

## Underwater Welding techniques

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### ABSTRACT

Welding demand in offshore and marine applications is increased with the increasing in oil and gas activities as well as increasing in the marine transportation and industrial applications. In this paper, a brief description of the different commercial underwater techniques will be presented taking into account showing detailed description of a few advanced welding techniques

### I. INTRODUCTION

The increasing demand for oil and gas has led to increase the offshore oil and gas activities and to move the exploration into the deep water. The desire to build, maintain and repair offshore structures has brought the need for underwater welding. Underwater welding is the process of welding at elevated pressures, normally underwater. Underwater welding can either take place wet in the water itself or dry inside a specially constructed positive pressure enclosure and hence a dry environment. It is predominantly referred to as "hyperbaric welding" when used in a dry environment, and "underwater welding" when in a wet environment. **Principle of Operation**  
The welding circuit must include usually a knife switch operated on the surface and commanded by the welder and is used for safety reasons. When DC is used with (+ve) polarity, electrolysis will take place and cause rapid deterioration of any metallic components in the electrode holder. For wet welding AC is not used because of electrical safety and difficulty in maintaining an arc underwater.

### Classification of Underwater Welding

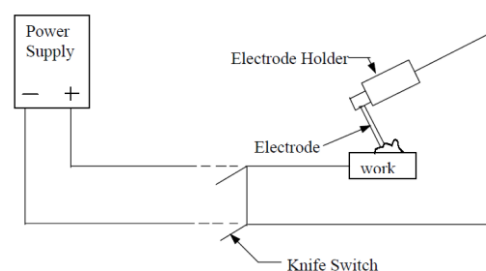
Underwater welding can be divided into two main types:

- 1- Wet Welding
- 2- Dry Welding

#### 1- Wet Welding

Wet welding process is carried out at ambient water pressure in which, the weld is exposed to the water. This is carried out by a special water-proof stick electrode, with no physical barrier between water and welding arc. The increased freedom of movement makes wet welding the most effective, efficient and economical method. Welding power supply is located on the surface with connection to the diver/welder via cables and hoses. When DC is used with +ve polarity, electrolysis will take place

And cause rapid deterioration of any metallic components in the electrode holder. Fig. 1, shows the overall wet welding process diagram. For wet welding AC is not used because of electrical safety and difficulty in maintaining an arc underwater.



**Figure 1:** Schematic Diagram of Underwater Wet Welding Technique

### Equipment for underwater wet welding

The underwater wet welding equipment has to meet all the safety aspects. Due to the limited time spent under water, the diver-welder has to be provided with satisfactory operating conditions. Equipment has to be regularly maintained according to stipulated regulations in order to insure its proper functioning. Main equipment needed for wet underwater welding can be summarized in the following:

- **Diving equipment**

The diving equipment includes dry diving suit, dry suit full-face mask, surface supply umbilical cord, air tank on the surface with regulation manometer and compressor for filling the air tank.

- **Welding power sources**

Intensive dynamic behavior of the power source is necessary to obtain a stable electric arc in greater depths. Welding power source must be adjusted for underwater wet welding, not only in the matter of good arc behavior but also in the aspect of diver-welder safety.

- **Safety switch**

For safety reasons, the electrical circuit is fitted with a safety switch, which interrupts or establishes the flow of current necessary for underwater welding or cutting as diver request or in case of accident.

- **Communication system**

For constant connection and coordination of works between the surface and the diver, two-way telephone communication system has to be applied in order to facilitate the realization and organization of underwater activities.

- **Welding cables, and welding and cutting holders**

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 platform structure, which may cause safety problems and difficulties in welding.

- **Mechanical tools system**

Mechanical tools for underwater works may be driven electrically, hydraulically and pneumatically. Electric drive is avoided because of safety problems, and mostly hydraulic and pneumatic tools are used.

The advantages and disadvantages of wet underwater welding technique are indicated in

Table 1.

Advantages	
-	The versatility and low cost of wet welding makes this method highly desirable.
-	Fast method.
-	It is less costly compared to dry welding.
-	The welder can reach portions of offshore structures that could not be welded using other methods.
-	No enclosures are needed and no time is lost building.
-	Minimal equipment needed for mobilization.
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Disadvantages	
-	There is rapid quenching of the weld metal by the surrounding water. Although quenching increases the tensile strength of the weld, it decreases the ductility and impact strength of the weldment and increases porosity and hardness.
-	<b>Hydrogen Embrittlement</b> – Large amount of hydrogen is present in the weld region, resulting from the dissociation of the water vapour in the arc region. The H <sub>2</sub> dissolves in the Heat Affected Zone (HAZ) and the weld metal, which causes Embrittlement, cracks and microscopic fissures. Cracks can grow and may result in catastrophic failure of the structure.
-	Another disadvantage is poor visibility. The welder some times is not able to weld properly.
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**Table 1:** Advantages and Disadvantages of Wet Underwater Welding Process

## 2- Dry Underwater Welding

Underwater wet welding is primarily used at shallow depths when need for larger depths emerge underwater dry welding procedures is first choice. Moreover, usage of underwater dry welding methods offers completion of full penetration welds with mechanical properties adequate to welding in normal conditions. Additionally, it is possible to perform preheating or post weld heat treatment in order to decrease hydrogen content and improve weld properties.

Underwater welding in a dry environment is carried out in chamber sealed around the structure to be welded. The chamber is filled with a gas (commonly helium containing 0.5 bar of oxygen) at the prevailing pressure. The habitat is sealed onto the pipeline and filled with a breathable mixture of helium and oxygen, at or slightly above the ambient pressure at which the welding is to take place.

This method produces high-quality weld joints that meet X-ray and code requirements. The gas tungsten arc welding process is employed for this process. The area under the floor of the Habitat is open to water. Thus the welding is done in the dry but at the hydrostatic pressure of the sea water surrounding the Habitat made possible by encompassing the area to be welded with a physical barrier (weld chamber) that excludes water. The weld chamber is designed and custom built to accommodate braces and other structural members whose centerlines may intersect at or near the area that is to be welded. The chamber is usually built of steel, but plywood, rubberized canvas, or any other suitable material can be used. Size and configuration of the chamber are determined by dimensions and geometry of the area that must be encompassed and the number of welders that will be working in the chamber at the same time.

There are different dry underwater welding methods, it can be achieved by:

### 2-1 Dry Habitat Welding:

Using a chamber in ambient pressure (at ambient water pressure) in a large chamber from which water has been displaced, in an atmosphere such that the welder/diver does not work in diving gear. This technique may be addressed as dry habitat welding. As shown in fig. 2, welders are completely in dry environment and weld properties are equivalent to one welded in normal conditions. However, much more fit-up time is necessary to fix the habitat and prepare it for welding.

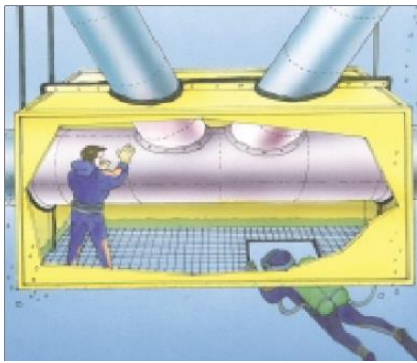


Figure 2: Specially designed habitat

### 2-2 Dry Chamber Welding:

Welding at ambient water pressure in a simple open-bottom dry chamber that accommodates the head and shoulders of the welder/diver in full diving gear as shown in Fig.3.

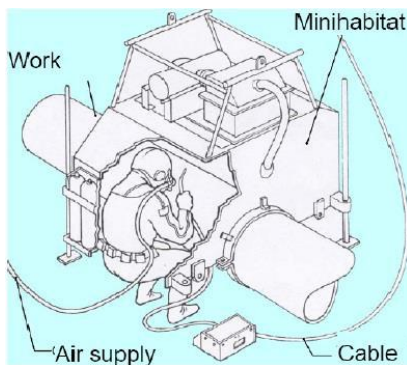


Figure 3: Dry welding in mini-habitat where the diver-welder is partially immersed in water

### 2-3 Dry Spot Welding:

Welding at ambient water pressure in a small transparent, gas filled enclosure with the welder/diver in the water and no more than the welder/diver's arm in the enclosure.

The advantages and disadvantages of dry underwater welding techniques are indicated in

Table 2.

Advantages	
-	Better diver safety
-	Better quality welds
-	No build up of hydrogen and oxygen pockets
-	Allows for heat treatment before and after welding
-	Surface monitoring possible
Disadvantages	
-	Requires large and complex equipment
-	Chamber has to be fabricated differently for different applications
-	Cost is very high and increases with depth
-	More energy requirement

Table 2: Advantages and Disadvantages of Dry Underwater Welding Process

The important applications of underwater welding are:

- ⇒ Offshore construction for tapping sea resources
- ⇒ Temporary repair work caused by ships collisions or unexpected accidents
- ⇒ Salvaging vessels sunk in the sea
- ⇒ Repair and maintenance of ships
- ⇒ Construction of large ships beyond the capacity of existing docks
- ⇒ Repair and maintenance of underwater pipelines

### 4- Future Scope for Underwater Welding

Considerable industrial effort has been made to improve process performance and control strategies for the various underwater welding processes. For future scope in underwater welding, the major efforts on research and development should be focused on the following topics:

- ⇒ Automation of the underwater joining and inspection of the welded structures
- ⇒ Mechanized underwater welding for actual usage of a very large floating structures
- ⇒ Investigation of the potential of using a robot manipulator for underwater ultrasonic testing of welds in joints of complex geometry
- ⇒ Application of advanced welding technique, like friction, laser welding and understand the behavior of materials after the welding and process optimization
- ⇒ Invention of new welding techniques and explore the possibility of its application in underwater welding
- ⇒ Generation of research data book on weld ability of materials during underwater welding

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### 3- Application of underwater welding