HYPERBARIC WELDING FOR CORROSION RESISTANT ALLOY PIPELINE REPAIR

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Overview

Topics

1. Manual Corrosion Resistant Alloy (CRA) hyperbaric welding
2. Pipeline repair strategy
3. Hyperbaric welding procedure qualification

Answer the following questions

1. **Why** investigate hyperbaric welding for CRA pipeline repair?
2. **How** is a manual hyperbaric CRA weld executed?

Summary / Conclusions
Questions


Why investigate hyperbaric welding for CRA pipeline repair
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CRA Clad and Lined Linepipe

+ Both have 3 mm CRA layer inside carbon steel

+ Metallurgically bonded (clad)
  - CRA plate metallurgically bonded to CS plate
  - Plate to pipe by bend press & weld
  - Can accommodate higher strain

+ Mechanically lined
  - CRA Liner pipe inserted in carbon steel pipe
  - Expand liner to plastically deform
  - Welded overlay ends

Lined

Clad

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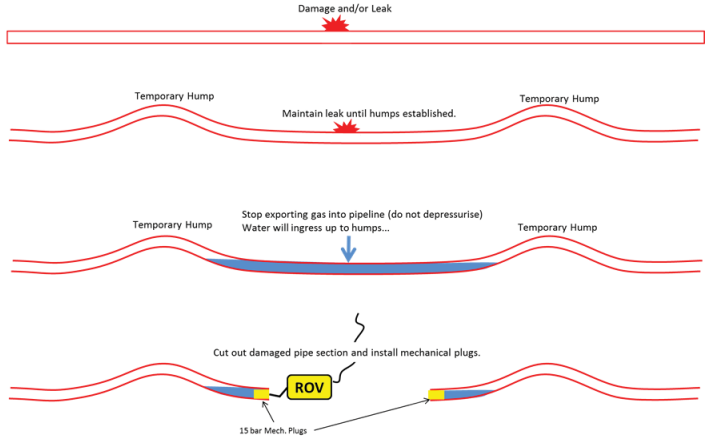
316 CRA Pipeline Repair

+ Emergency Response
+ Assess damage
+ Manage raw seawater ingress:
  - Maintain positive pressure
  - Pipeline humps
  - Temporary Clamp
  - Flush with treated seawater
+ Current permanent repair options for minor damage:
  - Grouted sleeve or grinding (dents or gouges)
+ Unqualified permanent repair options:
  - Hyperbaric welding
  - Mechanical connectors
  - Sectional replacement with pipelay vessel
+ Full pipeline replacement



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How to execute a manual hyperbaric CRA weld
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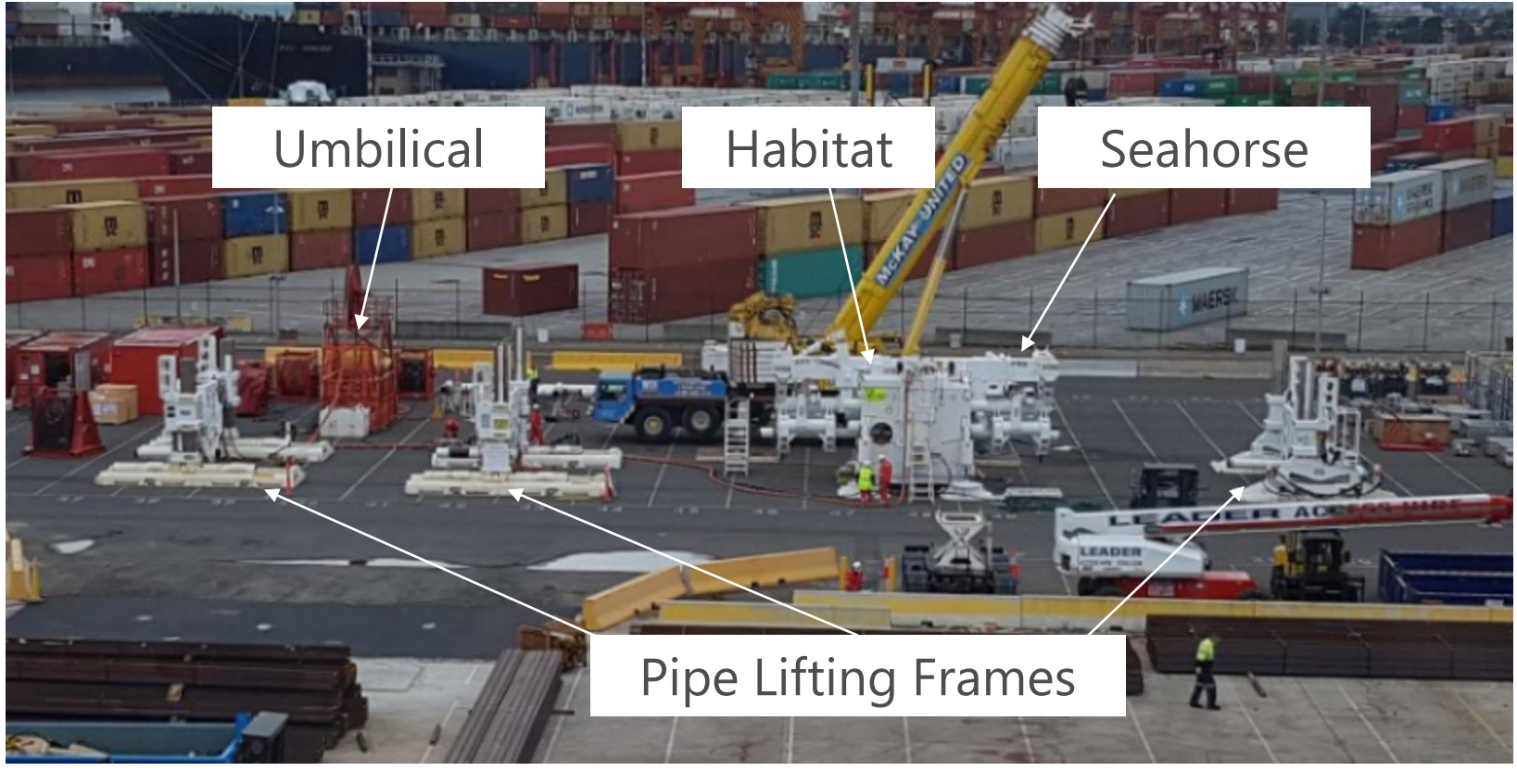
Diver Operated Emergency Pipeline Repair Spread (EPRS)



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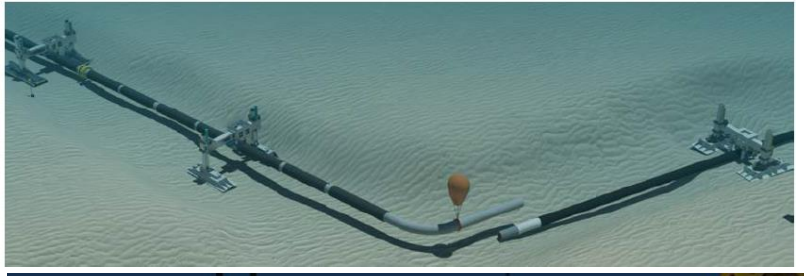
Habitat Deployment and Dry Underwater Welding

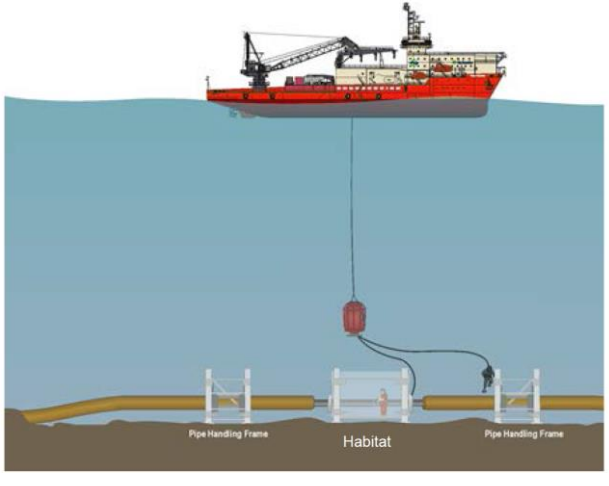


1. Position cut ends with handling frames

2. Lower habitat, seahorse clamp and transfer chamber over pipeline

3. Module deployed with umbilical and attached to habitat

4. Habitat blowdown, commence welding



Hyperbaric CRA Welding Qualification Trials

Objective

Determine if hyperbaric welding is a feasible option for repair of CRA clad and lined pipelines

Subsea7 Scope

"Complete hyperbaric welding trials to qualify a Proposed Welding Procedure Specification (pWPS)… using 100% manual Gas Tungsten Arc Welding process"

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Hyperbaric Welding Procedure Qualification Process

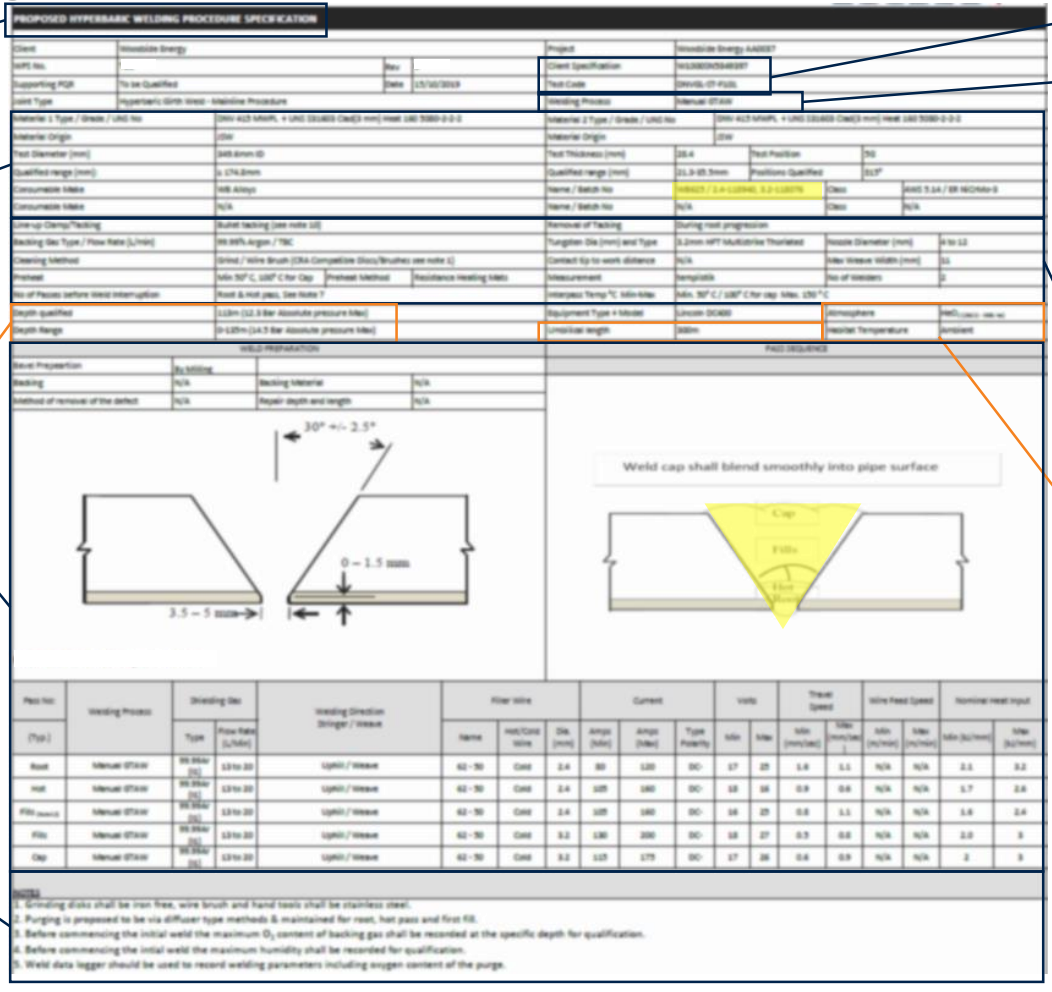
pWPS

Pipe details, welding consumable welding position

Hyperbaric special
- Depth

Weld prep and pass sequence

Notes



Specs

Manual TIG

Inconel 625 consumable

Welding equipment, number of welders, interpass temperatures

Hyperbaric special
- Umbilical Length
- Atmosphere
- Habitat temperature

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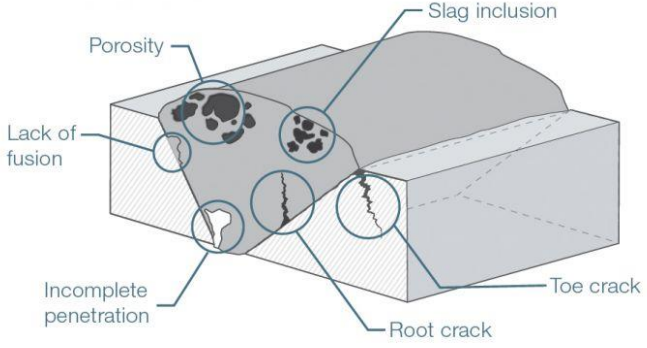
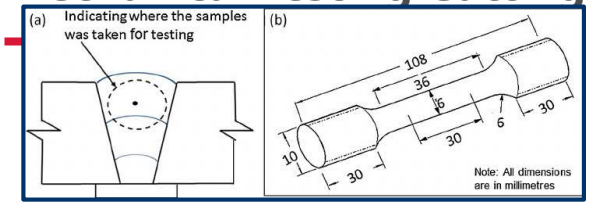
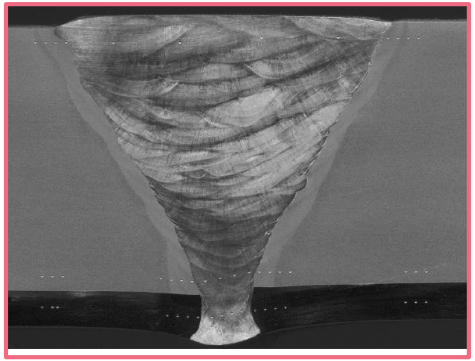
Qualification of pWPS

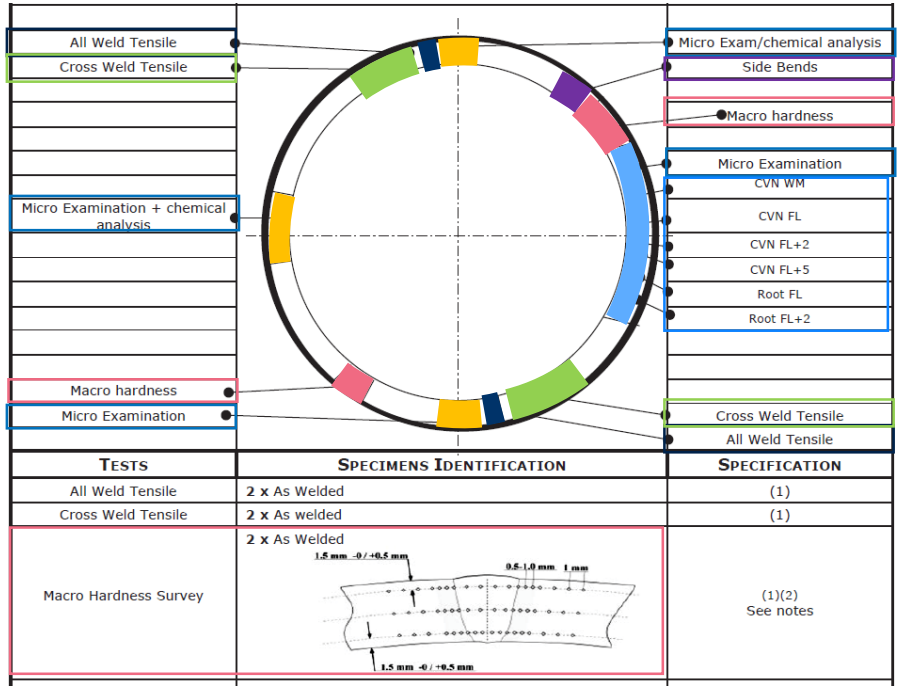
+ Non Destructive Testing
  - Visual
  - Ultrasonic
  - Radiographic
+ Mechanical Testing
+ Diver Welder Qualification



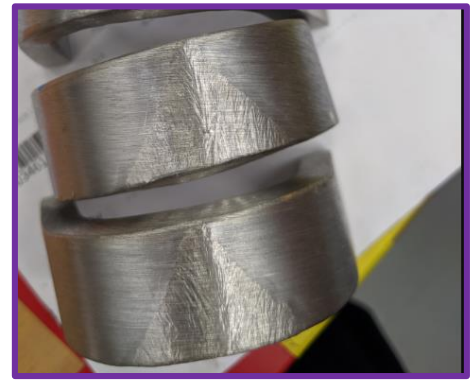
Mechanical Testing Cutting Sheet

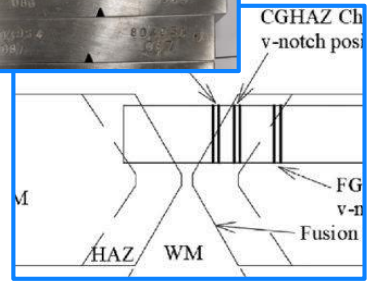






TESTS	SPECIMENS IDENTIFICATION	SPECIFICATION
All Weld Tensile	2 x As Welded	(1)
Cross Weld Tensile	2 x As welded	(1)
Macro Hardness Survey	2 x As Welded	(1)(2) See notes



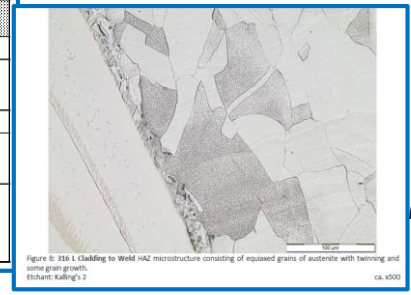


Chemical Analysis - ICP-OES,Combustion (C+S) (* Sub-Contracted To: Element Teesside (UKAS 0038)) *

	Al [%]*	C [%]*	Cr [%]*	Cu [%]*	Fe [%]*	Mn [%]*	Mo [%]*	Nb [%]*	Ni [%]*	P [%]*	S [%]*	Comments
023:	0.05	0.016	21.0	0.04	8.45	0.11	8.23	3.13	58.6	<0.005	<0.003	See Below
024:	0.05	0.013	20.7	0.06	12.9	0.18	7.85	2.91	55.0	0.005	<0.003	See Below

	Si [%]*	Ti [%]*	V [%]*	Comments
023:	0.09	0.17	<0.01	See Below
024:	0.12	0.15	0.01	See Below

Item 023: 0 DEGREES LOCATION
WELD METAL ROOT AREA . 0.5mm BELOW CLADDING INTERNAL SURFACE
Item 024: 270 DEGREES LOCATION
WELD METAL ROOT AREA . 0.5mm BELOW CLADDING INTERNAL SURFACE



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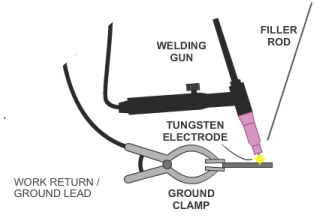
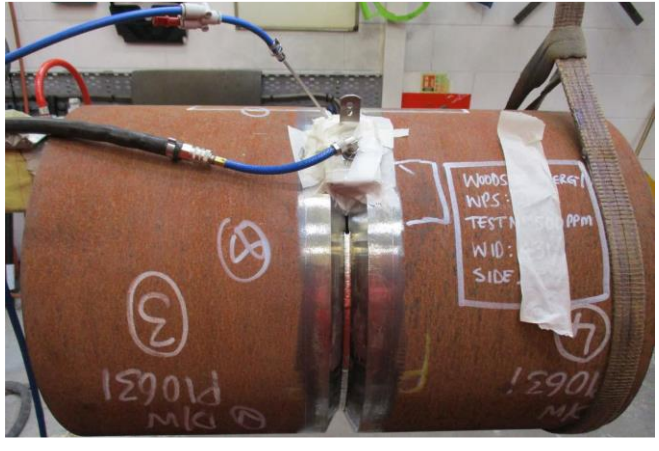
Manual Hyperbaric Welding for Carbon Steel Pipeline Repair

+ Welding Equipment inside habitat
  - Welding torches
  - Heating mats
  - Cutters, Grinders
  - De-gaussing machines
  - Welding masks
+ Welding Equipment on the vessel
  - Weld control
  - Welding machine
  - Shielding gas
  - Heating mat machines



CRA Welding in Air

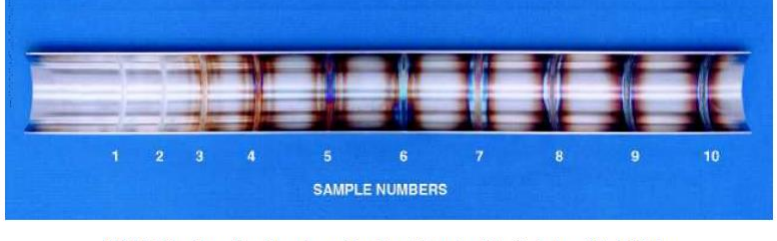
- Back purge to prevent oxidation
  - Purge Dams
  - Purge Gas
  - Oxygen analyser
  - Tape



This figure has been extracted from AWS D18.1/D18.1M:2009.

2. **The Tube Sample.** The tube sample was prepared using an automatic orbital "bead-on-plate" weld on the outside diameter of a 2 in [50.8 mm] stainless steel tube. The weld penetrated through the tube wall. The concentration of oxygen in ppm added to the pure argon backing gas for each weld was as follows:

No. 1—10 ppm	No. 3—50 ppm	No. 5—200 ppm	No. 7—1000 ppm	No. 9—12 500 ppm
No. 2—25 ppm	No. 4—100 ppm	No. 6—500 ppm	No. 8—5000 ppm	No. 10—25 000 ppm



Weld Discoloration Levels on Inside of Austenitic Stainless Steel Tube

Manual Hyperbaric Welding for CRA Pipeline Repair

+ Welding Equipment inside habitat
  - TIG torches
  - Heating mats
  - Cutters, Grinders
  - De-gaussing machines
  - **Breathing (AGA) masks**
  - **Heat resistant tape**
  - **Oxygen content analyser**
  - **Purge hoses**
  - **Exhausts**
+ Welding Equipment on the vessel
  - Weld control
  - Welding machine
  - Shielding and **purge gas**
  - Heating mat machines

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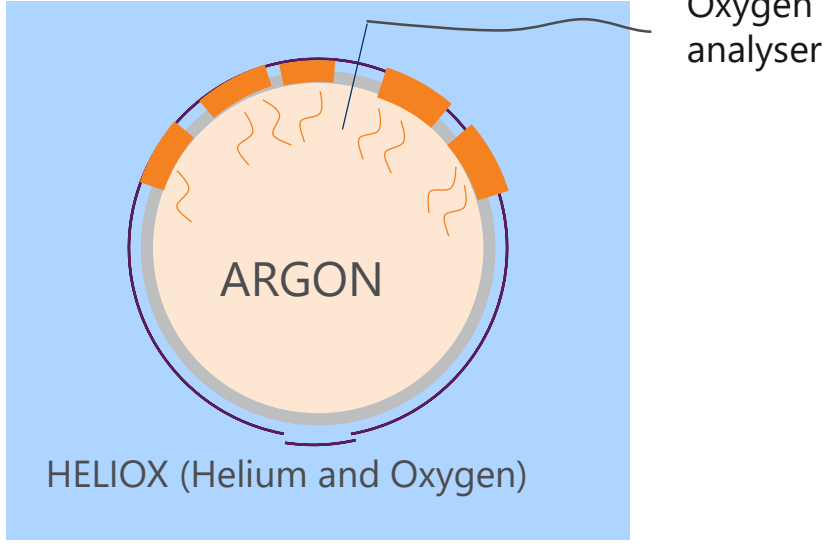
Purge Gas Challenges

+ Oxygen levels increased as soon as tape was removed to start welding
+ Despite having five purge shoes and injecting argon at 50 L/s (i.e. positive pressure)
+ Issue containing purge at 6 o'clock position



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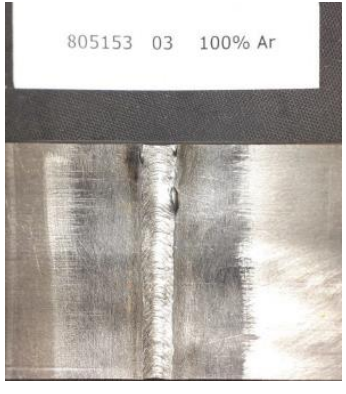
Impact of Depth to Oxygen Sensitivity

Surface welds



-25m welds

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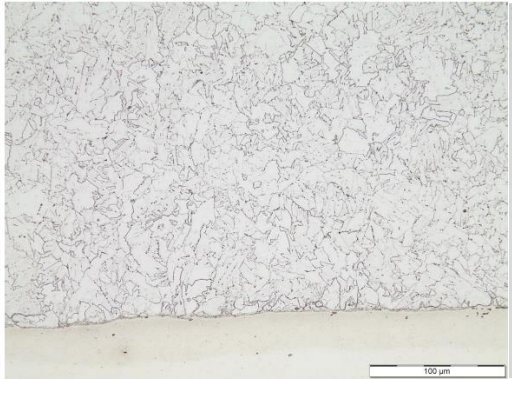
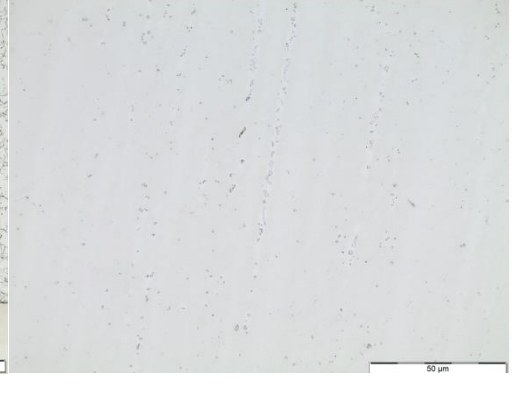
Mechanical Test Results

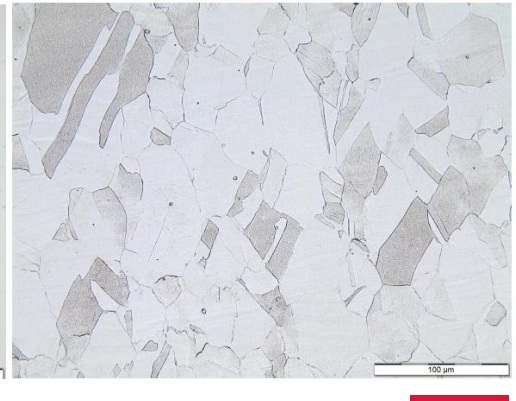
	0.2% Proof Stress (MPa)	% Elongation	Ultimate tensile strength (MPa)	Impact Toughness (J)	HV Hardness (kg/mm²)	Pitting Resistance Equivalent # (%Cr + 3.3 x %Mo + 16 x %N)
Test	All weld tensile		Cross weld tensile	Charpy	Vickers	Chemical analysis
Criteria	>SMYS + 80 *At least 80 MPa above minimum yield strength*	>18	>SMTS *Failure in parent material, above specified minimum tensile strength*	>35 *with 42 J average at minimum design temperature -30 °*	<325	>26 *Greater than cladding material PREN ie. 316*

Microanalysis: *"Essentially free from grain boundary carbides, nitrides and intermetallics"*

Side Bends: *No cracks*







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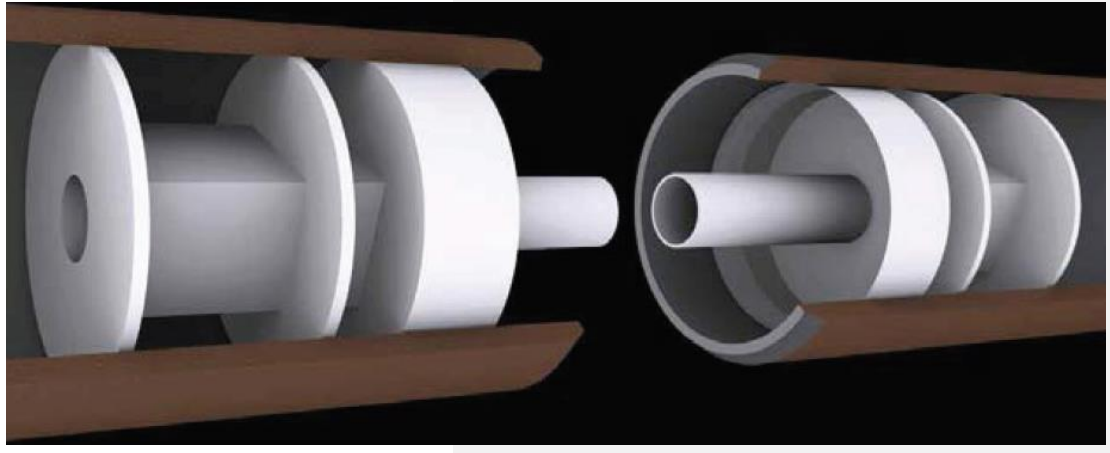
Technical Risks for Offshore Campaign

+ Suck and Blow
    - Burn through
    - Spatter
+ CRA Contamination
    - Seawater ingress
    - Carbon contamination
+ Out of roundness
+ **Magnetism**
+ Cut outs, full penetration repairs
+ Repair procedures
+ Soluble purge dams




Summary
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Summary

Hyperbaric welding of CRA clad or lined pipeline is feasible, however qualification of purge set up should consider:

+ Lower threshold of allowable oxygen concentration
+ Functionality of oxygen monitoring equipment in hyperbaric environment


Thank you for listening!
Questions?
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Welding Enclosures

Back up

+ Initially procured for mitigating suck and blow (12 o'clock)
+ Now considered for welding at 6 o'clock position
+ Will require diver welder to practice at the surface
+ Several configurations required for different welding positions
+ Long time to establish purge