UNDERWATER WELDING

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When I was young, I was always fascinated by welding carried out in underwater environment. Basically, flame and water are mutual exclusive as the flame would extinguish in water. There must be something specially devised such that underwater welding can become pragmatic. This leads me to further explore the subject with much interest.

WELDING IN UNDERWATER ENVIRONMENT

Welding in underwater environment, invented by the Russian metallurgist Konstantin Khrenov in 1932, is the process of welding at elevated pressures in underwater environment.

Hyperbaric welding can either occur *wet* in the water itself or *dry* inside a specially constructed positive pressure chamber and hence in a dry environment. It is predominantly referred to as "hyperbaric dry welding" when used in a dry environment, and "underwater wet welding" when in a wet environment. The applications of underwater welding are diverse — it is often used to repair ships, offshore oil platforms, and pipelines. Steel is the most common material welded.

A large number of welding techniques cannot be applied in offshore and marine applications whereby the presence of water is of major concern. In this regard, it is worthwhile to note that a great majority of offshore repairing and surfacing works are carried out at a relatively shallow depth, such as the splash zone.

The advantages of welding in underwater environment are generally of an economic nature, because this kind of welding for marine maintenance and repair jobs alleviates the need to pull the structure out of the sea and saves valuable time and dry docking costs. It is also a foremost technique for emergency repairs which allow the damaged structure to be safely transported to dry facilities for permanent repair or scrapping. Welding in underwater environment is applied in both inland and offshore environments, though seasonal weather inhibits offshore underwater welding during winter. In either location, surface supplied air is the most common diving method for underwater welders.

HYPERBARIC DRY WELDING

Hyperbaric dry welding is preferred to underwater wet welding when high quality welds are required because of the increased control over conditions which can be exerted, such as through the application of prior and post weld heat treatments. This improved environmental control leads directly to improved process performance and a generally much higher quality weld than a comparative wet weld. Thus, when a very high quality weld is required, dry hyperbaric welding is normally utilized.

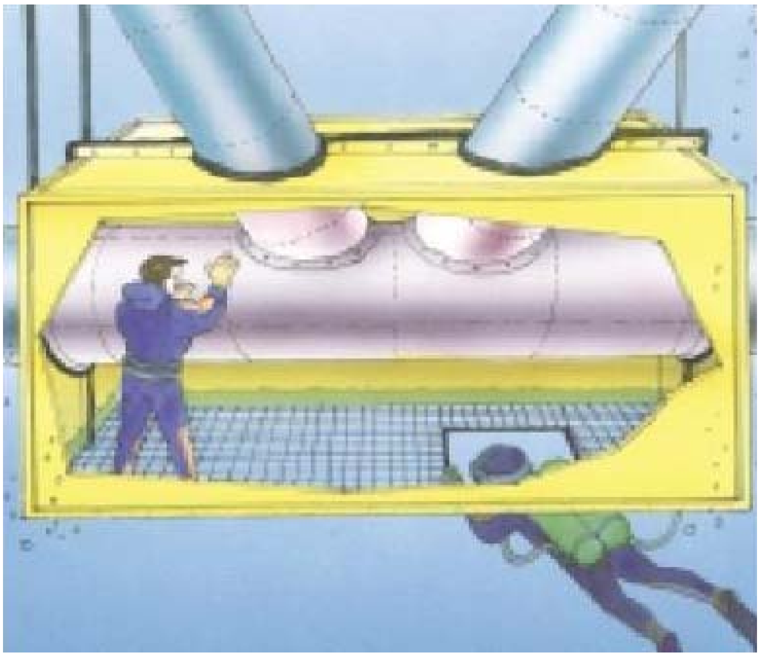


Figure2: Specially designed habitat for repair of K-node on offshore platform [2]

Welding in the dry (dry environment) will produce high-quality weld joints that meet most of the standard requirements. The hyperbaric dry welding involves a large welding chamber known as hyperbaric dry welding. It provides the welder-diver with all necessary welding equipment in a dry environment. The chamber or cofferdam is sealed around the welded part which is fixed to the structure. The chamber bottom is exposed to open water and is covered by a grating. The atmosphere pressure inside the chamber is equal to the water pressure at the operating depth. *Permanent welds are recommended to adopt Hyperbaric Dry Welding.*

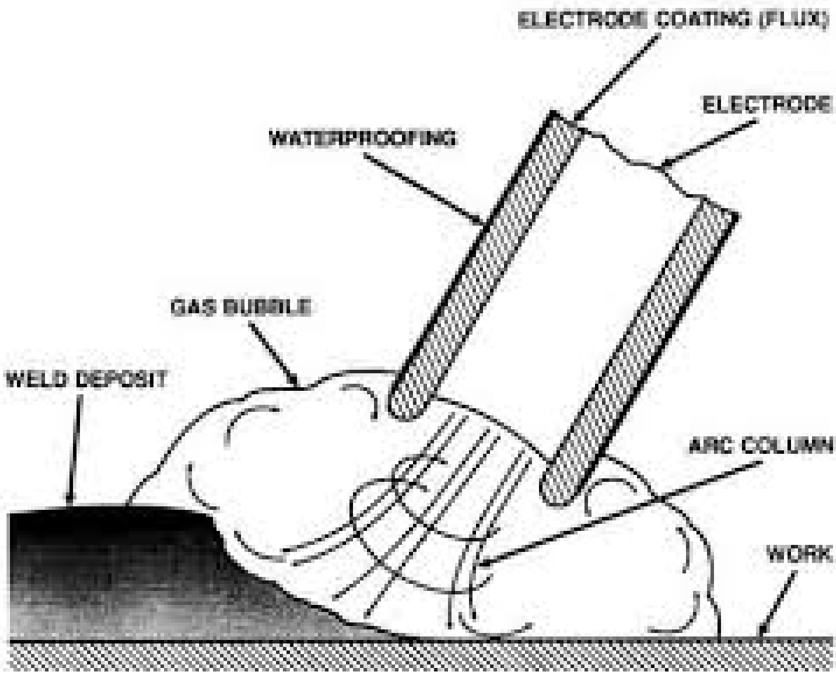
Hyperbaric dry welding involves the weld being performed at elevated pressure in a chamber filled with a gas mixture similar to atmospheric mixture sealed around the structure being welded.

Most arc welding processes could be operated at hyperbaric pressures, but all suffer as the pressure increases. The degradation is associated with physical changes of the arc behaviour as the gas flow regime around the arc changes and the arc roots contract and become more mobile. It is note-worthy that a dramatic increase in arc voltage which is associated with the increase in pressure. Overall a degradation in capability and efficiency results as the pressure increases.

In general, larger electrodes are used in underwater welding than are employed in normal welding, say 5mm or 5.6mm. These electrodes are recommended because the cooling action of the water solidifies the deposit more quickly. Higher deposition rates are also possible for the same reason. Usually, tee and lap joints are used in salvage operations because they are easier to prepare and they provide a natural groove to guide the electrode. These features are important under the hostile working conditions encountered underwater. Slag is light and has many non-adhering qualities. This means the water turbulence is generally sufficient to remove it and the use of cleaning tools is not necessary. However, where highest quality multipass welds are required, each pass should be thoroughly cleaned by abrasive wheels before the next is deposited. Manufacture specification shall be followed for the correct current & voltage input.

WET UNDERWATER WELDING

Welding in the wet environment is used primarily for emergency repairs or salvage operations in shallow water. The poor quality of welds made in the wet is due to heat transfer, welder visibility, and hydrogen presence in the arc atmosphere during welding. When completely surrounded by water at the arc area, the high temperature reducing weld metal quality is suppressed, and there is no base metal heat buildup at the weld. The arc area is comprised of water vapor. The arc atmosphere of hydrogen and the oxygen of the water vapor are absorbed in the molten weld metal. It contributes to porosity and hydrogen cracking. In addition, welders working under water are restricted in manipulating the arc the same as on the surface. They are also restricted by low visibility because of their equipment and the water contaminants, plus those generated in the arc. Under the most ideal conditions, welds produced in the wet with covered electrodes are marginal. *Temporary welds shall be welded under wet conditions.*



Underwater wet welding directly exposes the diver and electrode to the water and surrounding elements. Divers usually use around 300-400 amps of direct current to empower their electrode, and they weld using varied forms of arc welding. This practice commonly uses a variation of shielded metal arc welding, employing a waterproof electrode. The welding power supply is connected to the welding equipment through cables and hoses. The process is generally limited to low carbon equivalent steels, especially at greater depths, because of hydrogen-caused cracking.

In general, assuring the integrity of underwater welds can be difficult, especially for wet underwater welds, because defects are relatively difficult to detect if the defects are beneath the surface of the weld.

Underwater wet welding with a stick electrode is done with similar equipment to that used for hyperbaric dry welding, but the electrode holders are designed for water cooling and are more heavily water proof coated. They will get overheated if used out of the water. A constant current welding machine is used for manual metal arc welding. Direct current is used, and a heavy duty isolation switch is installed in the welding cable at the surface control position, so that the welding current can be disconnected when not in use.

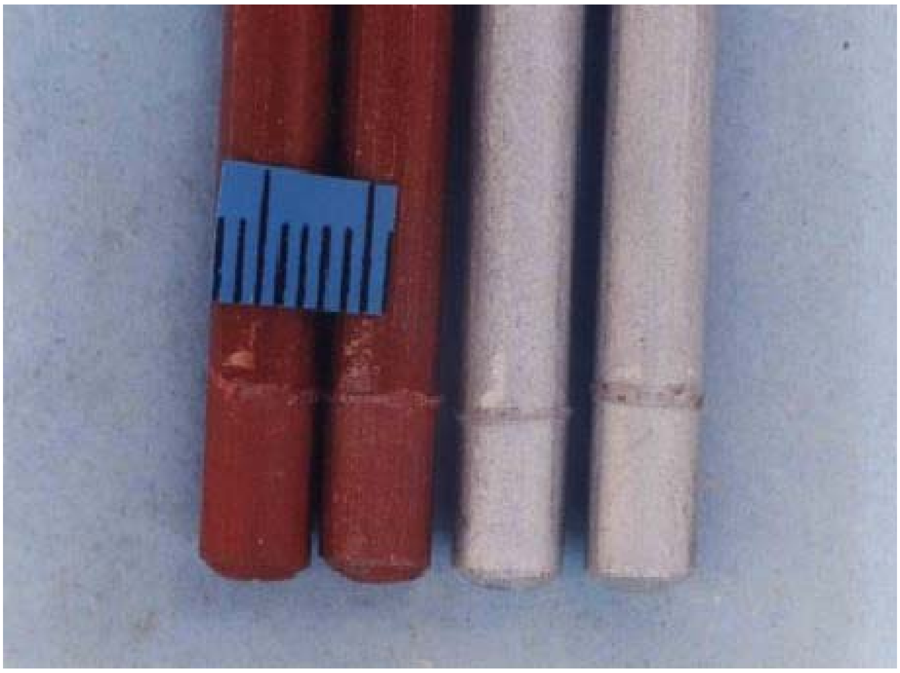


Figure 4: Tip of rutile underwater wet welding electrodes with double waterproof coating (1)

The electric arc heats the work piece and the welding rod, and the molten metal is transferred through the gas bubble around the arc. The gas bubble is partly formed from decomposition of the flux coating on the electrode but it is usually contaminated to some extent by steam. Current flow induces transfer of metal droplets from the electrode to the work piece and enables positional welding by a skilled operator. Slag deposition on the weld surface helps to slow the rate of cooling, but rapid cooling is one of the biggest problems in producing a quality weld.

The electrode types used shall conform to AWS E6013 classification or as appropriate to the parent material. The electrodes must be waterproofed prior to underwater wet welding, which is done by wrapping them with waterproof tape or dipping them in special sodium silicate mixes and allowing them to dry. All connections must be thoroughly insulated so that the water cannot come in contact with the metal parts. Should insulation leak, seawater will come in contact with the metal conductor and part of the current will leak away and will not be available at the arc. In addition, there will be rapid deterioration of the copper cable at the point of the leak.

Quality Control

The Welding Procedure shall be qualified in accordance with AWS D3.6 or EN ISO 15614 as appropriate. All Diver-Welders performing welding work shall be qualified to BS EN ISO 15618-1 or 2 & acceptance of the welds shall follow BS EN ISO 5817, Level B. The welder test to BS EN ISO 15618-1 or 2 shall carry out at similar welding conditions as in Production work (for example, Pressure, Depth of water).

Hazards and risks of wet underwater welding

The hazards of wet underwater welding include the risk of electric shock to welders. To prevent this, the welding equipment must be adaptable to a marine environment, properly insulated and the welding current must be controlled. Commercial divers must also consider the occupational safety issues that divers face; most notably, the risk of decompression sickness due to the increased pressure of breathing gases. There may also be long term cognitive and possibly musculo skeletal effects associated with underwater wet welding.

Preparation for underwater welding projects happens above, not below, water. Proper equipment inspections are crucial to reducing risk of shock. Direct current (DC), not alternating current (AC), should be used in power welding equipment. The operator shall wear rubber suit and gloves to avoid electric shock.

References

1. S. Kralj, Z. Kožuh, I. Garašić, State-of-the-art and trends of development in underwater wet welding and inspection, Proceedings of Welding and Joining 2005, The Association of Engineers and Architects of Israel, Tel Aviv, 2005.

2. Habitat technology-innovative underwater techniques, www.hydrex.be ,2006