steel	Stainless Steel	1/8”	Light/Med	110-160
	Aluminum	Aluminum	1/8”	Med/Heavy	110-160
5/16”	Carbon Steel	Carbon Steel	1/8”	Light	150-185
	Stainless Steel	Stainless Steel	1/8”	Light/Med	150-185

*Always use the equipment manufacturer’s recommended settings. Because of the wide range of equipment available, these ranges are only approximate. Voltage required will vary by machine capacitance ratings, material specifications, cable diameter, etc. Operators should adjust voltage according to visual inspection results. (See page 5.)

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Weld Failures with Contact CD Welding

There are two basic areas where CD welding can go wrong:

1. **Not enough metal is melted to form a good bond (Cold Weld).** This can be visually identified by no weld spatter and undercutting. When broken off, there will only be a small area of melted metal which will be dull gray in color.

2. **The molten metal cools before a bond is made. (Cold Plunge).** This most typically occurs with aluminum (and other non-ferrous alloys) but can occur with steel. There may or may not be a lot of weld spatter, but when the weld fails there will be bright shiny metal.

Not Enough Metal is Melted to Form a Good Bond (Cold Weld)

There are many causes of cold welds:

Factors With in Operator Control

- Tip on stud is crushed do to excessive pressure. (sometimes, especially with aluminum studs, an operator can apply repeated pressure to the stud tip and crush or shorten the tip. The shorter tip reduces arc length/time and does not properly melt the stud and/or base material)
- Coiled weld or ground cables. This reduces weld current delivered to the stud. The coil cables act like a large inductor and inhibit the flow of energy.
- Spring pressure is too high. The high spring pressure prematurely extinguishes the weld arc.
- Improperly Set Power Supply Controls. Always use the equipment manual for set up of the power supply.

Factors Outside of Operator Control

- Improperly formed tip on stud due to manufacturing process. (unlikely)
- Changes in alloys being welded
  This can usually be compensated for by changing the settings on the power supply.
- Equipment failure due to many possible causes including: leaky capacitor(s), malfunctioning output SCR, malfunctioning output control board, other misc. electrical problems.

The Molten Metal Cools Before a Bond is Made (Cold Plunge)

If the molten metal cools before the stud and base material are forced together there is little chance that the stud will be properly fused. After the stud is broken off the appearance will be shiny.

Factors With in Operator Control

- Improperly set plunge setting
- Incorrect spring or spring setting
- Varying gauges of sheet metal (settings can be adjusted, this is especially true for aluminum)

Factors Outside of Operator Control

- Springs inside of weld tool have fatigued and do not apply the same pressure
- Dirt inside of the weld tool prevents smooth operation and hangs up or slows weld tool motion

  Either of these MAY be compensated for by increasing spring pressure.

Other CD Welding Problems

There are three other areas where CD welding can have problems:

1. **Arc Blow.** This can be visually identified by weld spatter or fillet on only one side of the stud. It will look like molten metal was "blown" out from one side of the stud.
2. **Sliding Studs.** The stud slides during the welding process. It will look like a metal skid mark and be shiny.
3. **Center Punch Marks.** CD Studs (in contact mode) do not weld well to center punch marks.

Arc Blow

This problem will often cause incomplete fillet formation on one side of the stud. This incomplete cross sectional welding may lead to weld failure. There are two causes for this:

1. Molten metal runs away from the ground. Incomplete or insufficient grounding can cause this problem.
   Solution: Double Ground. The addition of another ground on opposite sides of the weld area will reduce this problem. The object will be to always weld between the grounds. If you need assistance contact your Image Ind. Representative.

2. Welding near the edge (1/4 inch or less) of a piece of metal will potentially cause this phenomena. Unusual electrical current patterns are set up near the edges of metals and this can effect the flow of metal.
   Solution: Place another piece of sheet metal of the same type and thickness next to the edge you are welding. This will "fool" the electrical currents and they will act like you are welding in the middle of the sheet metal.

Sliding Studs

This is a problem where the stud finishes a weld in a different location than where it was initially placed on the sheet metal. This typically will be accompanied by a shiny metal skid mark. There are three primary causes of this:

1. The operator is pushing down with a great deal of pressure and/or is holding the weld tool at a slight angle.
   Solution: Check the spring for proper type and pressure setting. Check the plunge setting. Always use the lightest spring setting that provides acceptable welding results. This will reduce the amount of pressure the operator needs to use to weld the stud. Also check the foot or nose piece to ensure that it is flat and provides a stable surface for welding.

2. The chuck is worn. This will allow the stud to be at a slight angle and can allow the set up to slide during the weld process.
   Solution: Check the chuck for wear and replace if needed. (See page 3.)

3. The weld tool internal parts are excessively worn.
   Solution: Contact your Image Ind. Representative for possible repair or replacement.

Center Punch Marks

When the tip of the CD stud is located in a center punch mark, the overall length of that tip is effectively reduced. This reduction in length will dramatically effect weld time and, therefore, weld quality. If the depth of the mark can be consistently controlled and kept to 0.005" the weld parameters may be able to be adjusted to compensate for the difference in weld time. However, our experience has shown that this kind of control on the depth of the center punch marks is not practical.

Image Ind. Inc. does not recommend using center punch marks with Contact CD welding. If additional ideas for location are required, contact you Image Ind. Representative.

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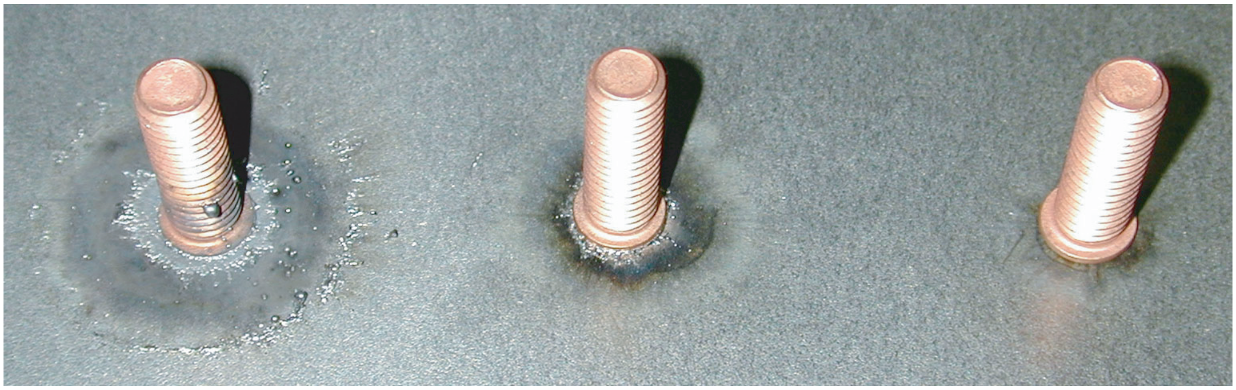
Visual Inspection of CD Welds

Hot Weld	Excessive weld metal splattered around the weld base
Cold Weld	No molten metal forming a fillet and visible undercutting
Good Weld	Some molten metal forming a small fillet around the stud flange



Hot Weld Good Weld Cold Weld

The amount of weld spatter in combination with the weld fillet is a good indicator as to the quality of the weld. Settings should be adjusted accordingly.

Physical Inspection of Weld Studs

Physical tests should be performed as part of the qualification procedure before beginning production welding to ensure the set-up parameters are correct. This should be done at the beginning of a new shift or after changing stud diameters or materials.

Most physical tests are destructive and should be done only on test plates.

Some suggested physical tests are as follows:

1. Bend Test — The stud to be tested should be bent 15° away from its weld axis and back to 0° or until failure occurs. Bending can be done with a hammer or with the aid of a bending tool such as a tube or pipe. Failure should occur in the stud material itself or, on thin plate, a plug of base metal should be torn out.

2. Torque Test — The stud should be torqued until a pre-specified load is attained or until the stud fails. Failure should occur in the stud material itself or, on thin plate, a plug of base metal should be torn out.

3. Tensile Test — There are many commercially available "stud pullers". This device grabs onto the stud and pulls it away from the base metal. This can be a good tool when there is uncertainty about weld strength. This can test a stud to failure which can be used as a qualification test. Also the stud can have a tensile load to a predetermined limit. Testing to the predetermined limit can be used as a periodic quality test for production. Note: on thinner base metals this test may actually pull the base metal and cause a reverse side dimple so the predetermined limit must take into account the base metal thickness.

Maintenance of a Stud Welding System

A majority of the maintenance of an stud welding system is in:

1.) Stud welding weld tool
2.) Welding cable
3.) Control cable

These items simply receive the most wear.

CABLE MAINTENANCE

When checking cables for continuity it is important to slightly pull on all the connectors so that if there is a break the wires will be pulled apart. The continuity check can be performed with a standard Ohm meter. All cables: ground, control and weld cables should be periodically inspected.

Also, the cables themselves should be closely inspected for any snags or kinks that could be causing a problem. Insulation around the cable should be periodically checked for wear to ensure proper safety. Finally, for operator convenience, the control cable and the weld cable should be fastened together (electrical tapes works well) to help movement of the weld tool.

WELD TOOL MAINTENANCE

The weld tool, since it carries out most of the welding functions, should be periodically (at least every 3 months for drawn arc and stored arc systems and 6 months for CD and gap systems) disassembled and cleaned. Special attention should be given to the lifting or locking mechanisms. This shaft must be absolutely free with no binding inside the weld tool and there should be no contact between the stud and the ferrule or spark shield. Never lubricate the lifting or locking mechanisms. It should be cleaned with a dry cleaner such as electrical contact cleaner. Caution should also be exercised when reassembling the weld tool to be certain not to pinch wires or the weld cable. This could cause erratic welding problems which are usually difficult to isolate.

Note: on Gap CD units the front cover has an internal ground connection. The unit will not function if this connection is broken. Care must be taken when reassembling the front cover.

CONTROLLER MAINTENANCE (Arc Stud Welding Systems Only)

To check the controller, you simply free-air trigger the weld tool at various time settings. If the amount of time that the weld tool stays lifted corresponds to the time you set on the unit, the timing module is usually good. NOTE: if your unit has a "Lift Check" button on the controller this must be pressed in to check the timing functions.

POWER SUPPLY MAINTENANCE

The power supply contains electronic control boards. Normally, these items do not require maintenance. However, in harsh environments, particularly those with grinding or sanding, metallic dust can enter the welder. This conductive metallic dust can cause unexplained problems with the welding system. Periodically removing the power supply cover and blowing out the power supply is a good idea. Frequency will vary depending on the environment. (Always disconnect power before opening any power supply. CD units will continue to store energy after they have been unplugged. Make sure all energy is discharged before blowing out power supply.)

Personal Safety Precautions

A) If the power source has a stick welding mode the output terminals and any tools connected are always electrically "hot". In stud welding mode the output terminals are electrically "hot" only while welding. Use only the proper tool with the selected welding mode.

B) **Always protect yourself from possible electric shock.**

1) Never allow contact between the electrically "hot" portions of the circuit and your bare skin or wet clothing. Wear dry, hole-free gloves to insulate your hands.

2) Always insulate yourself from ground by using dry insulation when welding in damp locations or metal floors, gratings or scaffolds and particularly when large areas of your body can be in contact with possible grounds such as sitting or lying down.

3) Maintain all the equipment such as stud weld tool, electrode holder, ground clamp, welding cable and welding machine in good, safe operating condition.

4) NEVER dip the stud weld tool or electrode holder in water for cooling.

5) If two welders are connected together, the open circuit voltage can be the sum of the two. Never touch the electrically hot portions of the circuit.

6) If the welder is used as a power supply for automatic welding, there same precautions are applicable to the automatic unit.

C) When working above floor level, protect yourself from a fall should you get a shock or startled. Never wrap the electrode cable around any part of your body.

D) **Arc burn may be more severe than sunburn.**

1) When stud welding, safety goggles should be worn by the operator. A shaded No. 3 lens is suggested.

2) When stick welding, arc-air gouging, or observing the same, use a head shield with the proper filter and cover plates to protect your face and eyes from sparks and the ultraviolet rays of an arc. The filter lens should conform to ANSI Z87.1 standards.

3) Use suitable clothing to protect your skin and that of people around you from the arc rays and sparks.

4) When stick welding or arc-air gouging, protect nearby personnel with suitable, non-flammable screening and warn then not to watch the arc or expose themselves to the arc rays, hot spatter or metal.

E) Droplets of molten slag and metal are thrown or fall from the welding arc. Protect yourself with oil free protective garments such as leather gloves, heavy shirt, cuffless trousers, high shoes and a cap to cover your head. When welding out of position, or in confined areas, wear ear plugs.

F) When in a welding area, always wear safety glasses. Safety glasses with side shields are a must when near a slag chipping area.

G) Move fire hazards to a place safely away from the welding area. Welding sparks and hot materials generated at the welding arc will go through small cracks and openings into adjacent areas.

Personal Safety Precautions (Continued)

H) When not manual arc welding, place the welding tool where it is insulated from the ground system. Accidental grounding can cause overheating and create a fire hazard.

I) Connect the ground cable as close to the welding area as practical. Ground cables connected to the building framework or other locations some distance from the welding area increase the possibility of the welding current passing through lifting chains, crane cables of other alternate circuits. This creates fire hazards. Overheating of lifting chains or cable can cause them to fall.

J) Welding can produce hazardous fumes and gasses. Use adequate ventilation and avoid breathing these fumes and gasses. Welding on galvanized, lead or cadmium plates produces toxic fumes.

K) No welding should be done in locations near chlorinated hydrocarbon vapors such as degreasing and painting stations. The heat and rays of the arc can react with the solvent vapors to form phosgene, a highly toxic gas, and other irritating by-products.

L) Do not heat, weld or cut tanks, drums or containers until the necessary steps have been followed to insure that no flammable, irritating or toxic vapors can be formed by the residue.

M) Vent hollow castings or containers before heating, cutting or welding. A pressure build up may cause it to explode.

N) For more detailed safety information, consult the pamphlet, "Welding Safety", published by the U.S. Department of Health, Education and Welfare, DHEW (NIOSH), Publication No. 77-131. It is also recommended that you purchase, read and follow the directions of "Safety in Welding & Cutting, ANSI Standard Z49.1" for $5.00 from the American Welding Society, Miami, Florida, 33125.

Power Supply Safety Precautions

A) Always connect the frame of the power supply to ground in accordance with the National Electrical Code and the manufacturer's recommendations.

B) Installation, servicing or trouble shooting should only be done by qualified personnel trained to work on this type of equipment.

C) Before servicing any piece of equipment, turn off the disconnect switch at the fuse box.

D) When operating, all covers must be on the equipment.

Definitions of Stud Welding Terms

Amperage See Current

Arc-Blow The effect where the weld fillet runs away from the ground connection. The electric fields generated during the weld repel the fillet material away from the location of the ground. If this is a concern, it can frequently be addressed through the use of double grounds.

Bellows This is the rubber boot that slides over the chuck adapter. This helps to keep dirt, weld spatter and other foreign contaminants from entering the internal weld tool mechanism.

Burn-Off The amount of stud consumed during the weld. This "burn-off" material forms the weld fillet.

Burn Through A condition where the weld excessively distorts or actually melts through the base material. This is caused by an excessively hot weld or by using base material that is too thin.

Capacitor A passive electrical component that stores electrical energy

Chuck The device that holds the weld stud during the welding process. It fits into the chuck adapter. This is a consumable component and should be replaced when worn.

Chuck Adapter This component of the stud weld tool holds the chuck and connects to the internal lifting mechanisms. The weld current flows from the weld cable to the lifting mechanism to the chuck adapter to the chuck and finally into the stud.

Cold Plunge A condition where the molten weld pool has cooled prior to the stud being pushed into the weld pool.

Cold Weld Not enough weld energy was used in the welding process. Typically this is characterized by reduced or no fillet and apparent undercutting.

Control Cable This is the thin cable that connects the stud weld tool to the controller. This cable carries the trigger signal from the weld tool to the controller and the lifting voltage back from the controller to the weld tool.

Controller The controller initiates the pilot arc, sends the lift signal to the stud weld tool, starts the weld current at the right instant, and controls the duration of the weld. The controller can be a separate "box" or an internal component as in self contained units.

Current The flow of electricity is referred to as current and is expressed in Amperes (Amps). There are two types of current: Alternating Current (AC) and Direct Current (DC). Direct current always flows one way: from negative to positive. DC is polarized which means there is a definite negative and positive connection. Alternating current (the type you get from a wall socket) flows back and forth. AC is non-polarized, you can reverse the connections and not alter anything. Stud Welding uses DC current.

It should be noted that current is an electron flow. The amount of current required determines the size (diameter) of the cable needed. The larger the cable the more current it can carry. See resistance.

Discharge The release of electrical energy, typically used in reference to capacitors.

Double Ground Used to improve welding properties. Frequently used in aluminum CD welding and ferruleless drawn arc welding.

Ferrule A ceramic shield used in arc stud welding. The purpose of the ferrule is to contain sparks, heat and molten metal in the weld zone while keeping gasses and impurities out.

Definitions of Stud Welding Terms

Ferrule Grip Holds the ferrule during the weld sequence. This is a consumable item and should be replaced when worn.

Fillet The ring of weld metal that surrounds the stud after welding.

Flux Ball The flux load press into the end of most weld studs. During the weld process the flux load vaporizes and consumes the oxygen at the weld site. This helps to eliminate contaminates in the weld itself.

Foot This stud welding component is attached to the legs and it holds the ferrule grip. The combination of the legs, foot and ferrule grip determine plunge.

Ground All equipment should be grounded (the exception is double insulated equipment). The reason for grounding is that the voltages used are always at a potential level different from the ground, and if a good conduction path is established between the equipment and the ground there can be no potential difference developed between the equipment and anyone who is standing on the ground. thus, if any voltage is leaked it will be conducted away through the ground path rather than through the operator. For the equipment to be properly grounded you must be able to read continuity (no resistance between the ground pin on the plug and any conductive surface on the equipment.

Hang Up A condition where the stud weld tool does not plunge the stud into the weld pool properly and only a partial weld occurs. This can be caused by the internal mechanisms binding or more commonly by the stud hitting the ferrule. Remedy by adjusting the foot.

Hot Weld Too much energy was used during the welding process. This is characterized by excessive splatter (CD) or a washed out fillet (Arc)

Lift This motion is essential to the stud weld process since it creates a gap which the current must bridge. This air-gap increases the electrical circuit resistance and generates the heat necessary to melt the stud and parent material for the weld. If no gap exists there would be a direct short to the base material and sufficient heat would not develop. Short lift may cause molten metal to bridge the arc gap and seriously hamper weld quality. Excessive lift may result in the arc being interrupted and inconsistent which can cause poor weld results. See resistance.

Pilot Arc This is the initiating arc which is first formed while the stud is being lifted off the work. It establishes the path for the weld current.

Plunge The amount of stud, typically 1/8", which protrudes beyond the ferrule when the stud weld tool is in its normal state. This represents the portion of the stud to be used in forming the weld fillet (Arc). Short plunge may cause incomplete fillet formation while too much plunge may cause excessive splatter which may also leave incomplete fillets or uneven fillet formation.

Also, used to describe the dropping action of the weld tool. As in: The stud is now plunging into the base metal

Plunge Damper A device which slows the rate which a stud plunges into the weld pool. This reduces the amount of splash from the molten metal and helps to form a uniform weld fillet. This typically is only necessary for stud diameters over ½"

Power Supply The power supply can be external, such as a generator or a transformer-rectifier. Ideally, it should have an open-circuit DC voltage in the 70-120 volt range. The current required depends on the stud diameter to be welded. A general rule of thumb is 100 amps for every 1/16" diameter. For example: a 1/4" stud will require 400 amps of weld current. A power supply can also be internal and are call self contained units. Smaller units (1/2" diameter stud capacity) usually hook up to 220 or 440 volt single phase power. Larger units require 220 or 440 volt three phase power.

Definitions of Stud Welding Terms

Protrusion See plunge.

Resistance This is the opposition to current flow and is expressed in Ohms. The more resistance the more Ohms. Whenever electrical flow is impeded by resistance heat is generated (it is this heat that allows stud welding to work). For example, a 40 foot cable will have twice the resistance of a 20 foot cable of the same type.

SCR Silicon Controlled Rectifier. An active electrical device which can be turned on and off to allow the passage of current. An electronic switch.

Spark Shield CD welding and some Short cycle arc welding. This is a shield to reduce visible flash and to contain any spatter generated during weld

Stud Weld Tool This is the unit the operator holds. It is connected to the controller via the control cable and to the power supply via the weld cable. Besides holding the stud, the weld tool handles the lift, plunge and trigger functions. In other words, the weld tool tells the controller when to begin the weld cycle, the it executes all the weld functions from the controller to complete the cycle

Time This is the duration of the weld. The general rule is that as the stud diameter increases, the weld time is increased. In cases where there is limited base material thickness, shorter than normal weld time is used and the amperage is increased to give sufficient heat to the weld.

Voltage Is the electrical potential difference from one point to another. Electrical current flow is the result of an electrical path (such as a wire) being established between two points of different potential, or voltage levels. If the potentials are continually interchanging and the current flows back and forth, it is AC voltage. This is the type of voltage a generator would provide. On the other hand, if one potential is always higher than the other, such as a battery, it is DC voltage. In DC the higher potential is called positive and the lower potential is called negative.

Weld Cable This is the large diameter cable which carries the power for the pilot arc and the welding current to the arc stud.

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