

## Out of Position Wet Welding with AWS-E6013 Electrode Grade at Three Water Depths

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### Introduction

Shielded metal arc welding (SMAW) is frequently used in underwater wet welding (UWW) repair of aging offshore platforms and power plants. Actual underwater structural repairs with wet welding require out-of-position welding. Welding vertical-down is likely better than vertical-up in producing acceptable wet welds. In vertical-up welding, the liquid puddle does not have adequate support to form the weld bead, with the liquid metal running down by gravity. On the other hand, in vertical-down welding, the pressure of the arc will be able to give vertical support to the liquid metal and fill the cavity made by the arc to form acceptable weld beads. Note that the welding parameters (current and welding speed) must be carefully selected to produce good wet welds in the vertical-down position. It is conceivable that the gravity force of a large volume of liquid metal associated with high welding current and slow welding speed can overcome the arc pressure and run out of the weld pool resulting in unacceptable welds.

This paper presents the application of E6013 electrode in vertical down welding. Bead-on-plate (BOP) welds were deposited on A-36 steel plates at three water pressures, i.e. water depths of 0.5, 50 and 100 m.

### Procedures

Wet welds were made with AWS E6013 electrodes in a hyperbaric chamber capable of simulating water depths up to 200 m; the chamber was filled with potable water. The wet welds were made using a gravity welding system that was placed inside the chamber. A schematic illustration of the gravity welding system used to make the vertical down wet welds is shown in Figure 1.

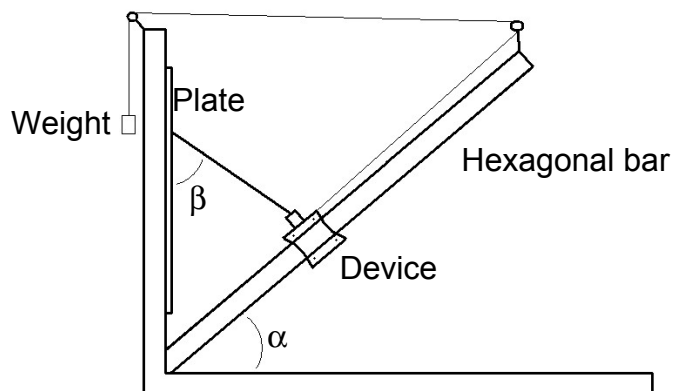


Figure 1 – Illustration of the vertical down welding system

The commercial E6013 electrodes had steel core rods of 3.25 mm in diameter and 1 mm thick flux coating. The electrodes were waterproofed with commercial varnish to protect the flux from water absorption.

BOP wet welds were produced on A-36 steel plates (1/2"x4"x10" thickness, width and length, respectively). In order to find the best welding parameters, different combinations of welding current, electrode-plate angles ( $\beta$ ), counterweights, and hexagonal support bar angles ( $\alpha$ ) were tested. Three BOP were made for each depth, using the best parameter. Three samples were removed from each weld bead. The first sample is located at 20 mm from the bead beginning; the second is located at mid-length of the weld and the last at 40 mm from the bead finish. Defects, bead morphology and porosity measurements were made on the wet weld deposits.

**Results and Discussion**

The best welding current values identified for the E6013 electrode grade in the vertical down-position for the three water depths, welding speeds, electrode-plate angle ( $\beta$ ) and hexagonal bar angle ( $\alpha$ ) are shown in **Table 1**.

Table 1 – Welding parameters selected in the tests.

Depth (m)	Current (A)	Travel speed (mm/s)	Electrode-plate ( $\beta$ ) angle	Hexagonal bar ( $\alpha$ ) angle
0.5	130	3.0 – 3.5	65°	30°
50	180	3.5 - 4.0	65°	30°
100	184	3.5 – 4.0	65°	30°

Visual examination of the BOP welds showed irregularities on the weld bead surfaces that increased with water depth. Undercut and porosity were also observed, as shown in Figures 2 to 4. The weld metal porosity was 0.60, and 1.72 vol. pct. for the wet weld made at 50 and 100m depths, respectively, which satisfied the macroetch test acceptance criteria from the Specification for Underwater Welding AWS D3.6M:1999 for Class B welds.



Figure 2 – Bead-on-plate wet weld deposited with E6013 electrode at 0.5 m water depth (the welding direction is from left to right-hand side).



Figure 3 - Bead-on-plate wet weld deposited with E 6013 electrode at 50 m water depth (the welding direction is from left to right-hand side).



Figure 4 - Bead-on-plate wet weld deposited with E6013 electrode at 100 m water depth (the welding direction is from left to right-hand side).

It was observed that the weld bead depth decreased as the water pressure increased, as can be seen in **Table 2** and in the macrographs shown in Figure 5.

Table 2 – Geometric parameters of weld beads.

Depth (m)	Width (mm)	Reinforcement (mm)	Penetration (mm)
0.5	6.98	1.96	2.24
50	8.08	1.12	1.06
100	7.91	1.26	1.04

\*Average values of 9 measurements for each depth.

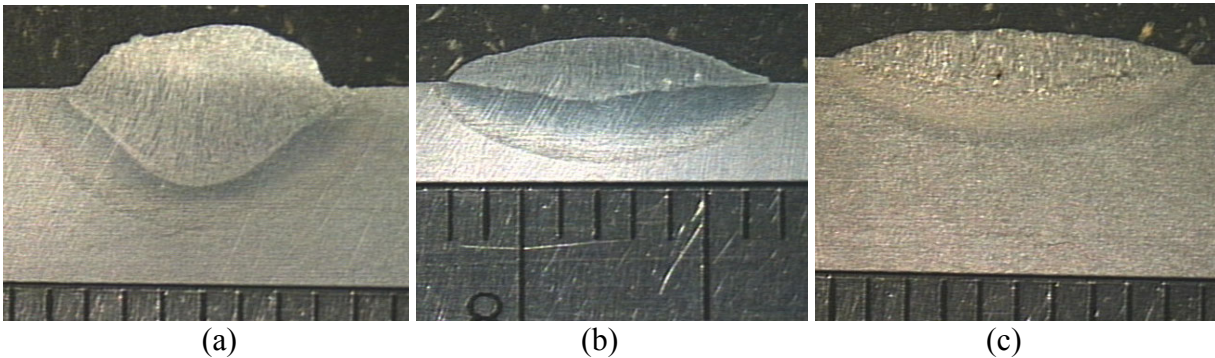


Figure 5 – macrographs of welds made at (a) 0.5, (b) 50, and (c) 100 m water depth. The scales shown are in millimeters

The biggest difficulty to produce vertical-down wet welds using the gravity welding system was to control the welding speed. This parameter is important because it controls the size of the weld pool. At high welding speeds, the weld pools tend to be smaller, with shallower penetration and smaller weld bead sizes. Undercut is the most frequent defect. At slow welding speeds, the weld pool becomes larger, with deeper weld penetration and larger bead sizes. In the latter case, the liquid metal floods the weld pool and causes short-circuiting that extinguishes the arc. As a result, discontinuous weld beads with unfilled sections of the cavity (made by the welding arc) were produced. Also, the weld beads tend to have irregular shape, sometimes without reinforcement).

With the gravity welder used in this work the welding speed depends on the welding current value selected, the electrode-plate angle ( $\beta$ ), and the hexagonal bar angle ( $\alpha$ ), as shown in Figure 1.

### Conclusions

- Successful BOP wet welds were deposited in the vertical-down position with E6013 electrodes at 50 and 100m using a gravity welder.

- Undercutting was the defect more frequently observed on the wet welds.
- Porosity of the wet welds was 0.0, 0.60, and 1.72 vol. pct. for 0.5, 50, and 100m water depth, respectively, which complies with the AWS D3.6 Specification for Class B welds.
- The welding speed, which depends on the welding current and the ( $\alpha$ ) and ( $\beta$ ) angles has to be properly adjusted in order to produce acceptable wet welds.

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