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
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
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 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!
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
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
- CO₂ / H₂S 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
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

![Graph showing depth vs. relative distance](image)

- Depth (% WT)
- Relative Distance (m)

The graph illustrates the relationship between depth (% WT) and relative distance (m) for a preferential weld corrosion example. The data points are plotted, and the trend is indicated by a dashed line. The graph suggests localized corrosion at certain relative distances.
EXAMPLE DIAGNOSIS

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

Significant concentration on the weld. The 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)
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
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)

- 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**

- Biofilm development Slowed, but NOT controlled
- FeS concentration Continues to rise
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?