ARC WELDING

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The components of bat gates are attached to one another by arc welding. The best way to learn welding is to take a beginners course at a community collage or trade school, then to practice, practice, practice. In most libraries you can find books describing beginning welding practices. The *Welders Handbook*, by Richard Finch (1997, The Berkley Publishing Group, New York, New York) is particularly popular, and well suited to the beginner.

Welding of gates is nearly always done in the field with portable DC (direct current) arc welders. The most frequently used welders weigh under 150 pounds, and consist of a gasoline engine geared to a generator. Most welding is done within the range of 100–135 amps, just within the range of small portable welders. Larger welders operate more efficiently, but their greater weight (300–400 lbs.) limits their use to sites with easy access.

All welding machines are rated with a **duty cycle**, the percentage of time the arc welder can be used before it must rest. A machine rated with a duty cycle of 60% can be operated for six out of every 10 minutes. Exceeding the duty cycle can cause stress to the welder through over heating, which will in turn decrease its rated output. This at first may seem like a hindrance, but it is seldom that a welder can carry an arc for more than a few minutes because of the necessity of moving to a more comfortable position, insert a new welding rod into the holder, shifting to a new position on the seam being welded, or to take a rest.

Arc welding is accomplished by attaching the grounding lead from the welder to the metal to be welded, then placing an electrode (welding rod) in the electrode holder attached to the end of the second lead. When the electrode is brought into contact with the grounded metal, an electrical circuit is closed with electricity passing through the electrode then back to the welding machine through the ground lead. As the electrode is raised slightly from the metal surface an arc is created. The arc both heats the grounded base metal, and also begins to melt the filler metal in the center of the electrode. The filler metal is sprayed into the weld, adding material to help fill gaps and bond the base metal pieces together.

An electrode consists of a center core of high strength metal covered with a flux coating. When an arc is struck, the flux is gradually burned away creating a gas shield within the arc, and glassy solidified flux on the weld. This shield prevents contamination of the molten metal puddle by atmospheric gases which could weaken the weld. This solidified “slag” can be chipped away, exposing the weld beneath.

WELDING SAFETY

Before you start to weld you must be wearing appropriate protective equipment. The greatest hazard is from ultraviolet light (radiation) burns to the eyes and the skin. These burns are similar to sunburn except deeper and more serious due to its great intensity. Burns can be prevented by simply shielding the skin and eyes from the arc. Always wear long sleeved shirts and pants. The fabric should be natural fiber, avoid synthetics which will melt when hit by molten metal. The hands are protected with long, insulated, leather welding gloves. When welding be sure to button the top button on you shirt to block spattering metal and to avoid UV burns to the neck and throat.

On your feet you will want to wear high topped leather boots. Your pants should not have a cuff, and extend down over your boot tops to prevent hot metal or slag from finding its way inside. Never wear nylon tennis shoes when welding. Hot metal will melt its way straight through to your foot!

A welding helmet is used to protect the head and eyes from the arc. The hood is fitted with a window containing a colored lens in the front. The lenses can be purchased in various shades, with #10–#12 being best for most work. When working underground, the lighter #10 shade is most easy to use. Underground it is convenient to have a helmet with a large lens to maximize vision, and help accommodate the inevitable condensation that collects on the inside. Keeping a clean handkerchief or other lens cleaner handy is a great help. Select a helmet light in weight since you will be using it for long periods, and lighter ones cause less fatigue.

When working around other people, be sure to warn them before you strike an arc, so they can turn away. The arc burns at approximately 10,000 degrees Fahrenheit, and is roughly equivalent to looking directly at the sun. Severe eye burns can result, or even loss of eyesight if an arc is watched for prolonged periods. The closer people are to the arc, the more serious the potential burns. Sunglasses are provide inadequate protection for the light intensity of arc welding.

EQUIPMENT YOU WILL NEED

You will find that most portable welders have AC outlets to plug in extension cords to power grinders, drills, and electric lights. This is a big advantage since separate generators for this propose are not needed

The following equipment will be needed for gate assembly:

- ☐ Gas powered portable welder 100–135 amps DC.
- ☐ Electric work lights (halogen work lights are best).
- ☐ Extension cords for lights and power tools (should be 12/3 stranded wire).
- ☐ Hand grinder for dressing welds, and smoothing edges of steel plate. An eight-inch offset grinder is most useful.
- ☐ Soapstone for marking metal.
- ☐ Chipping hammer for removal of slag.
- ☐ Wire brushes for cleaning welds after chipping.
- ☐ Pry Bar
- ☐ Four-pound hammer
- ☐ Electric rotary hammer/drill for pinning gate segments to cave or mine walls. Appropriate sized bits for pins (1/8 inch larger than pin size). If renting the rotary hammer, get the largest size available!
- ☐ C-clamps. At least six which open 6" and two that open 8".
- ☐ Two shovels
- ☐ One mattock or pick
- ☐ One long pry bar (sometimes called a rock bar).
- ☐ One eight-pound sledge hammer.
- ☐ Four gate bar spacing jigs (see plans in appendix).
- ☐ One tri-square (“speed square”) for marking metal.
- ☐ One 24" carpenters level.
- ☐ One small hydraulic jack.
- ☐ one-inch nylon straps tied to form loops about 3 1/2 feet in diameter (used to wrap around and carry steel. Six needed. Each strap will use about 8 feet of nylon webbing.)
- ☐ One or two light weight cable come-a-longs for pulling steel into position. Optional.

WELDING ROD

Selecting correct welding rod is very important to achieving satisfactory welds. For cave gates you will want to use 1/8" diameter electrode. The following rods are commonly used with good results:

E-6011 — Easy to use, will burn through dirt and rust, but generates a large amount of spatter which will stick to the base metal near the weld as little globules of metal.

E-6013 — Easy to use, metal must be cleaner than when using E-6011. Excellent weld quality.

E-7018 — Produces high quality, attractive welds, but is more difficult to use. This rod is used when high strength is needed. The base metal must be clean and properly prepared before welding. This rod works well for bat gate construction when new, unrusted steel, is used. This rod is susceptible to moisture damage so must be kept dry and clean. Welding is enhanced by reversing the polarity of the welder.

All electrodes are stamped with a number. Lets look at **E-7018** rod as an example. The letter "E" means it is an electrode. The first two digits (i.e. "70") indicate the tensile strength of the filler metal (70,000 PSI). The next digit is the position in which the rod can be used. "1" is an all-position rod and "2" is a flat position only. The last digit means the rod can be used with both AC and DC welders. Most rods can be used with DC welders, but there are limitations on AC welding.

Welding rod must be stored in a warm dry environment. Even small amounts of moisture can damage or destroy welding rod, including high humidity. The rod should be kept in sealed waterproof containers until used. New rod commonly comes sealed in 50-pound metal cans or in 5-pound packages wrapped and sealed in plastic. Once opened moisture can begin to penetrate the flux causing deterioration of the rod. For field use, plastic screw-top containers are a sensible way to transport and store rod. Only small quantities of rod are removed from their storage container at one time.

Working in caves and mines is a particular challenge for keeping welding rod clean and dry. Most welders like to use a leather rod-pouch attached to their waist to transport working-quantities of rod. These small pouches keep the rod from becoming dirty, or damaged through rough handling.

Most DC welding is done with reverse polarity, with the electrode positive, allowing the electrode becomes hotter than the base metal. This works particularly well when using E-6011 and E-6013 rod. When welding with E-7018 rod, reverse polarity (electrode negative) provides a steadier arc, and allows smoother transfer of filler metal from the electrode to the workpiece. As an experiment try reversing the polarity and observe the difference in behavior.

WELDING TECHNIQUE

Your first step is to prepare for welding, cutting and clamping steel components and establishing bar spacing. Next attached the grounding clamp from the ground lead to the piece to be welded. Next insert a welding rod in the electrode holder, Be sure you are wearing gloves, long sleeved shirt or coveralls, and high toped boots. Put on the welding helmet and make sure it fits properly, making any adjustments necessary for a snug fit. You are now ready to start welding.

The welding machine should be set at 120–135 amps. Using 1/8 inch welding rod, this is considered a "hot" setting, but it will make it easier to strike and maintain an arc while learning to weld.

The electrode (welding rod) should laced in the holder at 90° to the handle. Other positions are possible but are usually only used for awkward welding. Hold the electrode about one-inch from the joint to be welded, then nod your head forward allowing the welding hood to drop into working position. Next drag, or scratch, the rod across the metal at the joint allowing electricity to jump between the steel and welding rod creating an arc. As soon as an arc develops, the welding rod should be held close to the base metal, about 1/8 to 1/4 inch away, to maintain an arc.

It is common, particularly while learning, to have the rod stick itself to the base metal. If this happens quickly move the rod holder from side to side to break it off. If it doesn't detach within a few seconds, squeeze the handle on the rod holder releasing the rod. The rod will quickly become very hot if it isn't broken free. If you have to detach the handle from the rod remember it is very hot; do not grab it with your hands to break it loose until it cools, or better yet, use a pair of pliers to grab it.

With a little practice you will learn to strike and maintain an arc. Next you need to learn to run a bead. Butt welds, where two pieces of metal are butted together side by side, is the easiest place to learn. With the pieces in a horizontal position, start at one end by striking an arc along the seam. Hold the rod in position momentarily then slowly move the arc back and forth across the joint in a figure-eight or circular pattern. Move the rod no more than 1/8 inch past the seam on either side. You will notice two things taking place. First the arc will melt the base metal on either side of the seam as you move the rod back and fourth. Secondly, as the rod arcs, the steel core melts, creating a small puddle of molten metal over the seam. Pay very close attention to this small puddle, since it is the beginning of the metal bead which will form the weld. Holding the welding rod at about a 45°, slowly weave back and fourth across the seam, alternately melting one side then the other. Filler metal from the welding rod is added to the growing puddle which will elongate to form the weld bead as you advance. Try to maintain a uniform puddle by maintaining a slow deliberate speed. It is much better to go too slowly, adding too much metal, than not enough.

By holding the welding rod at a 45° angle away from the puddle, you will force metal to pile up and be added to the growing puddle. With a little practice you will be able to maintain the arc, and produce more and more uniform beads. Your weld should advance at about 3 inches per minute. If you move much faster, you will be depositing inadequate filler metal in the weld. Slower, and you will be placing excessive metal in the weld. With practice you will develop a sense for the correct speed, and appreciate a good looking bead.

If for any reason you must stop welding, such as to place another rod in the holder, allow the weld to cool then use a chipping hammer to remove slag. Following chipping, use a wire brush to remove any remaining impurities. If any slag is left on the weld it can cause an inclusion, causing a weak spot. After cleaning, you can resume welding.

When welding two pieces together in a “T”, the tendency is to overheat the piece being attached, and underheat the base piece beneath. By directing the arc for a longer time on the base piece it will be heated the most, then touch the arc to the piece being attached just long enough to cause it to melt. If the arc is held too long to the piece being attached, it will melt out, or create an undercut just above the weld. This will weaken the weld, and should be avoided.

When moving the rod along the joint, don't move too fast. Make sure the metal is being melted about half way through to the other side. When the other side of the joint is welded, there should be solid metal left from one side to the other. This deep melting is often referred to as “penetration.” You want to make sure your welds penetrate the joint deeply for the most strength possible.