Underwater Welding & Cutting

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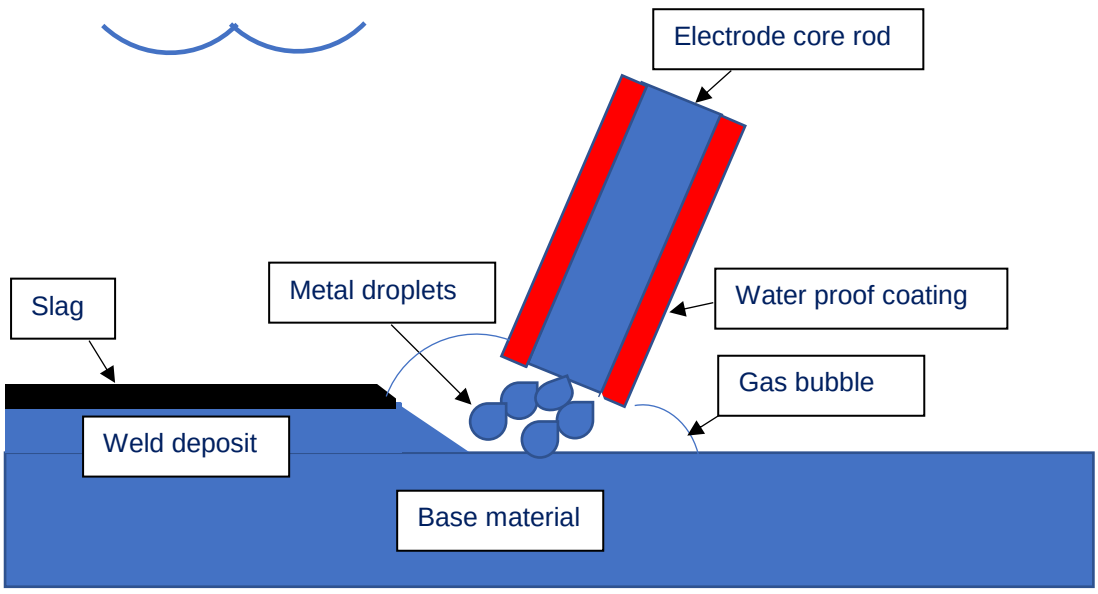
Underwater welding & cutting is generally divided into Dry and Wet underwater welding & cutting.

Dry underwater welding & cutting is performed in a chamber filled with a gas mixture sealed around the structure being welded or cut. The resulting work are generally of high integrity.

Wet underwater welding & cutting is performed in water. The process is generally limited to low carbon steels, especially because of rapid cooling rate and hydrogen pick up resulting in weld cracking. In the following this is the process that will be further explained. Underwater welding & cutting does not necessarily mean that you are a diver doing the welding submerged under water. Onboard a vessel it's much more likely that you have to do welding in a partly submerged compartment where you as a welder are above or partly above water but the actual welding takes place below water. Never the less the same stringent procedure and safety precautions must be followed

The Process

In the case of wet underwater welding & cutting with a coated electrode, the energy of the arc is so great that all the water around the electric arc evaporates in an instant, and a relatively stable bubble is created around the tip of the electrode. The bubble is retained until the moment the electric arc is interrupted. In underwater cutting, oxygen is employed and introduced to the weld site through a hollow electrode.



Safety

All the equipment used in wet underwater welding must be properly insulated, or the diver risks electrocution. Wet underwater divers also risk building up levels of hydrogen and oxygen gases which can explode. On to that there are the normal hazards associated with diving, such decompression sickness thanks to the breathing gases increasing pressure in the body.

Power source

For underwater electric arc welding and cutting procedures a Direct Current DC supply is necessary which can produce 400A at 60% intermittence. This is best served by diesel aggregates of minimal power of 12kW, which do not depend on the energy infrastructure. Rectifiers or Inverters may also be used, but due to high energy requirements there may be problems in operation. For arc welding a 300A sources may also be used, whereas electric arc cutting requires higher amperages. The power sources must have low Open Circuit Voltage (OCV) also known as idle voltage for safety reasons.

Use a Direct Current DC welding machine only. This will normally be a Rectifier or an Inverter. **Never make use of an Alternative Current AC welding machines. Transformers deliver AC power.** The electrical shock caused by AC current prevents voluntary relaxation of the muscles that control the hands. If electrocuted a diver may be unable to let go if his body or equipment accidentally enters the electrical circuit.

WECO Cruiser 402 is a Heavy Duty Direct Current professional 3 Phase inverter power source for MMA Welding and TIG DC applications with excellent arc characteristics.

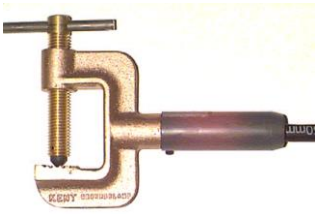
400 A 100% intermittence. Connects to 3 X 400Vac

Welding cables, Electrode holders, cutting torch and Return clamps

Special cables with special insulation class have to be used for underwater welding and cutting in order to prevent breakthrough of electric current into the water or to the structure being welded, which may cause safety problems and difficulties in welding. Welding cables of greater diameter have to be used in order to reduce the fall in voltage and excessive heating which may result in insulation disintegration. All the connecting systems have to be specially insulated. The welding and cutting torches have to be of special design, which means placing of electrodes at different angles (45° and 90°) as well as special class of insulation. In case of cutting torches where there is additional flow of oxygen, one has to beware of oxygen leakage, since this would mean fall in pressure, reduction of cutting efficiency and increase in oxygen loss. This is especially dangerous since oxygen and hydrogen generated by water decomposition can be collected in the structural parts. This mixture is of explosive character and it is very important to ensure that there is no contact between the electric arc and such gas pockets.

Electrode holder

Cutting torch



Return clamp

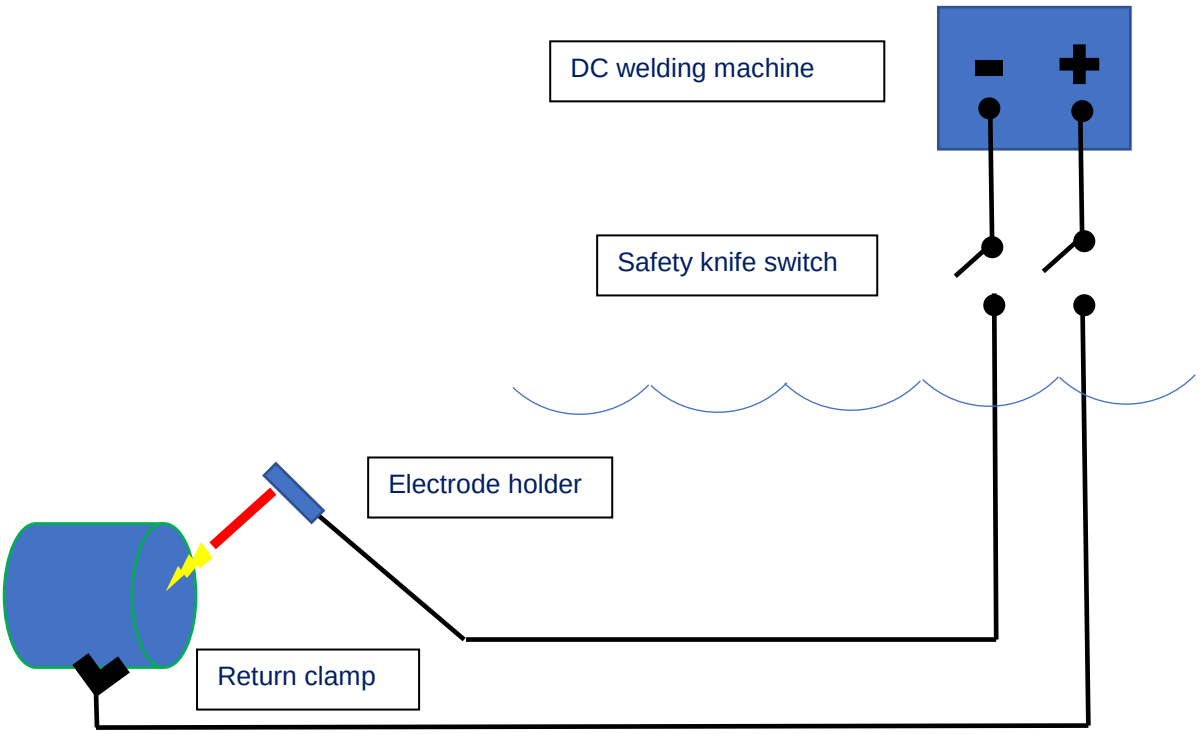
Connect the electrode holder cable connector to the negative pole - (straight polarity) Connect the return clamp cable connector to positive pole + (revers polarity). Polarity can be checked by immersing the electrode tip and return clamp into a bucket of salt water 50mm (2″) apart. Energize the electrode by closing the safety knife switch. A stream of bubbles should rise from the rod tip. If not reverse the polarity and retest.

A Safety knife switch must be installed on the secondary circuit. It must work so that when the diver is changing electrodes or doing anything other than welding or cutting, the safety knife switch must be in the open position. It is important that the opening and closing of the switch be directed by the diver. Each command should be confirmed by the diver using the terminology “make it hot,” or “make it cold.”

Safety knife switch that breaks current for both welding and return lead

Attach the return clamp of the DC welding machine as close to the work site as practical so that the diver is never between the electrode and the return. Clean the location where the return clamp is to be placed. The location should be in a position in front of the diver, as close as practical to the weld joint and should be scraped or wire brushed shiny clean. For diver safety, only G-type clamps should be used as return clamps for underwater cutting or welding operations. The clamp must be firmly secured to the work piece and the cable should have sufficient slack to prevent it from being pulled loose. The return should always be kept in the diver's forward line of vision.

Setup for underwater welding



Welding technique

When placing the electrode into the electrode holder the safety knife switch must be in the open position. After placing the electrode in contact with the joint the diver command "make it hot". This is to be confirmed by the tender operating the safety knife switch. Welding / cutting will commence. When the electrode has been consumed to within 50mm (2″) of the electrode holder, the diver command "make it cold." Welding / cutting stops. Before attempting to change electrode, the diver must maintain the electrode holder in the welding position until the tender acknowledges "make it cold". Only then will the diver change the electrode.

The welding technique is described as a pull or self-consuming method: With the drag technique, the electrode is simply crawling across the work and the welder only has to apply a slight **downward pressure**, whilst the electrode is being consumed. The welder must maintain the proper lead and side angle, together with a right travel speed, the electrode will make an orderly bead of suitable profile, almost on its own. The danger is that the electrodes burning rate becomes the travel speed resulting in a too narrow bead. The welding of two surfaces underwater creates unintended additional air bubbles that fly into the water surrounding the diver. This means that underwater welders often struggle with visibility.

The Welding Electrode

Good quality stick electrodes are needed to establish and maintain electric arc and to deposit weld metal under water. Best results are normally obtained using rutile type electrodes. It is necessary that electrode waterproof sheathing is keeping pace with electrode burning rate, so no part of electrode remains unprotected from water ingress during the welding process. It should be noted that, apart from actually reducing the current amperage, possible chemical aggressiveness of water could damage the compactness of coating causing it to degrade and reduce arc stability or even extinguish the arc. The great role in manufacturing high-quality electrodes for underwater wet welding lies in the watertight coating. Watertight coating has to protect the electrode from the outside from the influence of water also in case of chemical constituents and remain insensitive to high temperature of the electric arc and the electrode core. There are a significant number of companies and institutes involved in development and production of underwater wet welding stick electrodes. Sometimes electrodes for welding in dry environment are dipped in waterproof sheathing (varnish/lacquer) and used for underwater welding. It is proven that this approach may produce bad operating characteristics and poor quality of the weld. For higher strength steels, stainless steel and Ni-based electrodes are available. Electrodes with double coating have proven very good, especially because of high-quality coatings that prevent penetration of water and degrading of the coating.

The inferior mechanical properties of underwater wet welds:

The rapid cooling of the weld leads to great hardness in the heat-affected zone, low toughness in the welded joint and the appearance of porosity due to the capture of gas bubbles. Because of the rapid cooling, locally quenched structures of great hardness are formed in the welded joint. Their hardness reading sometimes exceeds 350 HV10 in the heat affected zone.

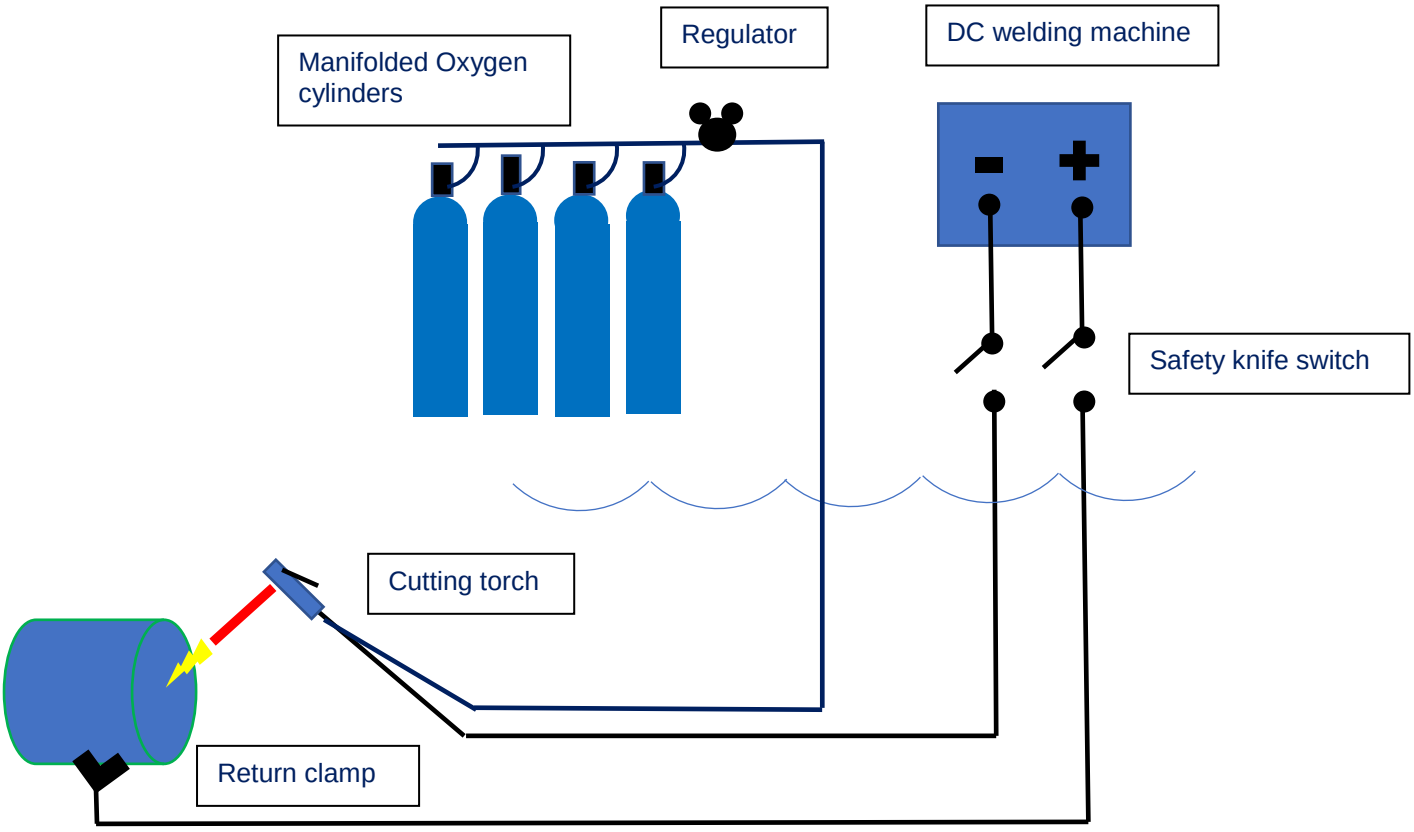
The high content of hydrogen in the column of the electric arc, molten metal in the transfer and in weld pool which results in hydrogen capture in the metal of the weld and in the heat-affected zone. This increases the susceptibility to the appearance of cold cracks, brings about porosity and degrades the mechanical properties of the joint. The high proportion of diffusible hydrogen which ranges from 30 to 80 ml H2/100g of the weld metal, makes such a structure susceptible to the appearance of hydrogen brittleness, i.e. it leads to the incidence of cold cracks caused by hydrogen.

The high oxygen content in the electric arc column, molten metal in the transfer and weld pool, which leads to oxidation, reduction of the proportion of alloy elements and the degradation of mechanical properties.

The disintegration and solving of the coating of the electrodes, which results in electric arc instability and the appearance of porosity.

In wet underwater welding, it has been proven that electrode oscillation and multi-run welding can substantially improve the mechanical properties by reducing hardness and increasing toughness. The risk of hydrogen-induced cold cracking is also reduced since every subsequent run treats thermally the previous layer, but this also enables diffusion of the hydrogen in the weld metal. In that case it is better to use smaller diameter electrodes for better control of weld pool and operative properties.

Setup for underwater cutting



Cutting technique

Underwater cutting can be performed using flame cutting (Petrogen oxy- gasoline system), plasma arc cutting, high-pressure water jet cutting, explosion cutting and mechanical cutting methods. In the following we describe the Oxy/Arc and Exothermic process.

When placing the electrode into the electrode holder the safety knife switch must be in the open position. Place the tip of the electrode against the work at the point where the cut is to be initiated and squeeze the oxygen lever to purge the rod and torch. With the oxygen still flowing the diver command “make it hot”. The tender will close the safety knife switch. Once the arc is struck and the electrode ignited, pull or drag the cutting electrode along the line to be cut. The angle of the electrode to the work should be between 30 and 90 degrees depending on the metal thickness. Maintain pressure to keep the electrode against the work. Keep the tip of the rod in the molten pool at all times. Move slowly at first, making sure full penetration is achieved. Do not try to keep an "arc" length. Keep the tip of the burning electrode in direct contact with the base material at all times. When the electrode has burned to within approximately 75mm (3") to the torch call for “make it cold”. Lift the rod from the work and release the oxygen lever. After the tender has confirmed the “make it cold”, remove the electrode stub from the torch. NB. Exothermic underwater cutting electrodes will continue to burn as long as the oxygen flow is maintained, even with the power off. The oxygen lever must be released to extinguish the cutting electrode. Exothermic electrodes require oxygen of at least 99.5% purity to sustain ignition without power. Oxygen pressure setting depend on type of base material, thickness to be cut and depth where cutting is taking place. Amperage setting depend on base material, thickness, cable size and cable length. Consult product manufacturer for details.

The Cutting Electrode

The traditional electrode for Underwater cutting is tubular. After the outer core have heated the metal to its ignition temperature a high velocity jet of pure oxygen is directed through the tubular cutting electrode at the heated spot. The metal oxidises and is blown away. The tip of the electrode, which is exposed to both heat and oxidation, is consumed in the process and needs to be replaced by the diver at regular intervals. This type of electrodes is limited to conductive materials. It will require a DC welding machine delivering up to 400 Amp.

Exothermic electrode consists of several small rods inside a steel tube. One of the rods is of a special alloy (Magnesium type) that will burn independently after an arc is struck and oxygen is flowing through the tube. The remaining rods are made of mild steel. An exothermic process describes a process or reaction that releases energy from the system to its surroundings in the form of heat. Exothermic electrodes can also be used for cutting non-conductive materials such as concrete, rock, coral, mastic, rope or marine growth. If used on non- conductive materials a striker plate (consisting of a steel or copper plate connected to the return cable) is necessary to initiate the arc and light the electrode. Once the electrode is ignited, maintain the oxygen flow and bring the electrode into contact with the target material. This type of electrodes requires a DC welding machine delivering 150-200 amp 100% duty cycle. A 12v or 24v battery can also be used to start the process.