PREFERENTIAL WELD CORROSION
ICORR / TWI EVENT, ABERDEEN

Neil Gallon / Michael Young · 25/09/2018

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INTRODUCTION TO ROSEN

- As part of the asset care business (ILI, Integrity), our Materials And Corrosion And Welding consultants are highly experienced and qualified in metallurgy, materials engineering, corrosion engineering, welding engineering and mechanical engineering.
- Qualified and experienced materials, welding and corrosion engineers *e.g.* Masters, PhD, IWE/EWEs, CEng etc.
- Based in the West End of **Aberdeen** on Queens Road and **Newcastle Upon Tyne**.
- ROSEN has extensive technical knowledge and experience in many fields including, but not limited to:
  - Materials Engineering and Metallurgical support
  - Corrosion management
  - Coating systems
  - Welding Engineering support
  - Failure assessment and root cause analysis
  - Life extension support
  - Procurement and manufacturing support and audits
  - Specification development, review and approval
  - Training

INTRODUCTION / CONTENTS
PREFERENTIAL WELD CORROSION (PWC)

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Contents

1. What is preferential weld corrosion?
2. Why are welds different?
3. Diagnosis of preferential weld corrosion and challenges
4. Mitigation of preferential weld corrosion (and corrosion local to welds)
5. Questions

PREFERENTIAL WELD CORROSION

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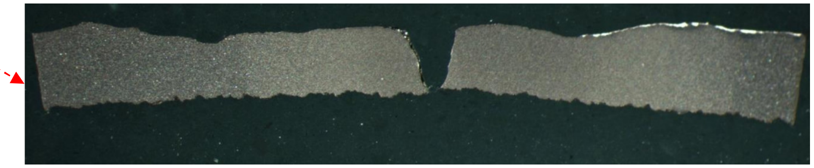
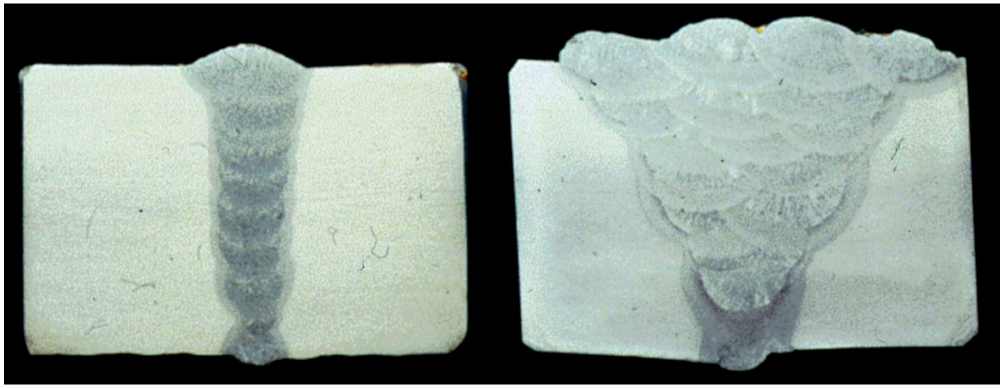
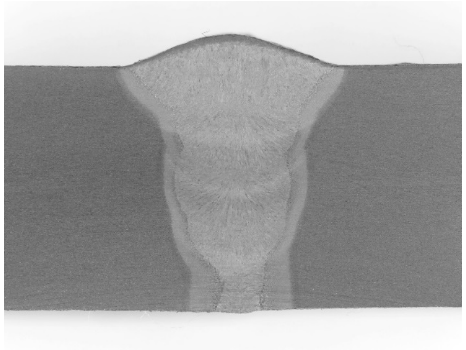
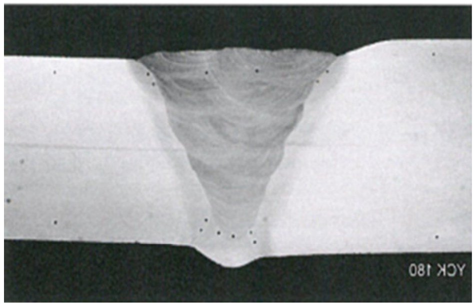
- What is preferential weld corrosion?
- Is it different from preferential corrosion at a weld?
- Which systems and welds are vulnerable – girth / longitudinal, topside, subsea, carbon steel, stainless steel etc.?



WELDING BACKGROUND

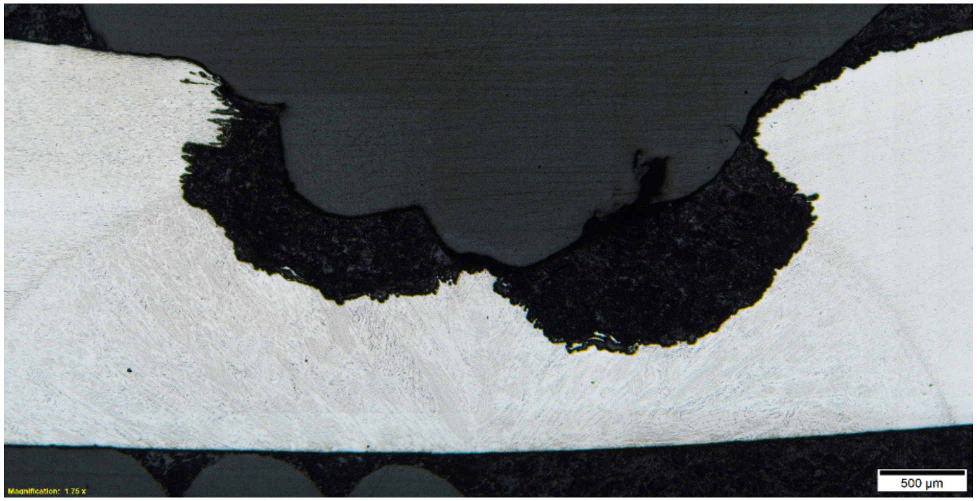






WELDING VARIABLES

- Consumable chemistry
- Welding parameters
- Microstructure
- Geometry
- PWHT / Stress relief
- Scale formation / passivation

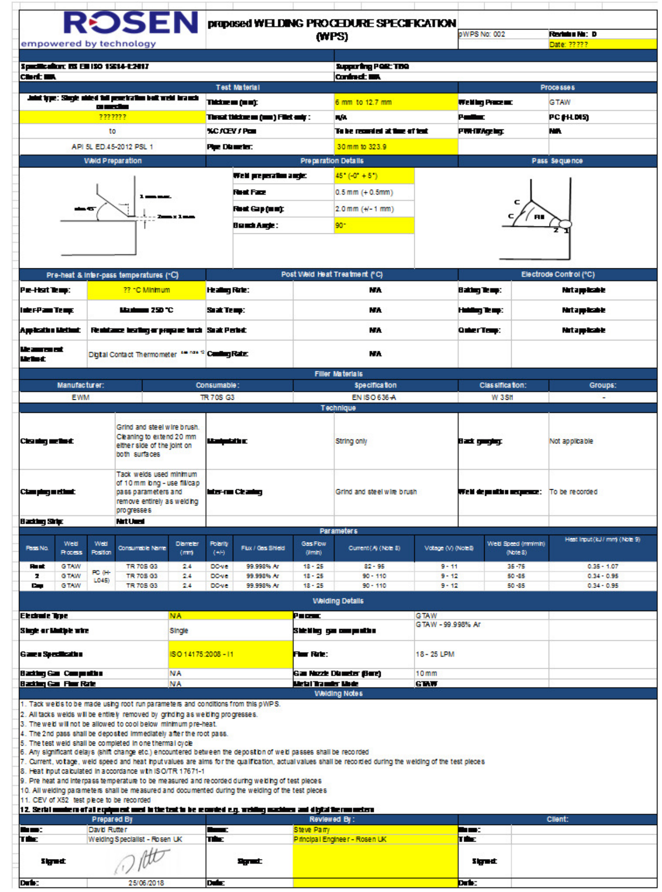


INFLUENCE OF WELDING CHEMISTRY

- Consumable chemistry
  - Galvanic differences between weld metal and base material
  - Traditionally welds are over-matched (eg. Ni additions)
- Base metal chemistry
  - Depending on dilution / environment weld metal can be cathodic or anodic to base material
  - Localised attack of either weld metal or HAZ

INFLUENCE OF WELDING PARAMETERS

- Welding process / technique
  - MMA, MIG / MAG, FCAW, TIG, SAW, stringer, weave……..
- Thermal control
  - Heat Input - current, voltage, travel speed
  - Pre-heat, inter-pass temperature
  - Cooling, morphology of HAZ….
- Joint configuration
  - Amount of dilution
  - Ease of fusion……
- And many more!



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proposed WELDING PROCEDURE SPECIFICATION (WPS)

pWPS No: 002 · Revision No: D · Date: ?????

Specification: BS EN ISO 15614-1:2017			Supporting PQR: TBC		
Client: N/A			Contract: N/A		
Test Material				Processes	
Joint type: Single sided full penetration butt weld branch connection	Thickness (mm):	6 mm to 12.7 mm		Welding Process:	GTAW
???????	Throat thickness (mm) Fillet only:	N/A		Position:	PC (H-L045)
to	%C /CEV / Pcm	To be recorded at time of test		PWHT/Ageing:	N/A
API 5L ED.45-2012 PSL 1	Pipe Diameter:	30 mm to 323.9			
Weld Preparation	Preparation Details			Pass Sequence	
	Weld preparation angle:	45° (-0° + 5°)			
	Root Face	0.5 mm (+ 0.5mm)			
	Root Gap (mm):	2.0 mm (+/- 1 mm)			
	Branch Angle:	90°			

Pre-heat & Inter-pass temperatures (°C)		Post Weld Heat Treatment (°C)		Electrode Control (°C)	
Pre-Heat Temp:	?? °C Minimum	Heating Rate:	N/A	Baking Temp:	Not applicable
Inter-Pass Temp:	Maximum 250 °C	Soak Temp:	N/A	Holding Temp:	Not applicable
Application Method:	Resistance heating or propane torch	Soak Period:	N/A	Quiver Temp:	Not applicable
Measurement Method:	Digital Contact Thermometer see note 12	Cooling Rate:	N/A		

Filler Materials

Manufacturer:	Consumable:	Specification	Classification:	Groups:
EWM	TR 70S G3	EN ISO 636-A	W 3Si1	-

Technique

Cleaning method:	Grind and steel wire brush. Cleaning to extend 20 mm either side of the joint on both surfaces	Manipulation:	String only	Back gouging:	Not applicable
Clamping method:	Tack welds used minimum of 10 mm long - use fill/cap pass parameters and remove entirely as welding progresses	Inter-run Cleaning	Grind and steel wire brush	Weld deposition sequence:	To be recorded
Backing Strip:	Not Used				

Parameters

Pass No.	Weld Process	Weld Position	Consumable Name	Diameter (mm)	Polarity (+/-)	Flux / Gas Shield	Gas Flow (l/min)	Current (A) (Note 8)	Voltage (V) (Note8)	Weld Speed (mm/min) (Note 8)	Heat Input (kJ / mm) (Note 9)
Root	GTAW	PC (H-L045)	TR 70S G3	2.4	DC-ve	99.998% Ar	18 - 25	82 - 95	9 - 11	35 -75	0.35 - 1.07
2	GTAW		TR 70S G3	2.4	DC-ve	99.998% Ar	18 - 25	90 - 110	9 - 12	50 -85	0.34 - 0.95
Cap	GTAW		TR 70S G3	2.4	DC-ve	99.998% Ar	18 - 25	90 - 110	9 - 12	50 -85	0.34 - 0.95

Welding Details

Electrode Type	N/A	Process:	GTAW
Single or Multiple wire	Single	Shielding gas composition	GTAW - 99.998% Ar
Gases Specification	ISO 14175:2008 - I1	Flow Rate:	18 - 25 LPM
Backing Gas Composition	N/A	Gas Nozzle Diameter (Bore)	10 mm
Backing Gas Flow Rate	N/A	Metal Transfer Mode	GTAW

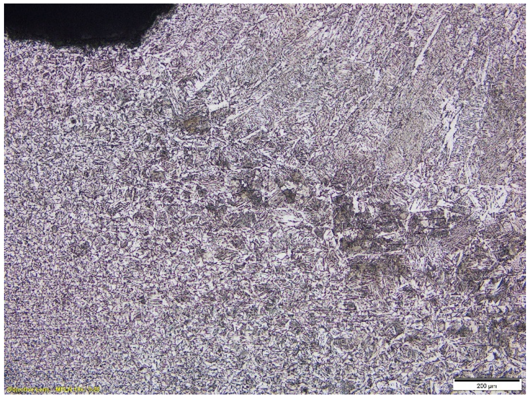
Welding Notes

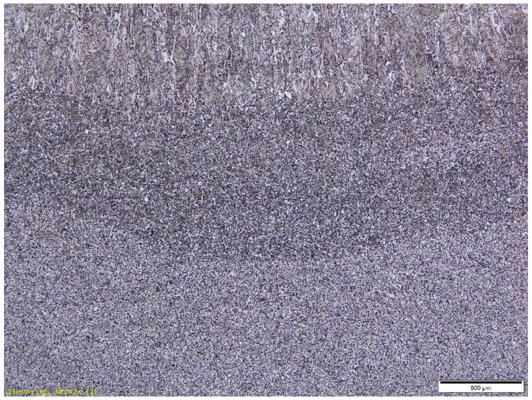
1. Tack welds to be made using root run parameters and conditions from this pWPS.
2. All tacks welds will be entirely removed by grinding as welding progresses.
3. The weld will not be allowed to cool below minimum pre-heat.
4. The 2nd pass shall be deposited immediately after the root pass.
5. The test weld shall be completed in one thermal cycle
6. Any significant delays (shift change etc.) encountered between the deposition of weld passes shall be recorded
7. Current, voltage, weld speed and heat input values are aims for the qualification, actual values shall be recorded during the welding of the test pieces
8. Heat input calculated in accordance with ISO/TR 17671-1
9. Pre heat and interpass temperature to be measured and recorded during welding of test pieces
10. All welding parameters shall be measured and documented during the welding of the test pieces
11. CEV of X52 test piece to be recorded
12. Serial numbers of all equipment used in the test to be recorded e.g. welding machines and digital thermometers

Prepared By		Reviewed By:		Client:	
Name:	David Rutter	Name:	Steve Parry	Name:	
Title:	Welding Specialist - Rosen UK	Title:	Principal Engineer - Rosen UK	Title:	
Signed:		Signed:		Signed:	
Date:	25/06/2018	Date:		Date:	

METALLURGY VARIATIONS

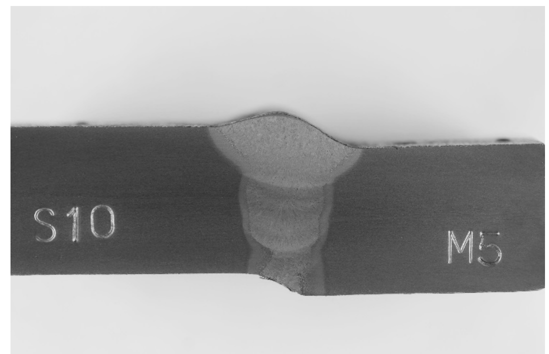
- Microstructure
  - Varying microstructure across the weld
  - Weld metal, CGHAZ, GRHAZ, parent metal
  - Differing grain sizes and orientations
  - Differing precipitate compositions and morphologies
  - Impurities / inclusions

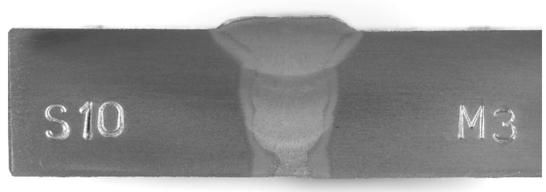


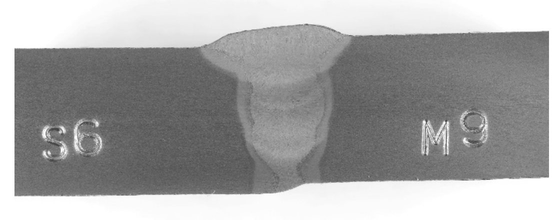


WELDING VARIABLES

- Geometry
  - Amount of root penetration
  - Size of cap
  - Toe angle
  - Any dressing?
  - Location of weld

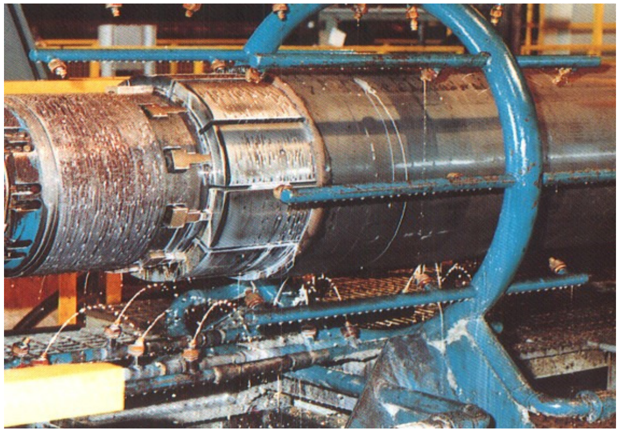






RESIDUAL STRESS

- Post Weld Heat Treatment (PWHT) / Stress Relief
  - Time / temperature of PWHT
  - Tempering / microstructural changes
  - Stress relief heat treatment?
  - Cold expansion of pipes, hydrotest?



WELDING INFLUENCES

- Scale Formation / Passivation
  - Stainless steels
  - Carbon steels
  - Pickling / reconstitution of passive layer

CORROSION RESISTANT ALLOYS

- Are they immune from PWC?
- Duplex (and superduplex, and hyperduplex….)
- Austenitic (304L, 316L, 254SMO……)
- Nickel based alloys (825, 625…..)

- Intermetallic phases
- Sensitisation / chemistry control
- Importance of pre-heat, heat input, post-weld heat treatment
- ASTM G48, G28, A262 Method E
- Pickling and / or passivation – how to do this on site?
- Isolation – welding of carbon steel to stainless steel

DIAGNOSIS

So how do we diagnose Preferential Weld Corrosion (PWC)?

With great difficulty!!! It is a grey area. For example, not specifically listed as a damage mechanism in API 571. Not always prevalent throughout the system….

Why?

- Preferential Weld Corrosion is rarely a singular casual factor. Other factors can lead to corrosion local to welds.
- Difficult to predict – you don’t know you’ve got it until it happens!
- It is difficult to inspect. For example:
  - Differentiating a localized corrosion (pin hole) feature on a weld as PWC?
  - “Tolerance” factors at welds – effecting inspection equipment e.g. UT
- Inspection difficulty a known issue – HOIS undertaking work on addressing issue (RPZ2). ROSEN involved
- In the absence of access (visual), can only effectively be diagnosed following metallography - destructive techniques.
  - Usually picked up at root cause analysis – too late!

DIAGNOSIS (CASUAL FACTORS)

Change of environment

"Galvanic Corrosion"

Graphitization

Presence of water / conductive solution

Atmospheric Corrosion

Temper Embrittlement

Strain Aging

Chemical injection

Sigma Phase Embrittlement

Coating Breakdown

Sensitisation

CO_2 / H_2S Corrosion

Oxygen Corrosion

Deposits

MIC

Erosion / Erosion Corrosion

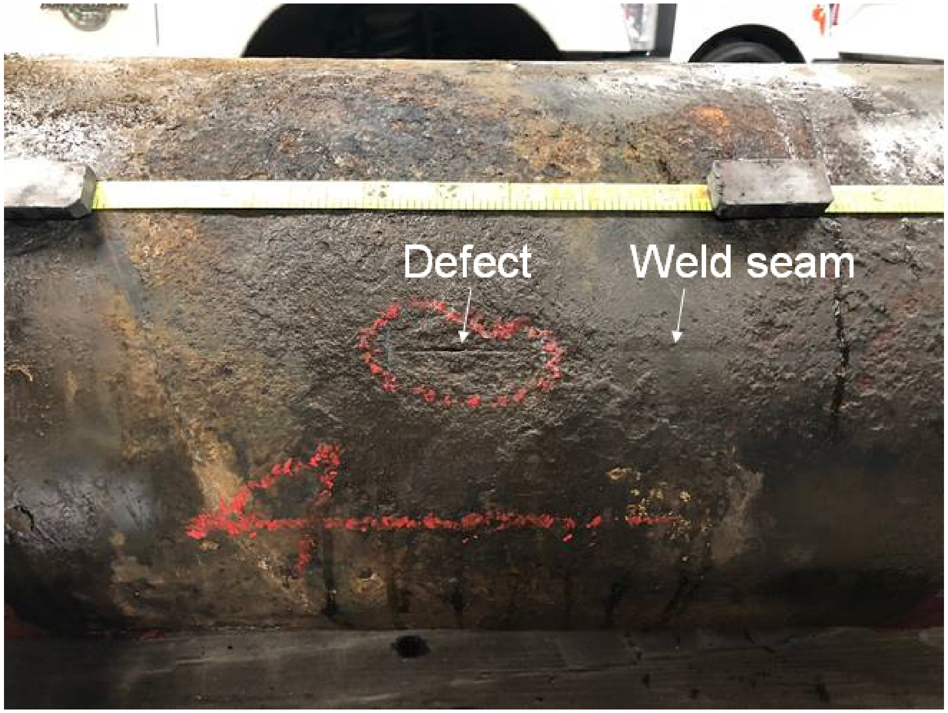
Brittle Fracture

CP under-protection

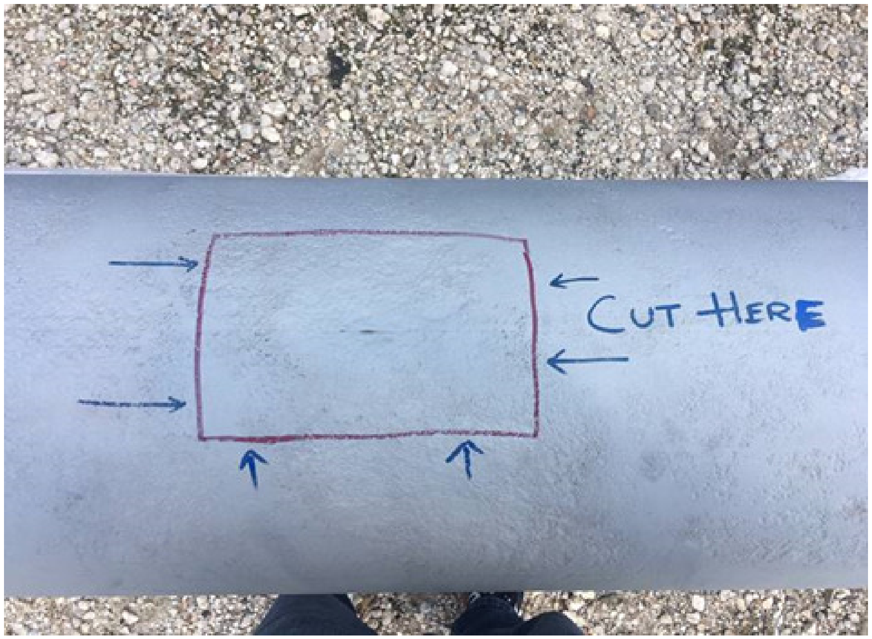
- All these factors can lead to corrosion at the weld – but not necessarily PWC as the pure scientific definition.
- Like TOLC, sometimes diagnosed by location only and not the pure scientific definition.

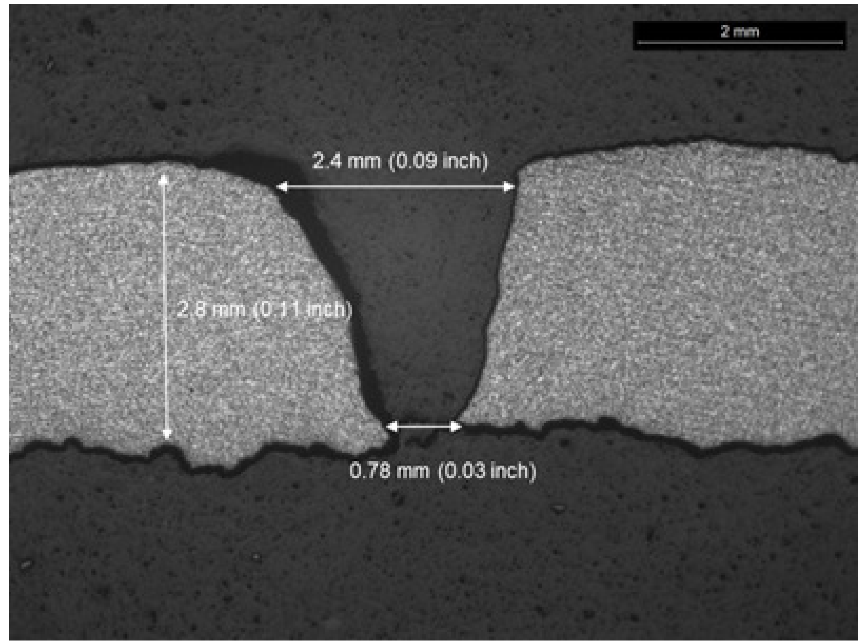
EXAMPLE DIAGNOSIS

External Corrosion on a buried pipeline



EXAMPLE DIAGNOSIS

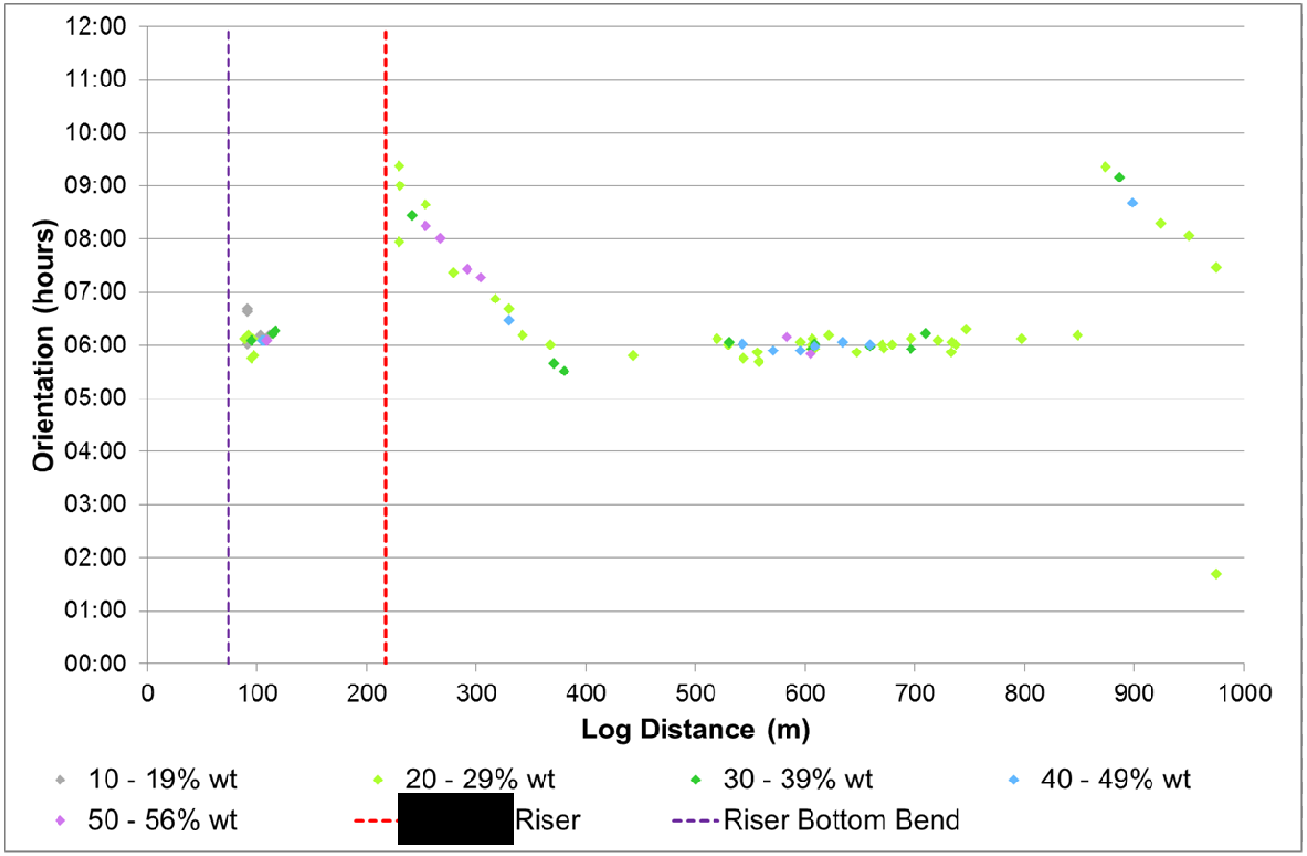




Is it Preferential Weld Corrosion?

- Yes – Weld root has preferentially corroded in favour of the parent material.
- However, welds area always a location of susceptibility…
- Causal factors in this case loss of external coating and cathodic protection

EXAMPLE DIAGNOSIS



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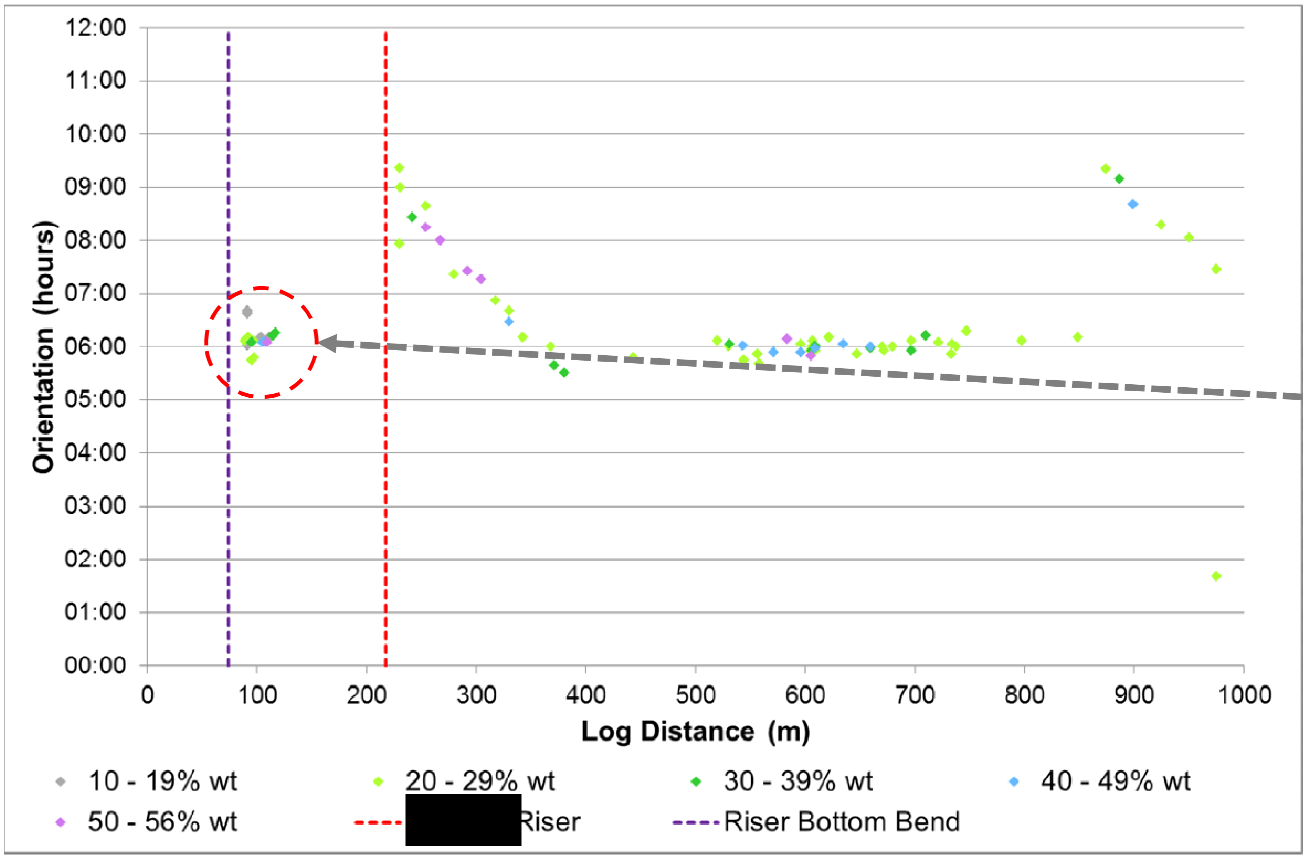
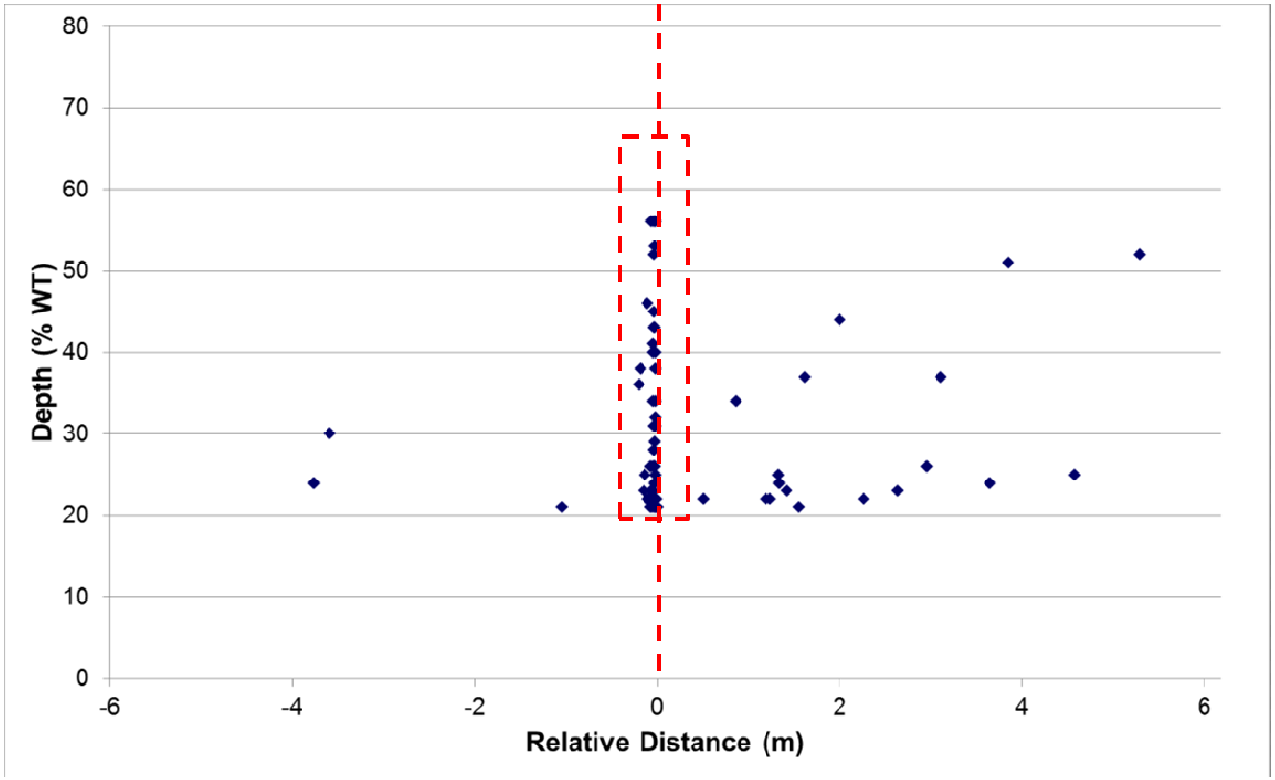
EXAMPLE DIAGNOSIS



- Crude Oil Line
- The features within the concentration immediately following the end of the subsea riser bend were a series of isolated pits, the majority of which were located in the vicinity of girth welds

EXAMPLE DIAGNOSIS



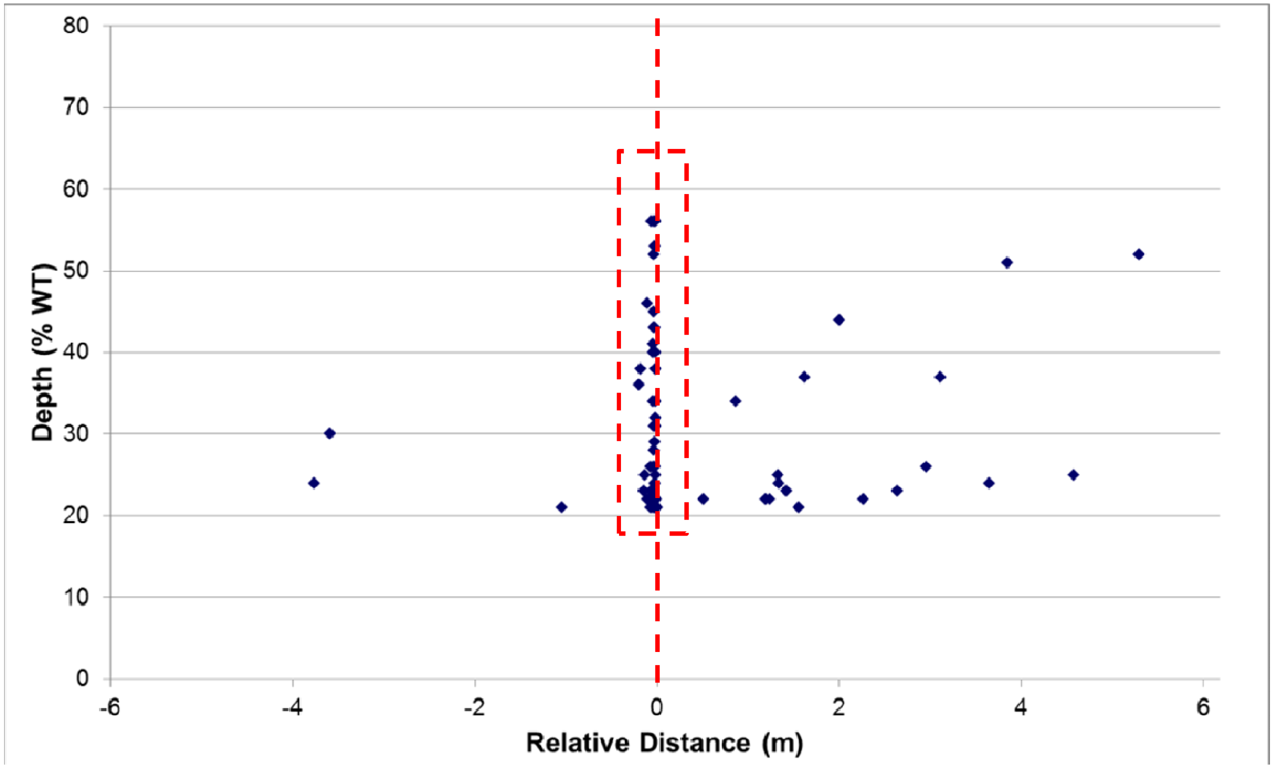
EXAMPLE DIAGNOSIS

Graph shows relative distance of detected features to the pipeline welds (red line)

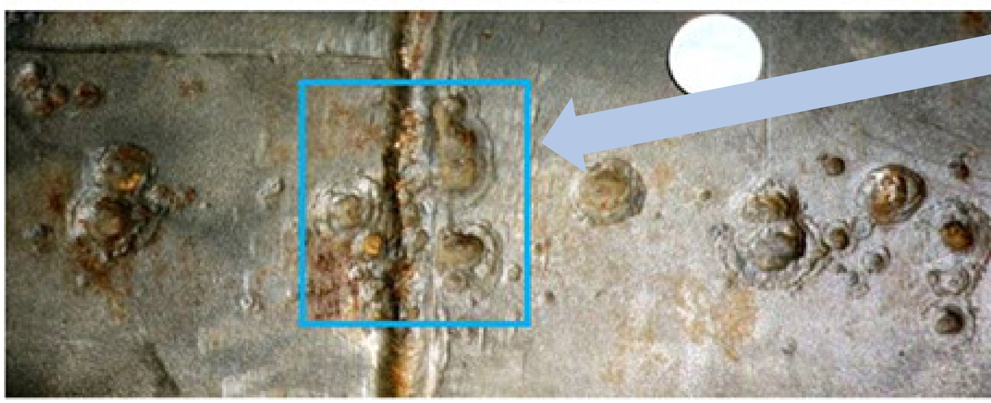
Significant concentration on the weld.

The is concentration of defects at the weld *could* be interpreted as the potential for PWC occurring at a (or some) girth welds in the pipeline.

However, was eventually diagnosed as MIC local to the weld.



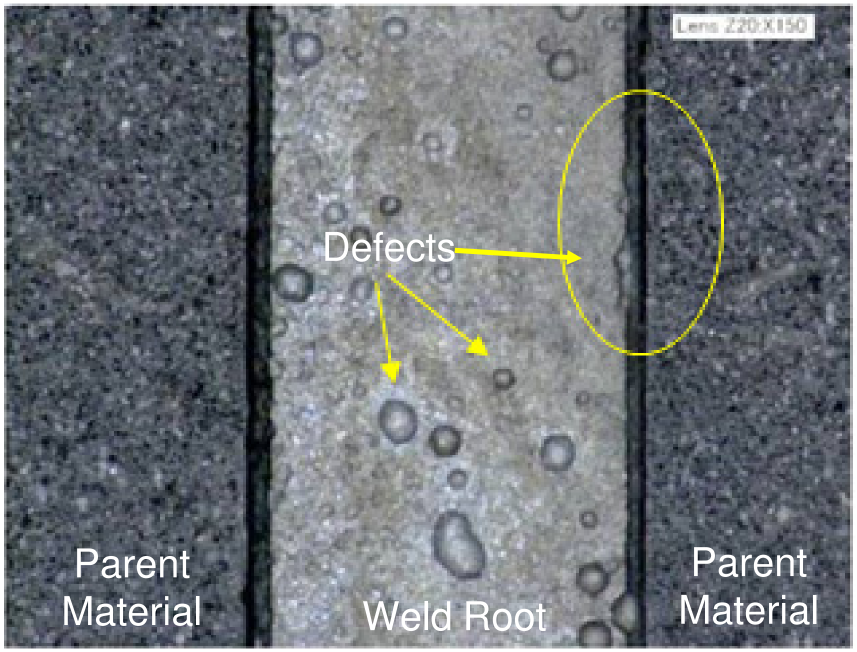
EXAMPLE DIAGNOSIS



Not PWC but MIC near welds (where biofilms and iron sulphide scales may not be effectively disturbed or removed e.g. by pigging)

PWC… MITIGATION

- No mitigation is a silver bullet - In fact it can either cause problems or provide false hope!
- E.g. 1% Nickel – Often cited as a fix – can ensure a cathodic weld metal
- However, it has been shown that the selective corrosion of the overalloyed weld metal can occur when the parent material is inhibited and the weld is not.
- Flow condition, under dosing can lead to poorly inhibited welds. Selection and testing issues (e.g. testing weld not the same as system weld)
- Weld can become anodic.
- Replacement if possible?
- Increased inspection frequency



(ALL) CORROSION MECHANISMS AT WELDS… MITIGATION

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- Again difficult.
- Focus on the primary/secondary casual mechanism.
- Internally
    - Chemical Injection e.g. corrosion inhibitor, biocide, oxygen scavenger
    - Process Control e.g. water control, cleaning pigs
- External
    - Coating – selection, correct application, backfilling
    - CP - Working correctly? Potentials within limits? No shielding
- No mitigation is a silver bullet.
- Replacement if possible?
- Increased inspection frequency

MIC AT WELDS… MITIGATION (PROBLEMS)

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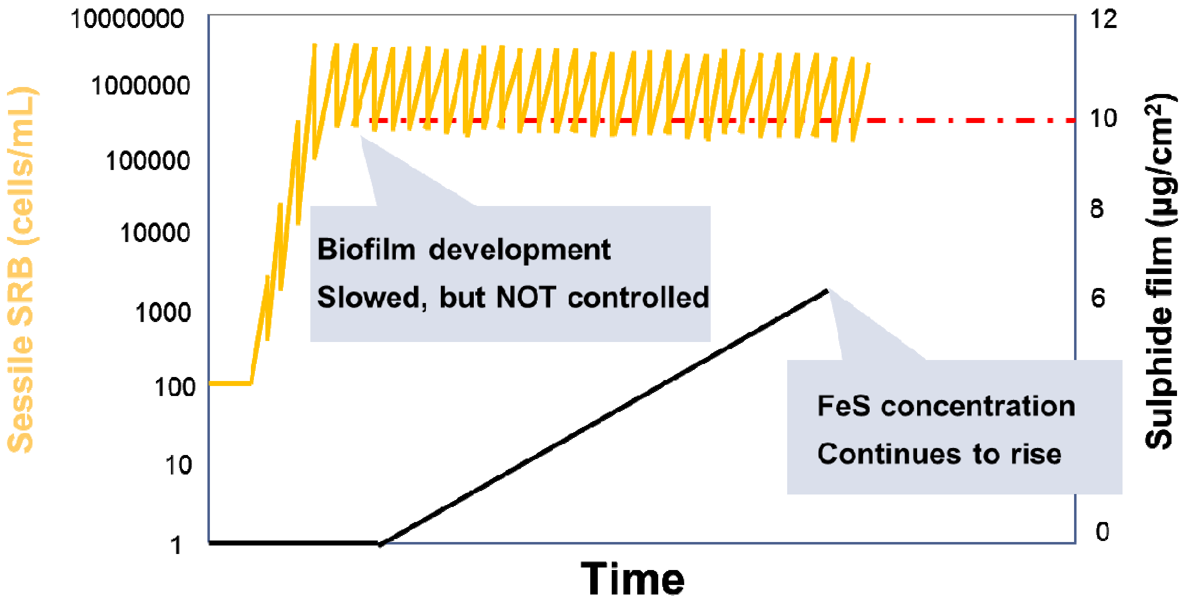
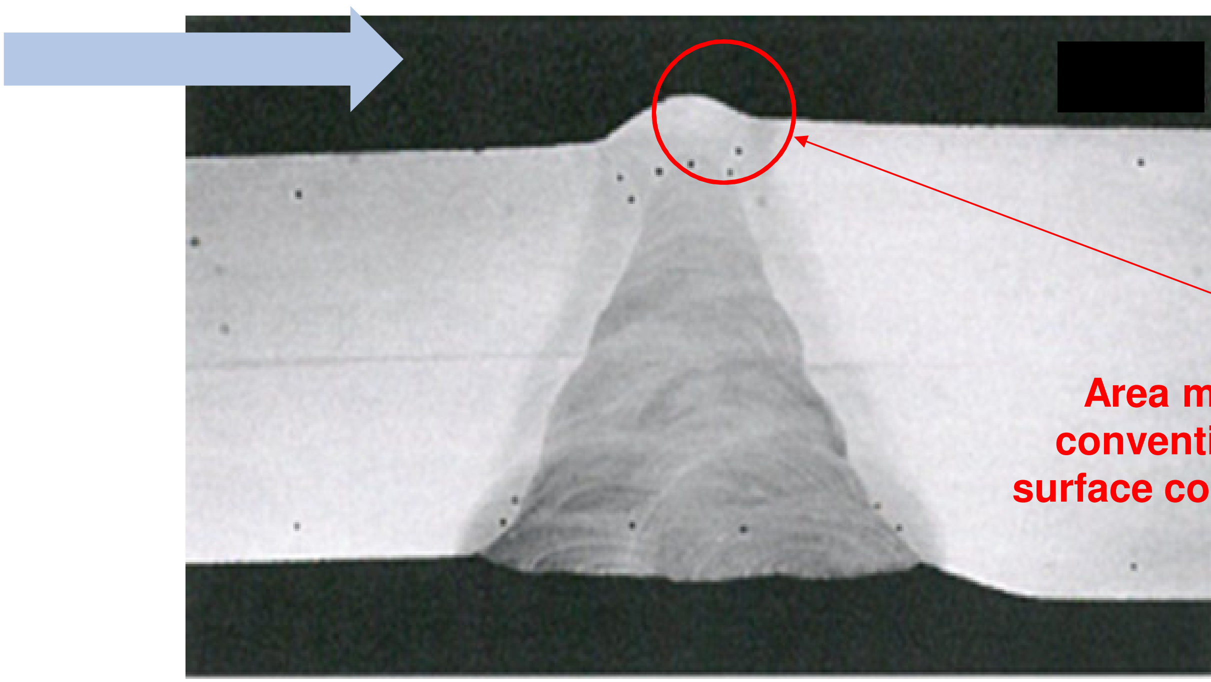
- Biocide problems
- Injection of biocide doesn't guarantee a reduction in microbial activity. This is especially pertinent to the welds
- Needs to be used in conjunction with clean pigs.
- But even then, not guaranteed to disrupt sessile activity.

Scenario B – Biocide (90% eff.) 6 hours/week but No Pigging



MIC AT WELDS… MITIGATION (PROBLEMS)

Cleaning Tool Direction / Chemical Injection Flow



Area may not be fully cleaned by conventional cleaning tools or poor surface contact / wetting with chemicals

Thank you for your attention

Any questions?