R-TECH MATERIALS

Microbiologically Induced Corrosion

Sarah Bagnall

ICORR South Wales & South West England Branch

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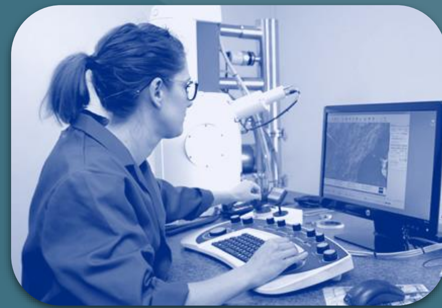
Our services

Testing of steel products for structural concrete



Failure Analysis Consultancy

Polymer & Composites Testing

Onsite services

Training Courses

Testing of components for water industry

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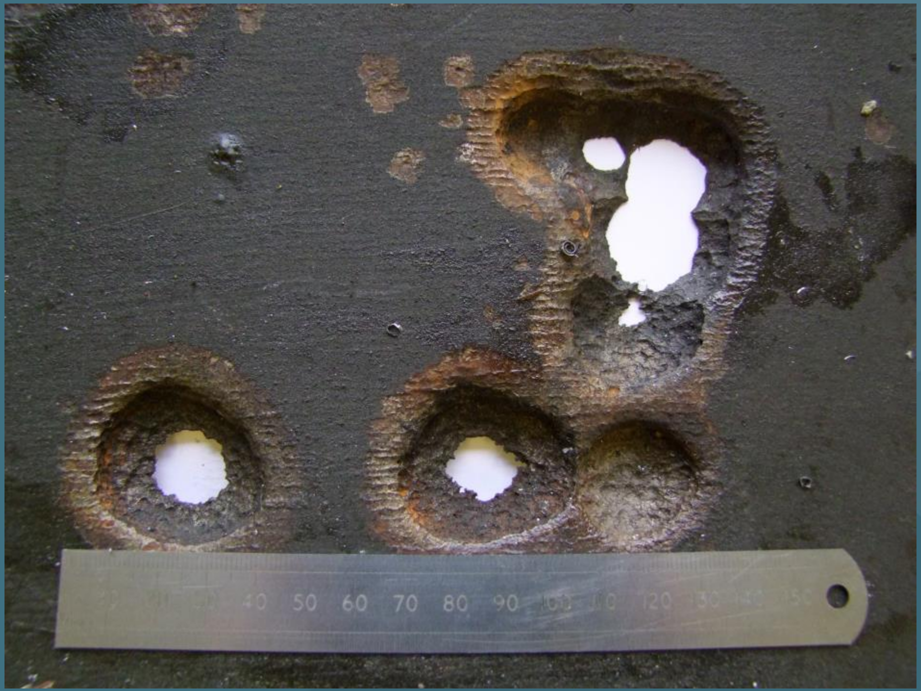
Microbial Induced Corrosion - Overview

- A form of corrosion caused by living organisms i.e. bacteria, algae or fungi.

- **Affected materials:**
  - Most common materials
  - Titanium is highly resistant

- **Consequences:**
  - Pitting or crevice corrosion which can occur rapidly



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Microbial Induced Corrosion

- Micro-organisms do not directly attack metal, but their by-products do.
- MIC is found where water containing organic material is always or sometimes present, especially where stagnant or low flow conditions allow and/or promote the growth of organisms.
    - Can occur due to insufficient drying after a hydrotest which leaves stagnant water and allows microbes to thrive.

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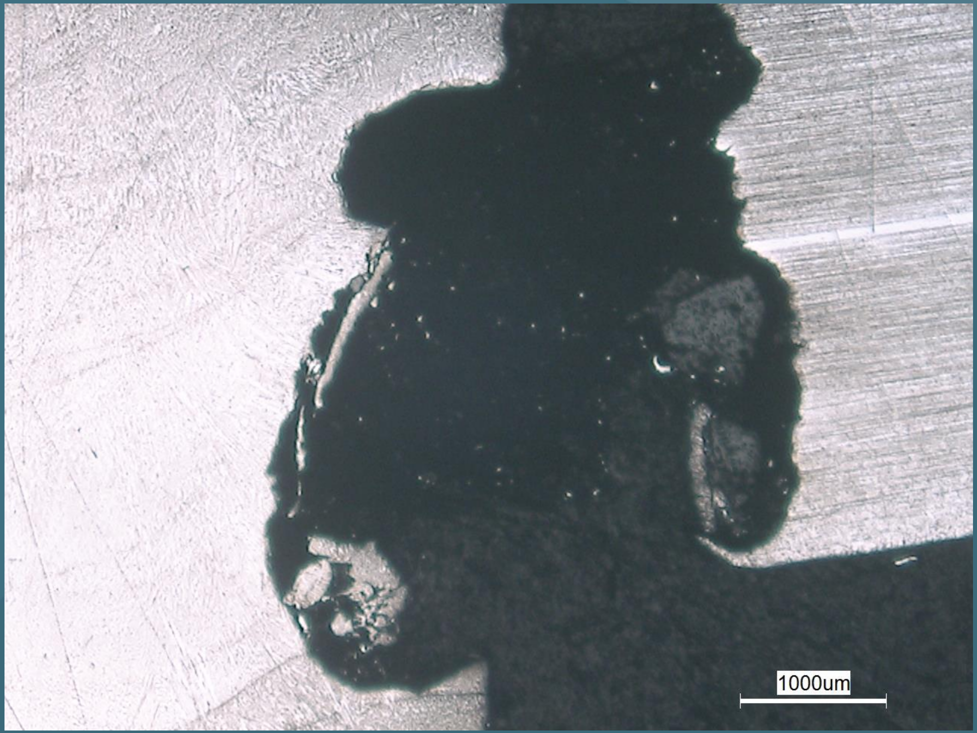
Microbial Induced Corrosion

- Biologically produced substances may actively or passively cause attack:
  - In passive, biological material acts as a chemically inert substance. The biomass acts as a shield beneath which concentration cells are established.
  - Involves under deposit corrosion which tends to involve large system surface areas.

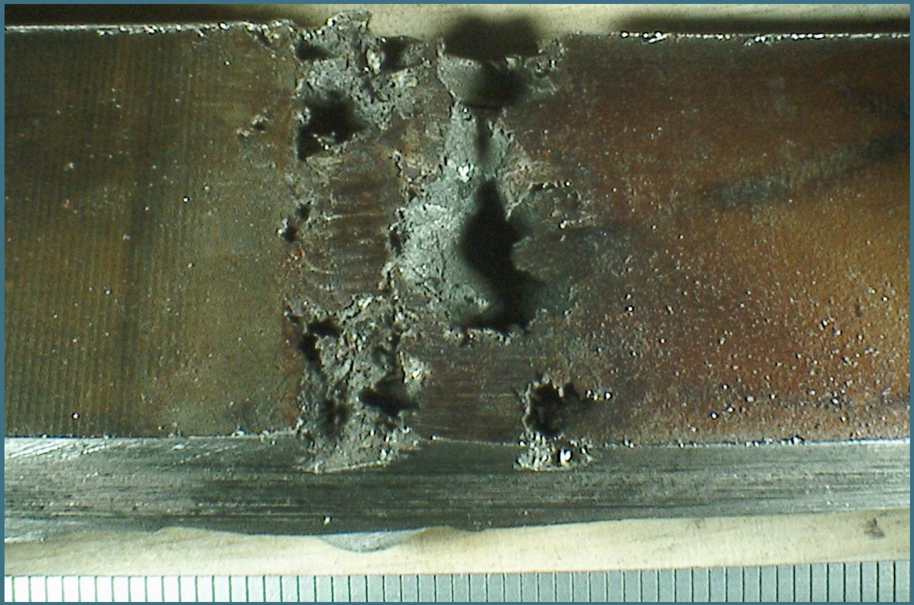


Microbial Induced Corrosion

- Active biological corrosion may be defined as the direct chemical interaction of organisms with materials to produce new corrosion chemistries or accelerate existing corrosion mechanisms.

- Factors that influence MIC are:
  - pH
  - Temperature
  - Flow
  - Oxygen concentration

Microbial Induced Corrosion



- Potentially troublesome bacteria are either aerobic or anaerobic
- Bacteria grow in a consortium in which several varieties of organisms coexist in an energy-efficient community.
  - Synergistic effects are common.
  - One type of organism may break down a particular molecule common to the system
  - A second organism may further degrade the molecular by-products
  - A third organism may use such by-products to obtain energy

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Microbial Induced Corrosion – Sulphate reducers

- Most common form of MIC involves sulphate reducing bacteria
  - Cause most localised corrosion issues associated with bacteria

- The bacteria types are anaerobic; they may survive in aerobic conditions but do not actively grow.

- Present in most natural waters including fresh, brackish, and sea water

- Sulphate or sulphite must be present

- Can tolerate temperatures as high as 80°C and a pH from 5 to 9.

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Microbial Induced Corrosion – Acid Producers

- Many bacteria produce acids…
  - Can be organic/inorganic depending on the bacterium.

Thiobacillus thiooxidans and Clostridium species have most often been linked to accelerated corrosion of steel.

- These are aerobic that oxidise sulphur compounds to form sulphuric acid.
- There is a symbiotic relationship between sulphur oxidisers and sulphate reducers.

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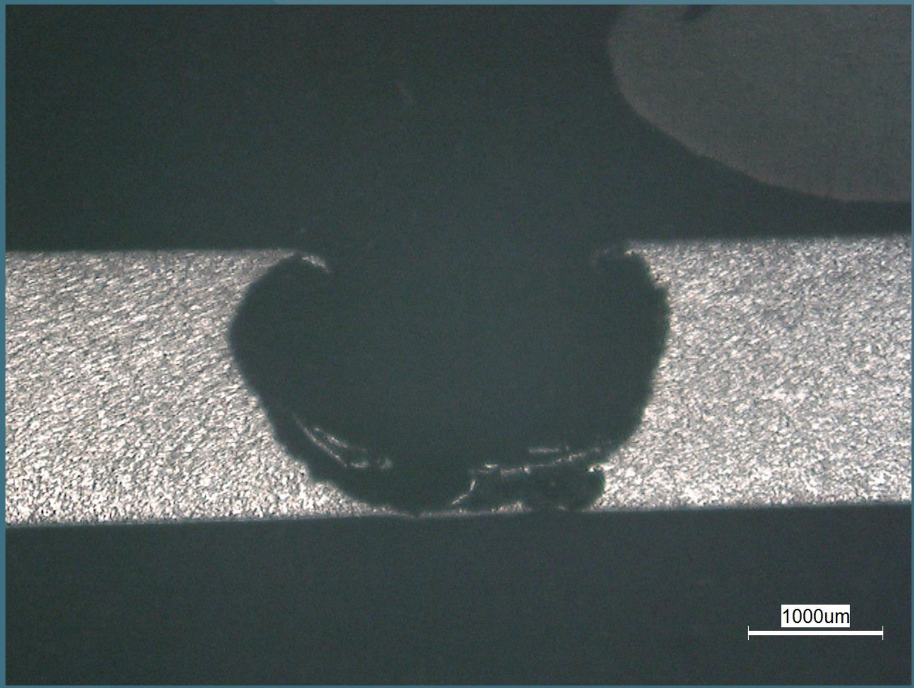
Microbial Induced Corrosion – Prevention

- To maintain operational usage of the unit as much as possible. A flow rate of 3 fps (1 m/s) will inhibit colony formation
- If downtime for long periods is expected, adequate drainage and drying is necessary.
- Ensure that equipment is drained and dried following a hydrotest.
- Periodically flushing and cleaning.
- Lines should be sloped to assist in drainage.
- Systems not designed for water containment should be kept clean & dry.



Microbial Induced Corrosion – Prevention

- Treatment with biocides such as chlorine, bromine, ozone, ultraviolet light, or proprietary compounds. Often, multiple biocides are needed to keep the levels of bacteria in the appropriate ranges.

- Biocides are generally not effective in a system that is already contaminated with colonies protected by a sludge layer.
  - Effective mitigation requires complete removal of deposits and organisms, typically using some combination of pigging, blasting, chemical cleaning, and biocide treatment.

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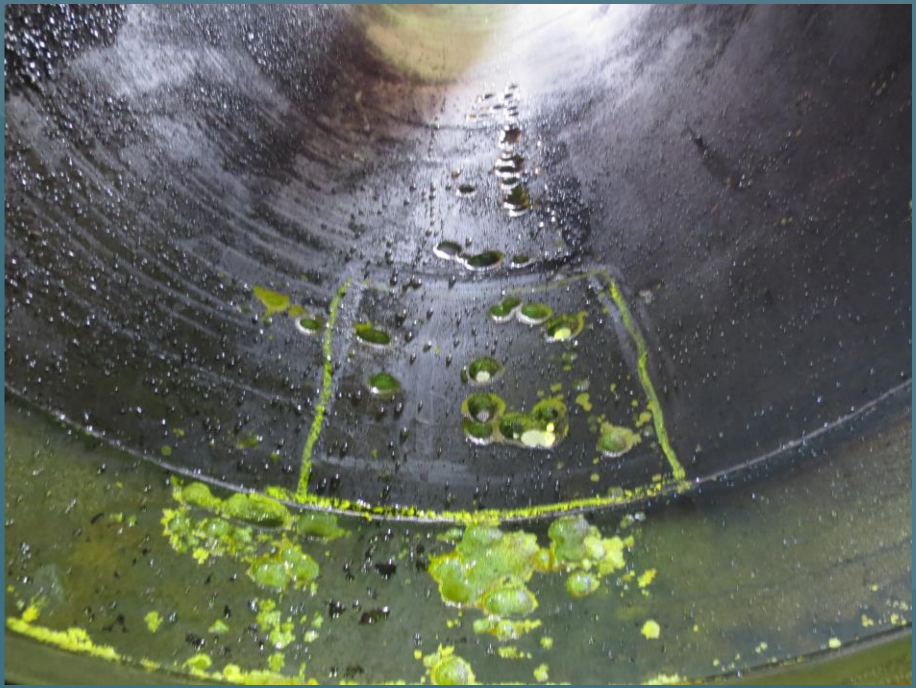
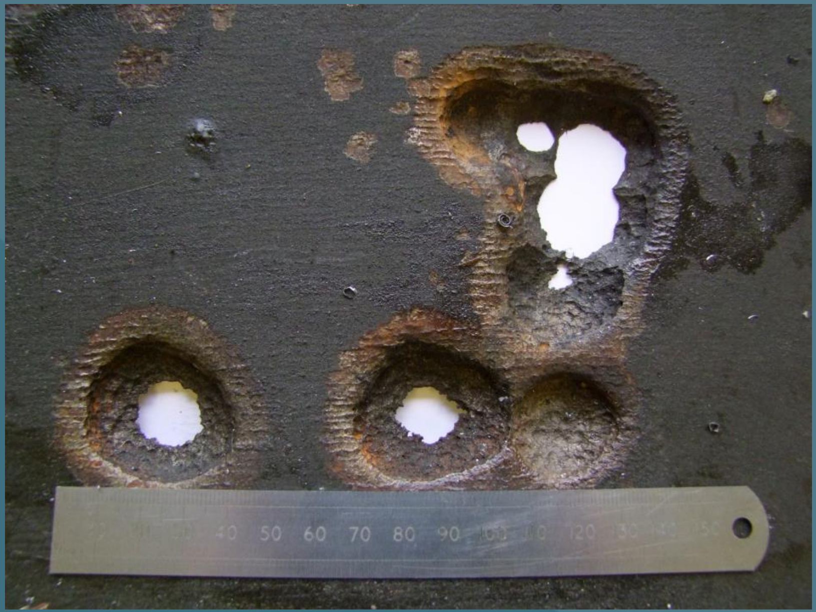
Case Study 1

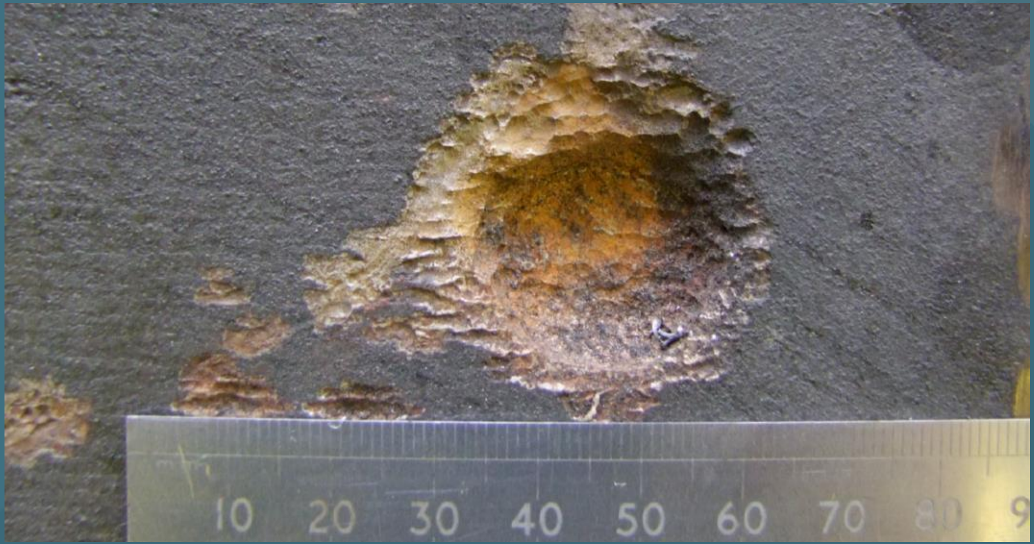
- Main crude feedline.
- In service for 31 years
- The pipeline had contained seawater at some point for approximately 10-12 months



Case Study 1

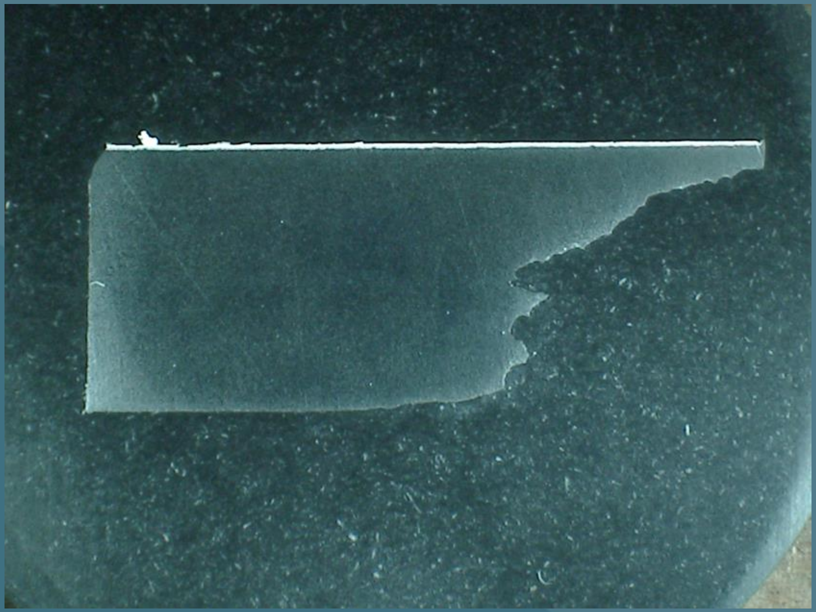
- Large pits which were clustered and overlapping.
- Lightly etched aureole around the pits.
- Pits exhibited a smooth and undulating appearance.

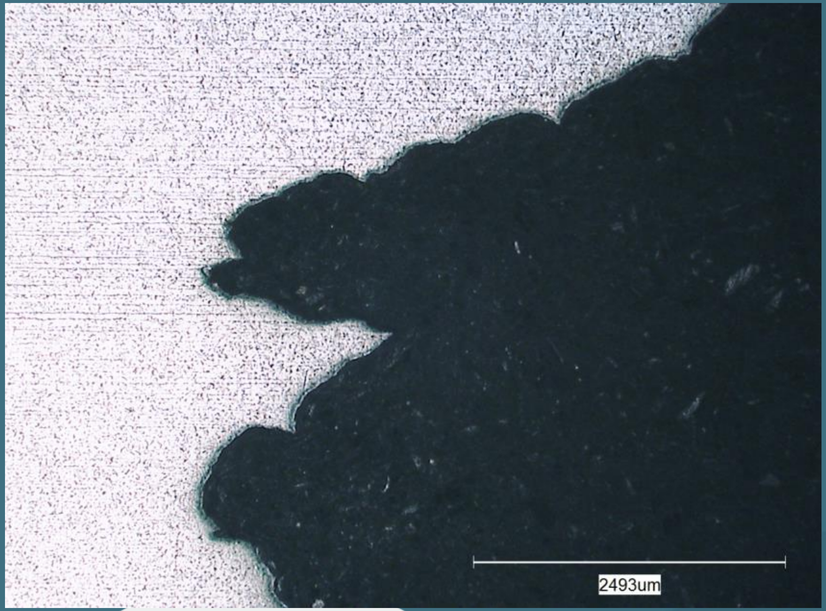


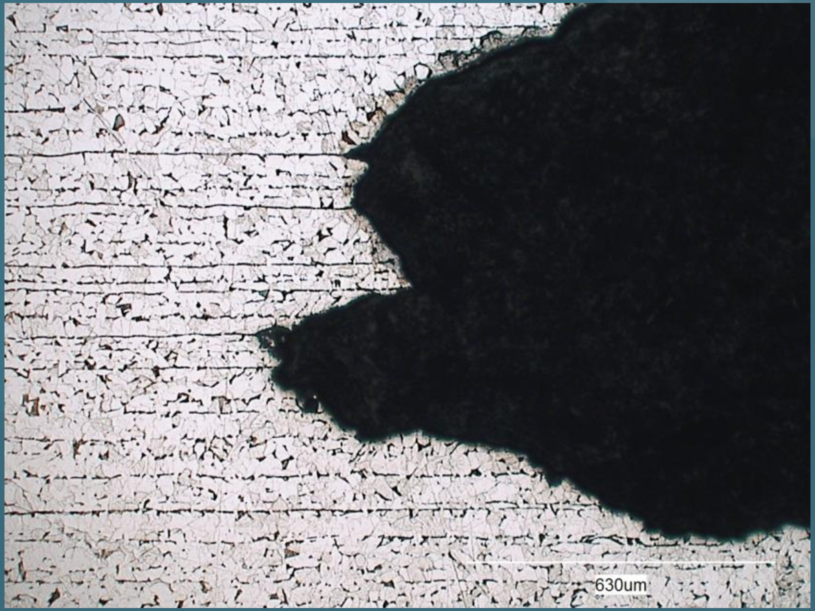


Case Study 1

- Heavy contamination with Sulphate generating bacteria/sulphide reducing bacteria was detected.
- Corrosion deposit also contained significant levels of sulphur and chlorine.







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Case Study 1

- In pipelines containing crude oil, any water contamination settles along the bottom.
  - This stagnant water most likely containing organic material and deposits (from the crude oil) enable microbes to thrive.

- The presence of seawater would have exacerbated the corrosion rate.

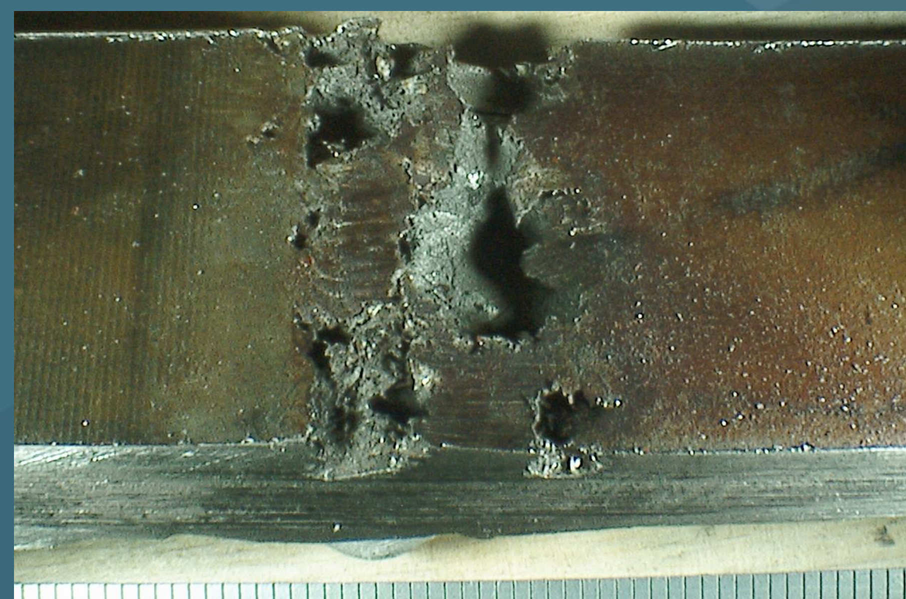
- Recommendations:
  - To apply a high quality bacteria-resistant epoxy coating to the inner surface of the pipeline. Needs to be treated with caution.
  - Keeping the pipeline as clean as possible, avoiding accumulation of dirt, sludge and foul watery deposits.
  - Avoiding stagnant conditions.

Case Study 2

- Super duplex stainless steel pipework from a seawater injection system
- The maximum operating temperature of the outlet was 35°C.

Case Study 2

- Area of perforation evident within the weld
- At internal surface – significant metal loss was apparent below seemingly intact surface



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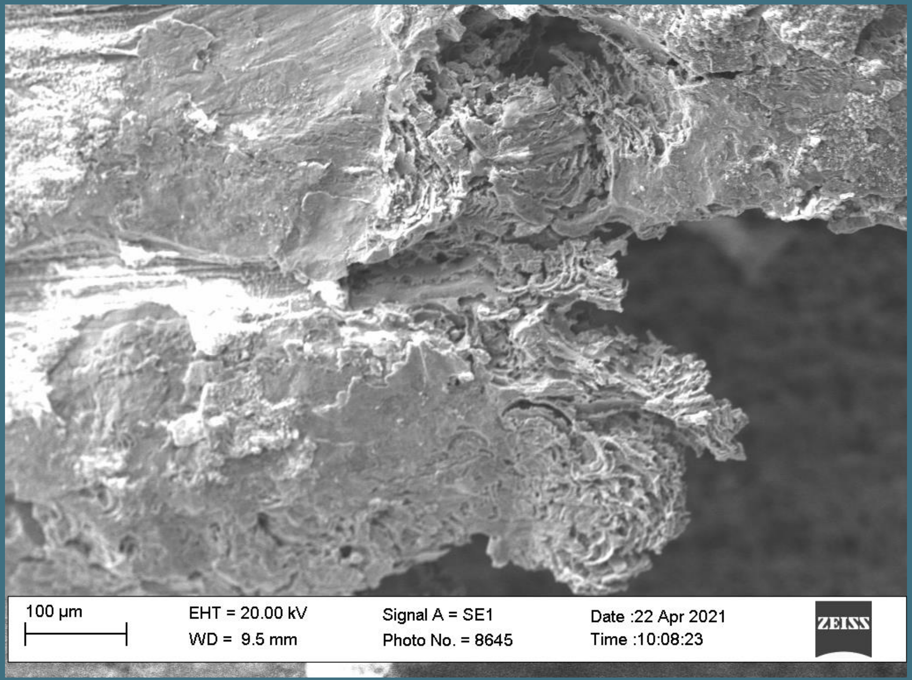
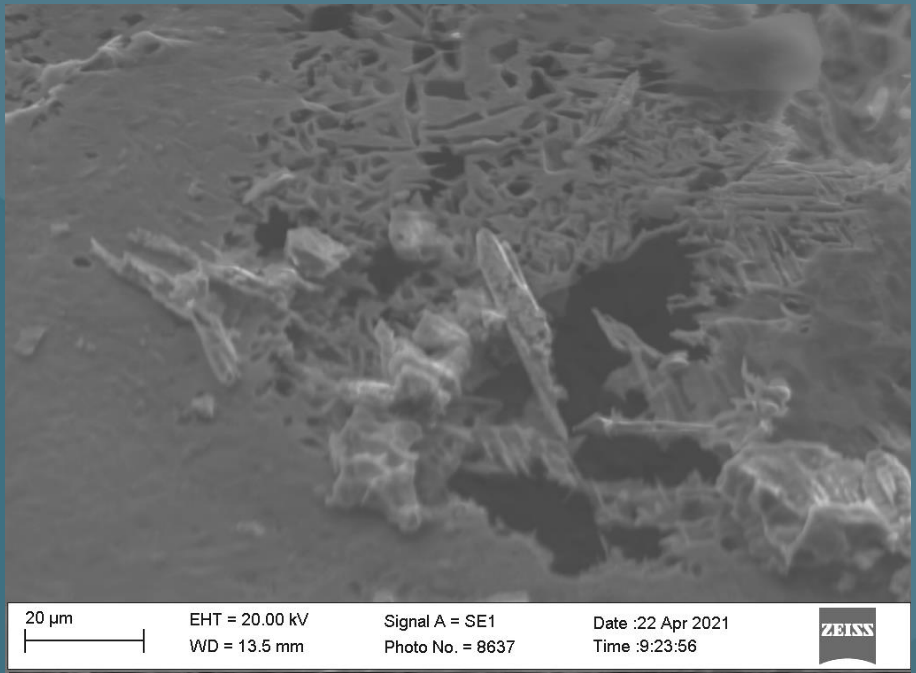
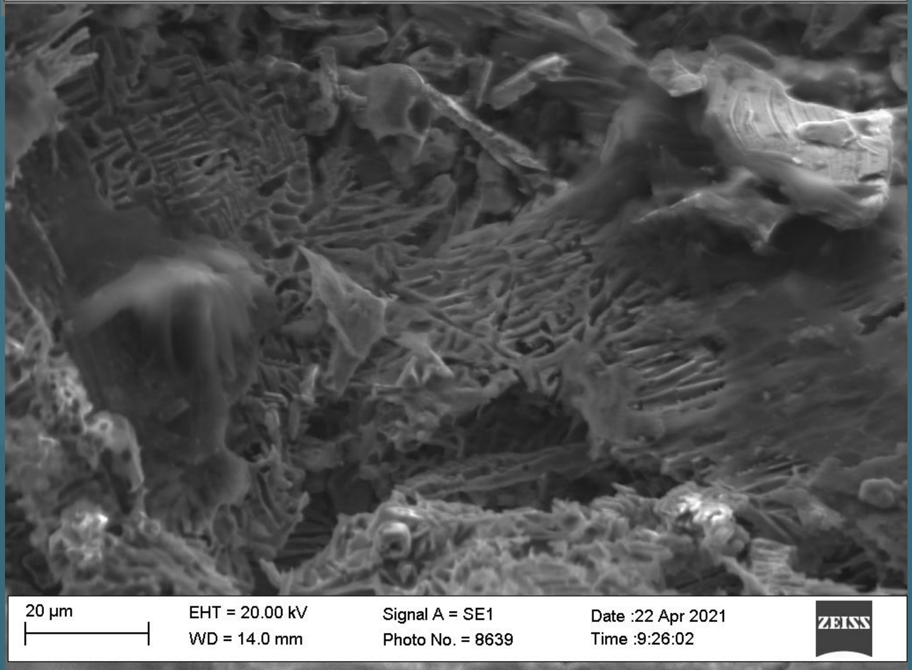
Case Study 2

- SEM showed areas of selective attack in the vicinity of the hole
- Deposit contained significant levels of chlorine and sulphur







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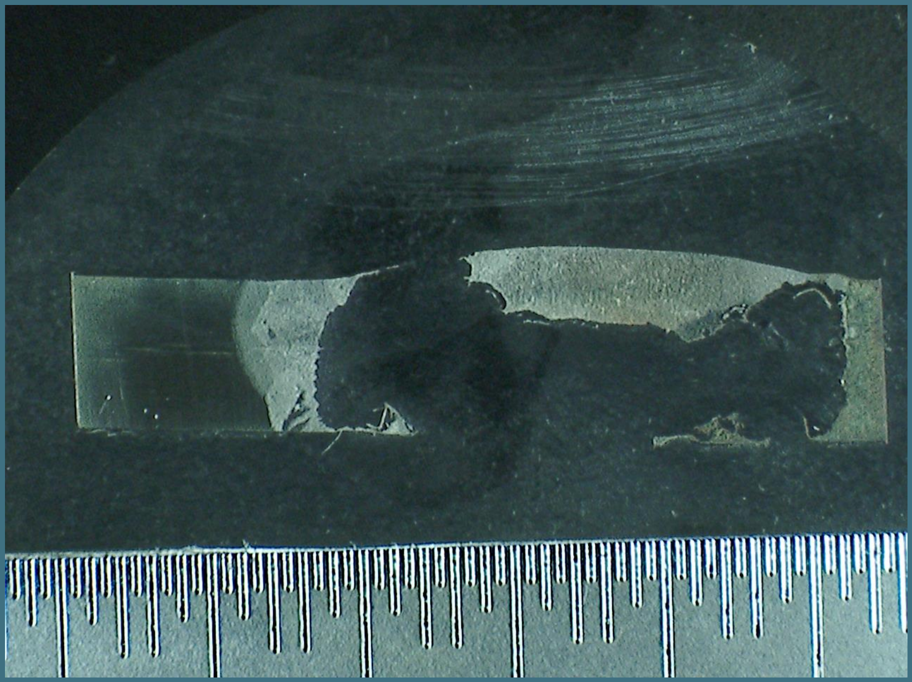
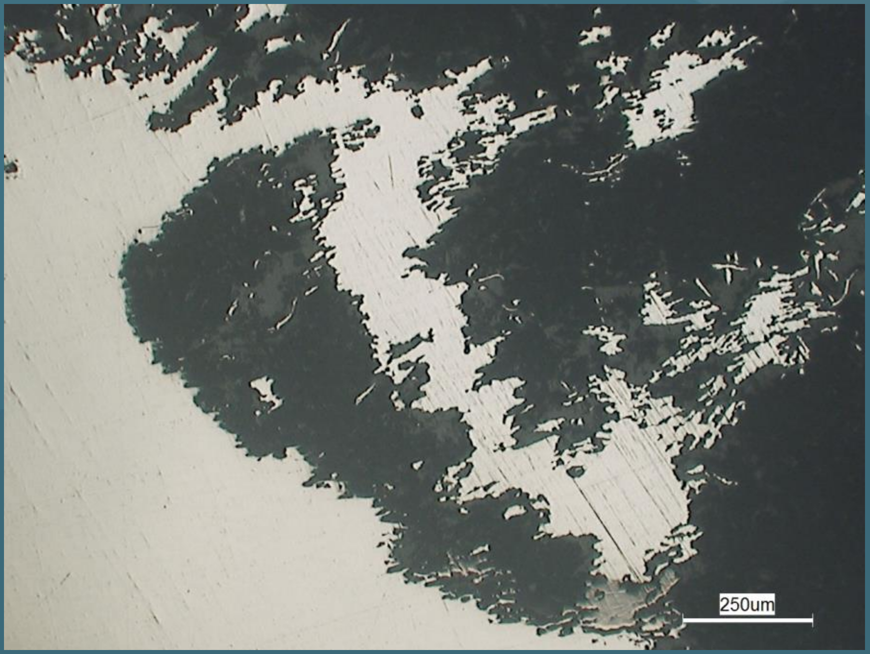
Case Study 2

- Significant undercutting and hemispherical pitting evident within the weld metal





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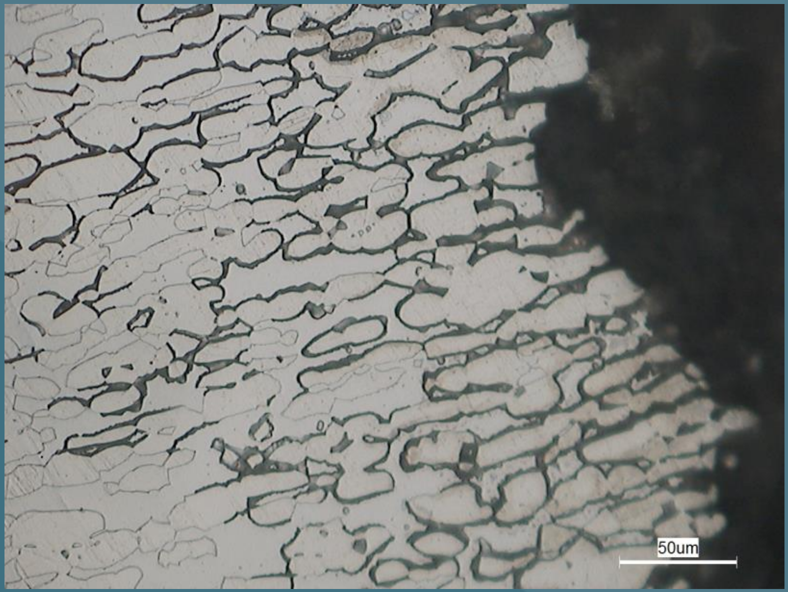
Case Study 2

- Sigma phase & carbide was evident along the austenite/delta ferrite phase boundary
- Chemical analysis of the weld and parent materials were compliant with the specification



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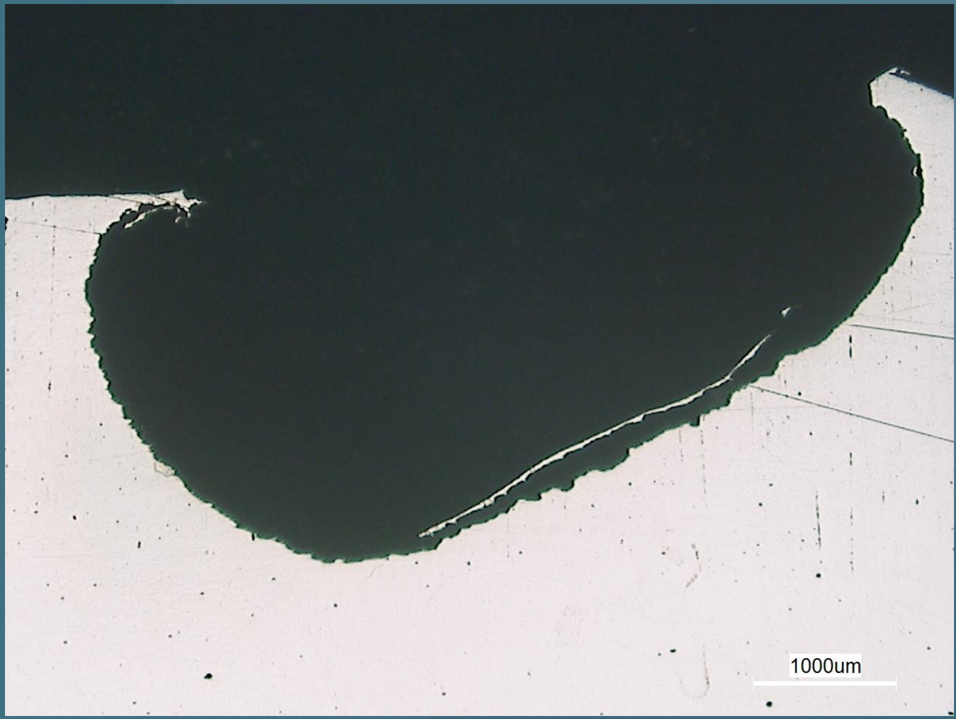
Case Study 2

- Mechanism was deduced to be Microbial induced corrosion
- The presence of sulphur and the morphology of the pitting may indicate the presence of sulphate reducing bacteria. No sample was available to confirm this.
- The presence of carbides/nitrides along phase boundaries increases the likelihood of corrosion



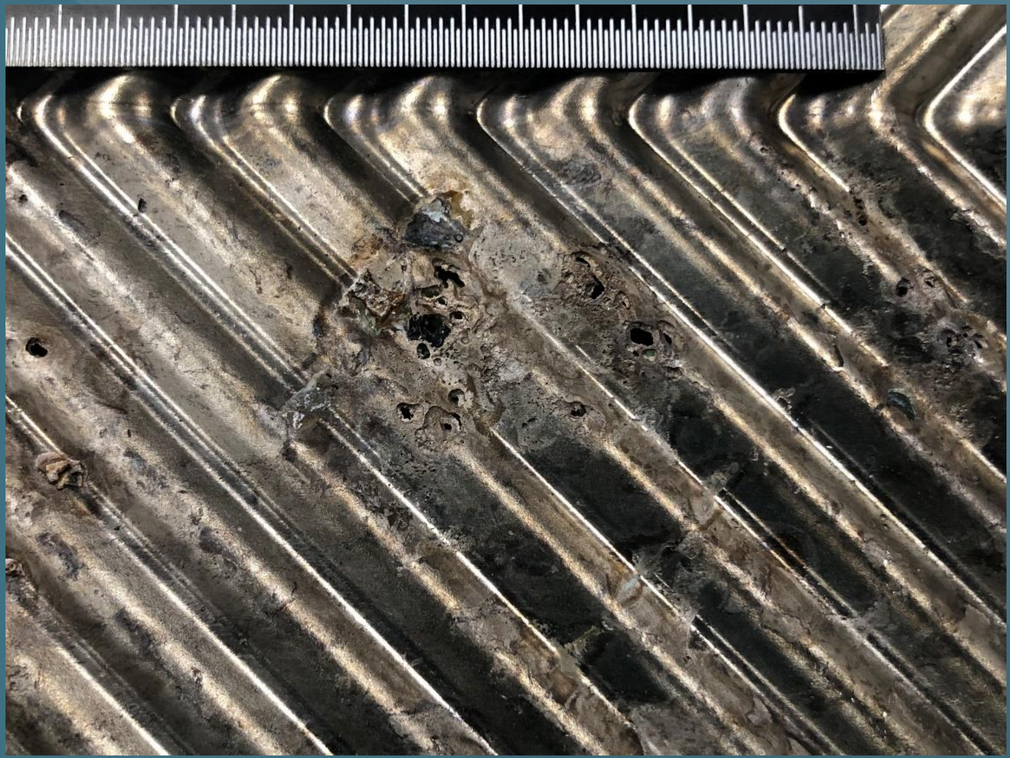
Case Study 3

Recommendations:

- Water quenching after heat treatment eliminates the issue of carbide precipitation. It is important to keep the time between exiting the furnace and water quenching as short as possible.
- During welding, the heat input should be optimised so that the cooling rate will be quick enough to avoid these detrimental phases, though not so fast that there remains excessive ferrite in the vicinity of the fusion line.
- To maintain operational usage of the unit as far as possible in order to ensure continued flow through the elbow.
- If downtime for long periods is expected, adequate drainage and drying is necessary
- Culture live micro-organism samples in order to confirm the bacteria that has caused the damage to the elbow. This would enable the root cause of the problem to be determined.

Case Study 3

- Nickel 200 plate heat exchanger.
- Process involved caustic to remove sulphur producing sulphide spent caustic.
- Installed in 2015
- Constant commission, aside from turnarounds where the heat exchanger is off for 6-8 weeks.
- Layup procedure involves water flush and drain.



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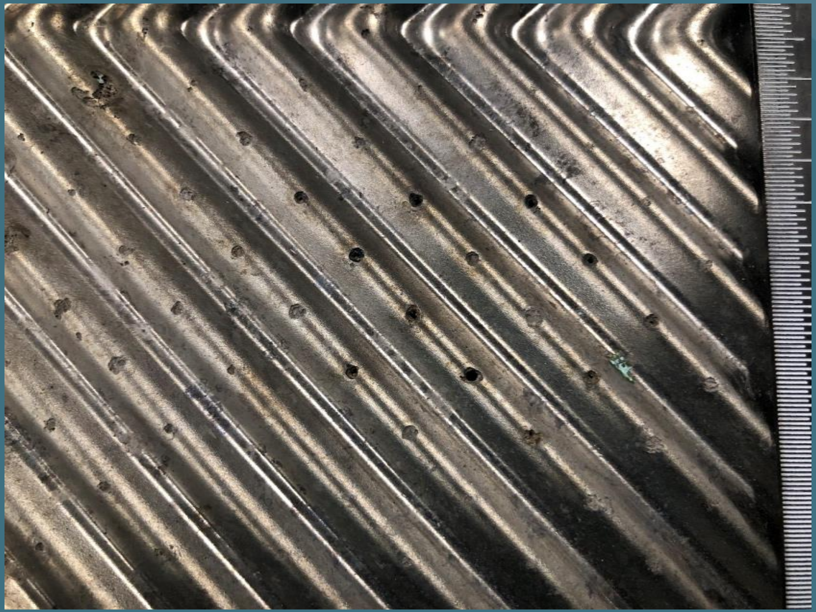
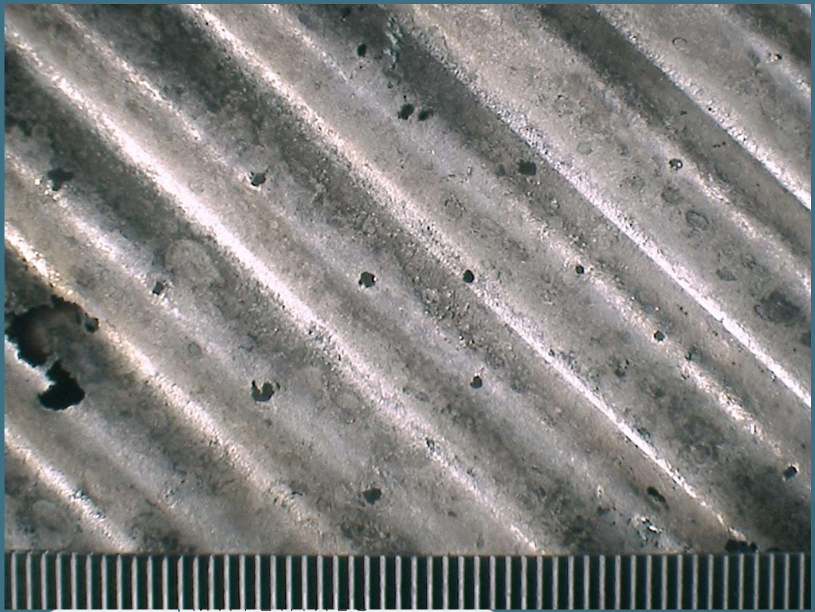
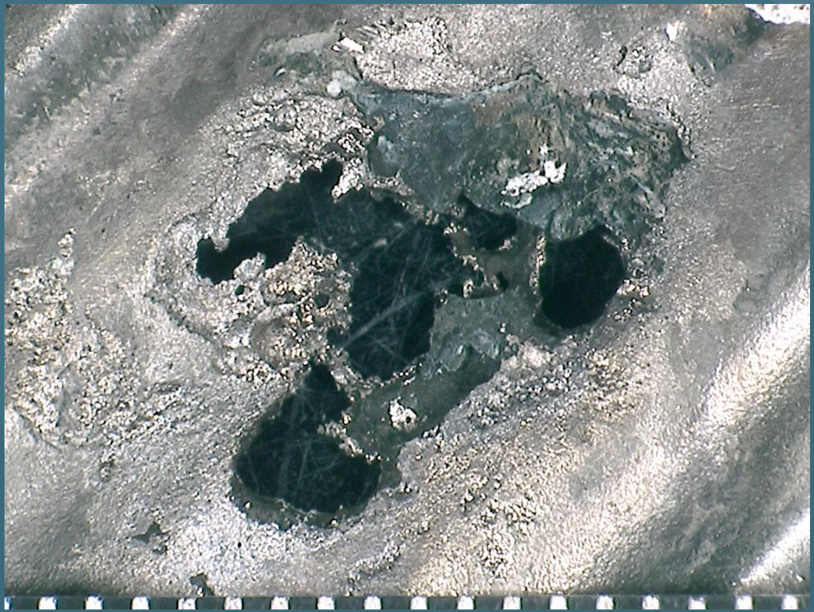
Case Study 3



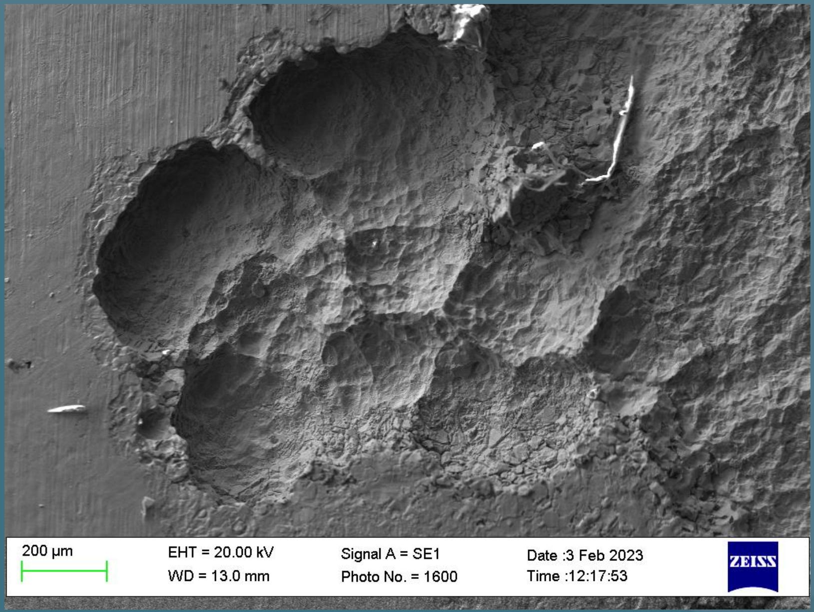
- Metal loss about the peaked regions.
- Concentrated about both peaks and troughs of the corrugated channels.
- Regions of gross metal loss were surrounded by instances of regimented pits situated about corrugation peaks at regular intervals (approximately 1cm apart).
- It is likely that these pits coincide with points of contact between adjacent plates.

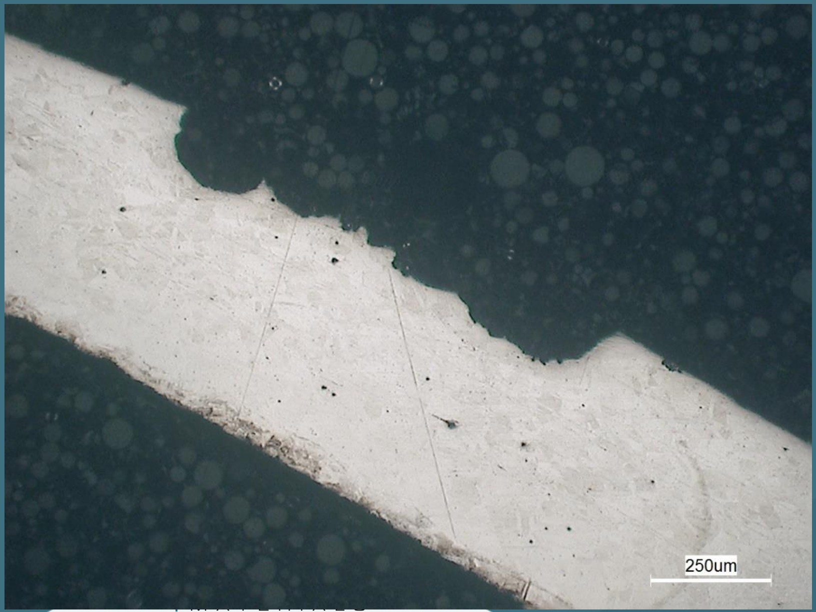


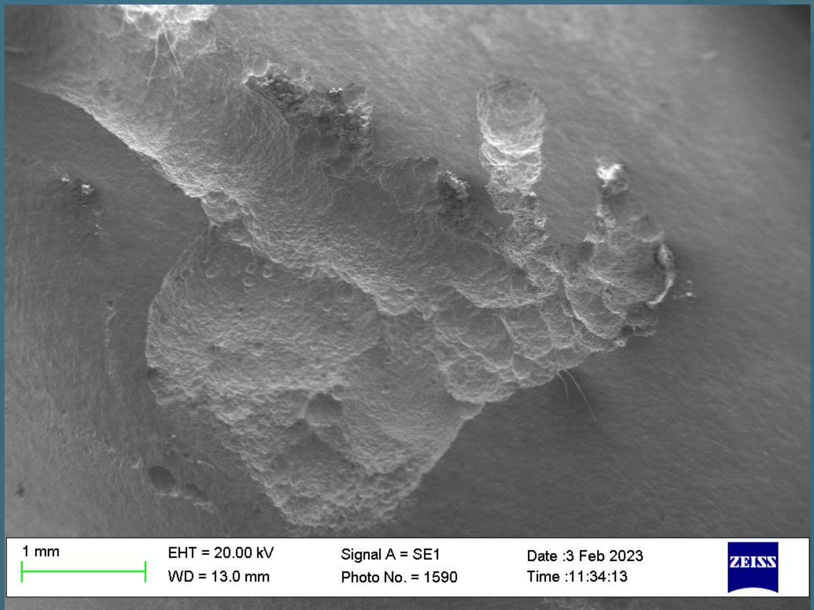


Case Study 3

- Corrosion deposit contained significant levels of sulphur and smaller amounts of magnesium, sodium, potassium and phosphorus.







Case Study 3

- The chief factor contributing to the outstanding performance of nickel 200 in highly concentrated caustic soda is a black protective nickel oxide film that forms during exposure.
  - In cases of MIC local breaks in the passive nickel oxide layer are produced; acidic metabolites secreted by bacteria either prevent passivation or destroy the existing passivating film. This results in more rapid local corrosion.

  - The heat exchanger was off-commission for 6 – 8 weeks during turnaround, following a water flush.
    - This would have allowed for micro-organisms to grow at those points of contact between the adjacent corrugated channels, where sulphur compounds could have also collected during operation, resulting in MIC.

    - The literature recommends that a space of 1mm – 5mm should be applied between plates to enable fluid flow

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Any Questions?

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