KREUZ SUBSEA

WET WEDLING CAPABILITY

Your Integrated Offshore Subsea Solutions Partner
What is wet welding?

“Welding at ambient pressure with the welder / diver in the water without any mechanical barrier between the water and the welding arc”

Applications

Majority and frequent on Structures underwater:

- Weather damages (Cyclone damages e.g. Katrina)
- Underwater structural joints nearing end of fatigue life
- Corrosion protection by adding anodes
- Minimal structure installation – joining subassemblies to jacket
- Conduction guide frame modifications – to accommodate additional wells in excess of the framing or directional angle on existing slot
- Change in operational requirements - adding I-tubes to TLP
Types of failures

- Chord member failure
- Horizontal diagonal brace crack
- Cracks on members supporting conductor support structure
- Horizontal member fatigue damage
- Critical T, K, Y Node Failure

Note: Pictures above are for illustration of issues and from different projects worldwide done by others.
Execution Flow

Level 1 guideline survey or special surveys

- Damage to primary structure or damage indicators
  - Design / assessment criteria check
    - Does the structure pass the design check?
      - Yes → No further actions
      - No → Level – II or III or IV surveys

Level – II or III or IV surveys

- Damages established? Locations and extent known?
  - Yes → No further actions
  - No → API-RP-2A-WSD

No further actions

- Engineering Assessments
  - Design considerations for selection of wet welding
  - Designing the repair

- Qualify Welding Procedure (Mechanical properties key!)
- Qualify diver welders
  - AWS D3.6M: 2010

Post surveys and Demobilize

- Pre-fabrication
- Job preparations
- Pre-job safety / HAZIDs
- Mobilize
- Perform welding
- Post surveys
- Demobilize

Yearly or special survey check wet welded areas

Type | Cost | Safety | Visibility | Accessibility | Weld Strength | Weld Quality
--- | --- | --- | --- | --- | --- | ---
Wet | Low | High | Low | High | Medium | Medium
Dry | High | Medium | High | Low | High | High

Weld Strength: Weld Quality

Weld Strength: Weld Quality
Surveys / Inspections

In accordance with API RP 2A-WSD, Level II and III (14.3 for Surveys) and Level IV (14.4.3 for Special surveys) arising out of direct exposure to a design environmental event like hurricanes, storms.

**Methods employed**

1) Visual Inspection (Visual)
2) Magnetic Particle Inspection (MPI)
3) Manual Ultrasonic Testing (MUT)
4) Alternating Current Field Measurement (ACFM)
1) Shielded Metal Arc Welding (SMAW)¹
2) Single diameter electrode – waterproof
3) Stinger bead technique
4) Visual and MPI for acceptance of welds

¹other welding processes are:
- Flux cored Arc Welding (FCAW)
- Friction Welding (FW)

**Variables**
- a. Weld Joint design (Groove/ Fillet) – Common Fillet
  (See Slide on design considerations)
- b. Base metal
- c. Filler metal
- d. Position of welding
- e. Weldment temperature
- f. Electrical Characteristics (DC Power)
- g. Technique
- h. Environment
Design Considerations - Welding

**Welding Critical Issues**
- Location, Water depth, Sea current, Swells
- Diver Skill & Safety
- Risk of Hydrogen Cracking in steels
- Weld Joint integrity including stress & fatigue
- Weld metal mechanical properties like UTS/YS Strength, toughness & ductility
- Weld quality like Lack of fusion, Cracking & Porosities

**Challenges**
- Safety
- Deposition Rate, Bubbling Effects, Steaming
- Stable arc
- Electrode diameter
- Welding Position & accessibility

**Risks**
- Electric Shock (Achieving adequate Welding equipment & cable insulation)
- Hydrogen and oxygen produced by arc (Avoid build up of gas pockets, which are potentially explosive)

- Visibility of the diver-welder
- One diver welder at any one time
- Small fillets, smooth and long radii for diver
- Scalloping ends and lobes for transition
- Not just a repair but strengthening of structures
Key **Hazards** to the diver are:

- Falling overhead loads
- Vessel motion induced movements
- Vessel DP failures and loss in position
- Electrical shocks
- Visibility related
- Unknown cracks – Undetected defects
- Intake sumps and open caissons
- Trapped gases

Additional tag lines

- DP checks prior to job start
- Shock proof, DC power source, earthling checks
- Venting of gases to surface through hoses
  - Voids to be checked for gas free
  - LO / TO for isolations
- Platform based equipment to eliminate issues from vessel motions

HAZID, Pre-Job Safety Assessments, PTW systems, Diver Welder pre-job training, Emergency response plan (and trials), multi-source weather forecasts, experienced crew and supervision management, proper structural engineering
### Pros and Cons

<table>
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<tr>
<th>Pros</th>
<th>Cons</th>
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<tr>
<td>Less Expensive compared to Dry welding</td>
<td>Hydrogen embrittlement</td>
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<tr>
<td>Faster</td>
<td>Faster quenching reduces strength and ductility</td>
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<tr>
<td>Higher tensile strength</td>
<td>Poor visibility (decomposition of flux constituents resulting in white bubbles)</td>
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<td>Easier access to welding area</td>
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Kreuz Capability Mix

**Marine Operations**
- Vessel Assurance and Integrity
- DP Operations
- Vessel working close to platforms and live assets

**Diving Operations**
- Compliant and certified to IMCA
- Familiarity with installing / repairing / retro fit onto existing structures
- Experienced dive management (ref separate slide)

**Wet Welding Operations**
- Previous habitat welding
- Survey & NDT tooling / techniques
- Hyperbaric / hot tapping experience
- Experienced diver welder team
Experienced Dive Management

Kurush Contractor
CEO / Director
33 years / Subsea Construction and Diving Industry/ Management positions in many companies and as a commercial diver

Dr. Jean-Yves Massimelli
QHSE Director
25 years / Occupational Health Specialist / managed certification projects / consultant to French Commercial Diving training center

Cyrus Cama
VP – Offshore Operations
25 years / Subsea & Diving projects in SEA, ME, India and Europe for Rockwater, Coflexip Stena, Global Industries, Stolt and Subtec

Tom Reynolds
Welding Consultant
41 years / BS Mech Engg / AWA certified welding engineer / served in AWS underwater welding committee / published & co-authored more than 15 papers / Global Ind, CBI

Vijayan Kallikot
Vessel Manager
39 years / Graduate Engineer / held various positions as Marine Engineer, Chief Engineer and Technical Superintendent.

Christopher Stilton
Equipment Manager
33 years / Sr. Dive Technician in Aberdeen and Canada / Served in Royal Navy / trained as aircraft mechanic.

Gurudev Singh
Engineering Manager
31 years / Various positions in Rockwater, Global Industries and Subtech / projects in APAC, ME and India.

Matthew Clyde Harrington
Equipment Manager
19 years / Qualified ROV OCM/ Experienced in work & Obs class / construction, dive support & survey / worked for Technip and DOF

Experienced offshore supervision and crew
References

   American Welding Society (AWS)

   Recommended Practice for planning, designing and constructing fixed offshore platforms
   – Working Stress Design
   American Petroleum Institute

3) Reynolds, Thomas J. 2010. Service History of Wet Welded Repairs and Modifications,
   Proceedings of the 3rd International Workshop on Underwater Welding of Marine
   Structures, Houston, Texas

   Repaired by Wet Welding Weathers Hurricane Lili, Proceedings of OMAE 2003: The 22nd
   International Conference on Offshore Mechanics & Arctic Engineering 8-13 June, 2003
   Cancum, OMAE99-2231
Kreuz Subsea is an integrated turnkey solutions provider in IRM and Subsea Construction Services – Unique and differentiating model
Going beyond limits