EFFECT OF CREVICE CONFIGURATION ON CORROSION BEHAVIOUR OF TENSILE WIRES OF FLEXIBLE PIPES UNDER DIFFERENT CONDITIONS

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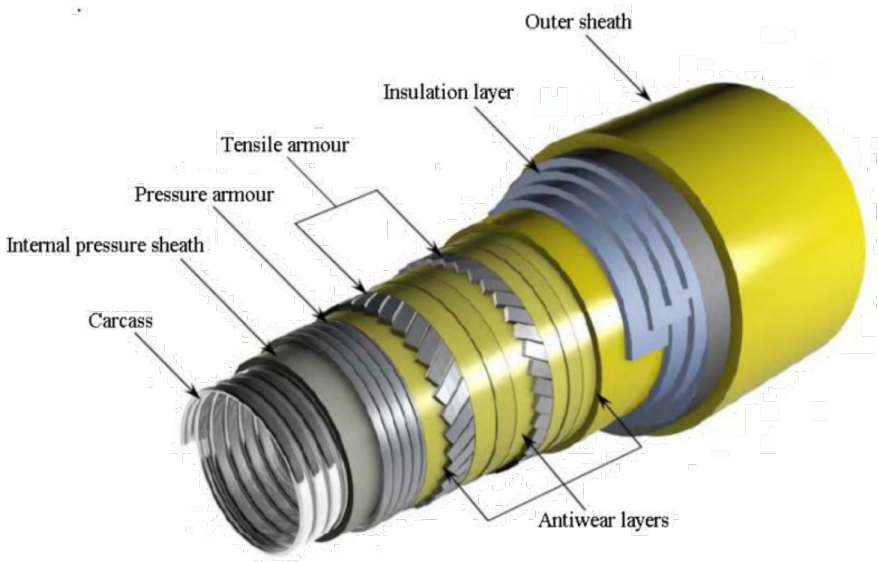
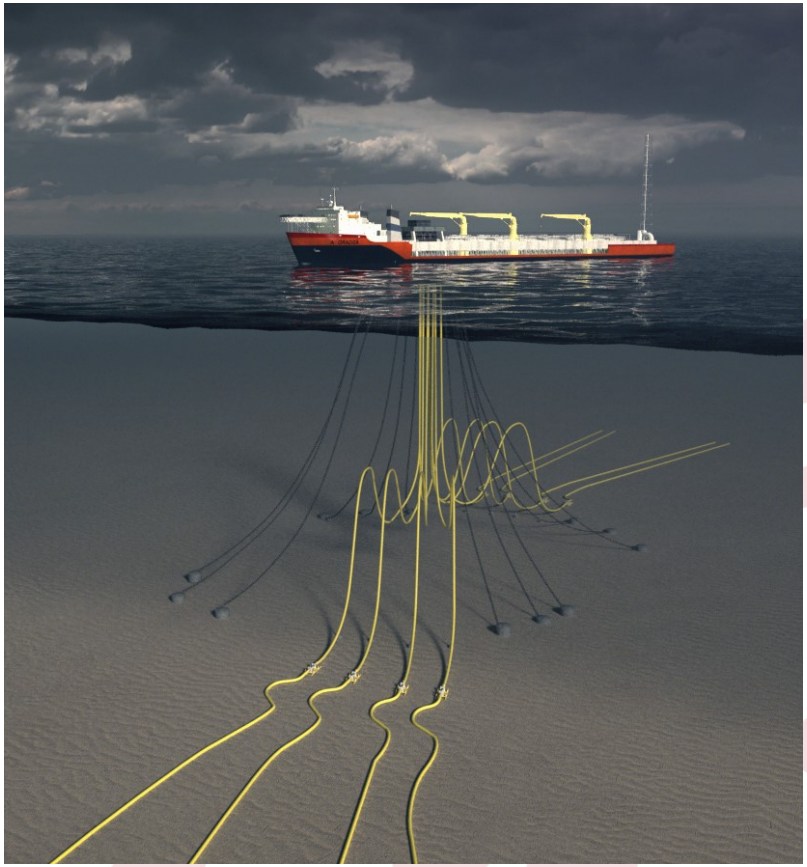
Backgroud

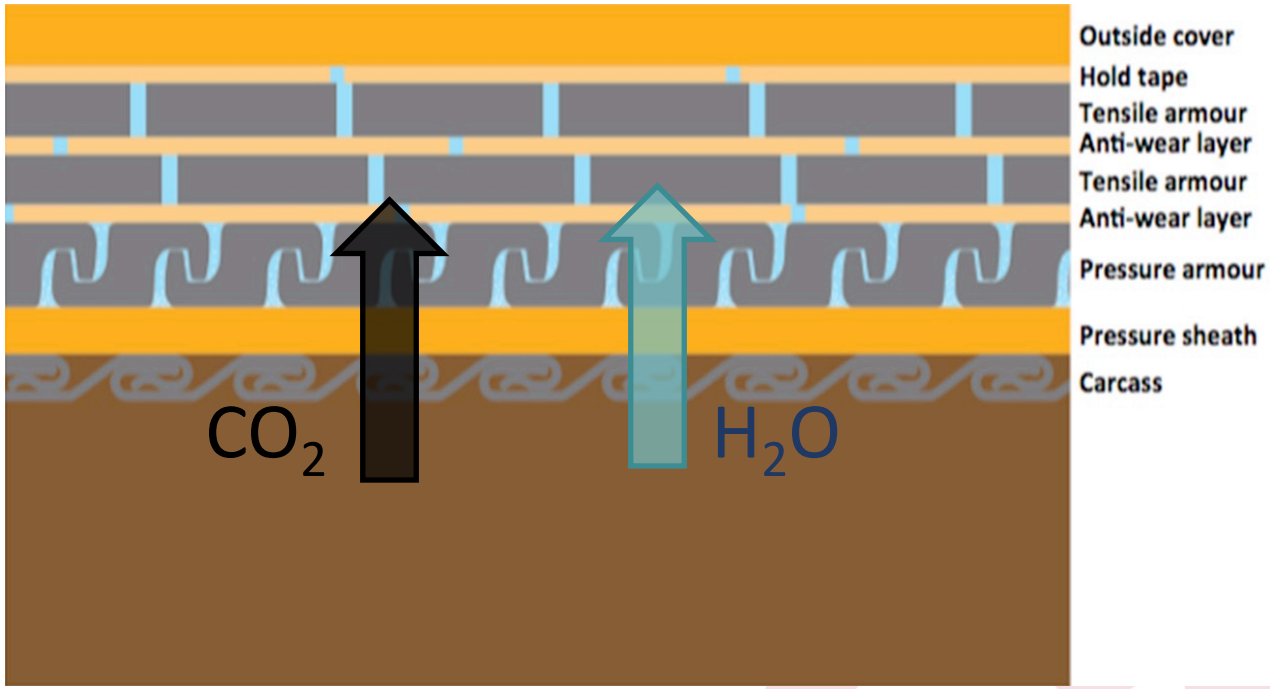
- Schematic indicating the multi-layer construction of flexible pipe designs





Backgroud

- The high strength steel wires are confined in the annulus and in contact with a corrosive environment formed by gases and water molecules diffusing from the bore through the inner polymer layers.

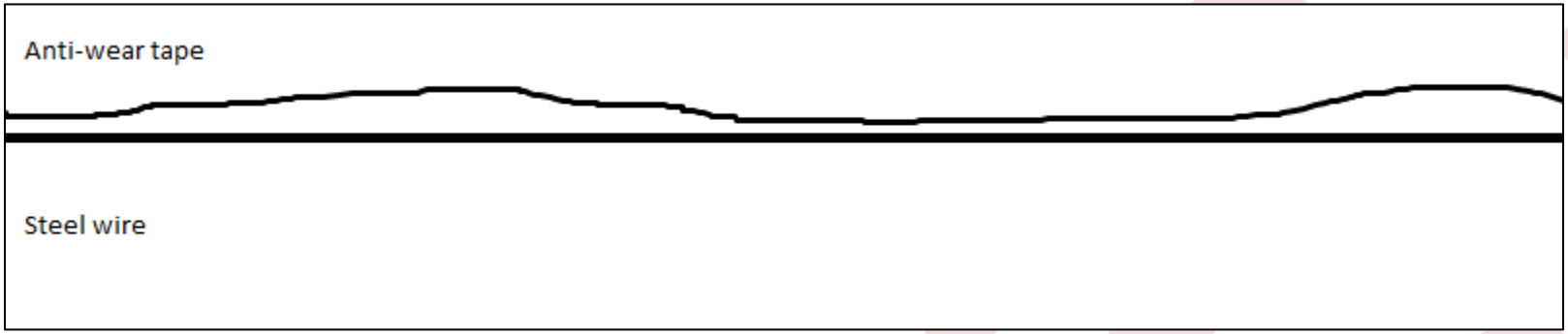


Backgroud

- The tensile wires are usually covered by antiwear tapes and this configuration can also interfere in their corrosion behaviour.

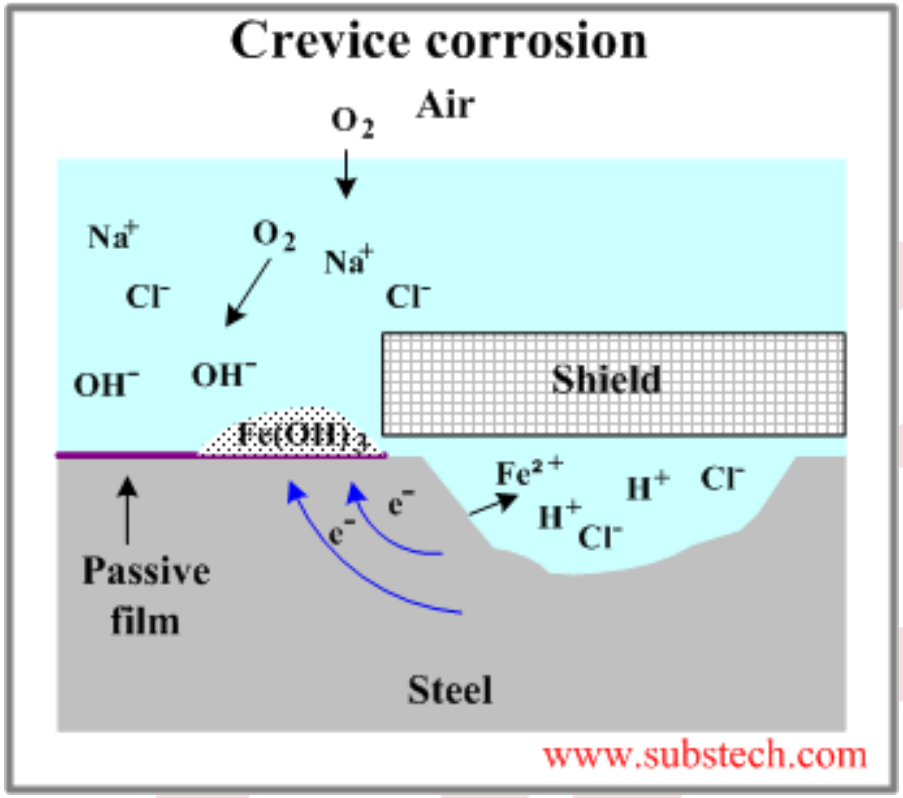
- The position of the tape relative to the wire is not uniform due to many variations in the manufacturing process of the pipe.

- **Some regions** → almost **absolute intimate contact.**
  Other region → there is a **gap** between the polymer and the steel → **allowing water and gases** to reach the **surface of the wire.**



Background

- If this gap is wide enough to guarantee sufficient mass transport of chemical species, the composition of the fluid in the annulus in this region will be relatively homogeneous.
- If this gap is so narrow that locally the chemistry of the corrosive environment develops differently than in the bulk, localised corrosion may occur.



Two questions

1) Does the polymer prevent the liquid from reaching the metal surface completely?

R: YES → **corrosion does not occur** under the polymer.

R: NO → **corrosion occurs** under the polymer.

2) But what is the morphology of the attacks, **localised or uniform**?

Uniform corrosion → where the **opening is large** enough to **allow mass transport** and **prevent the development of a different local environments**

Localised corrosion → where the **opening is so narrow** that the environment **develops differently in these regions.**

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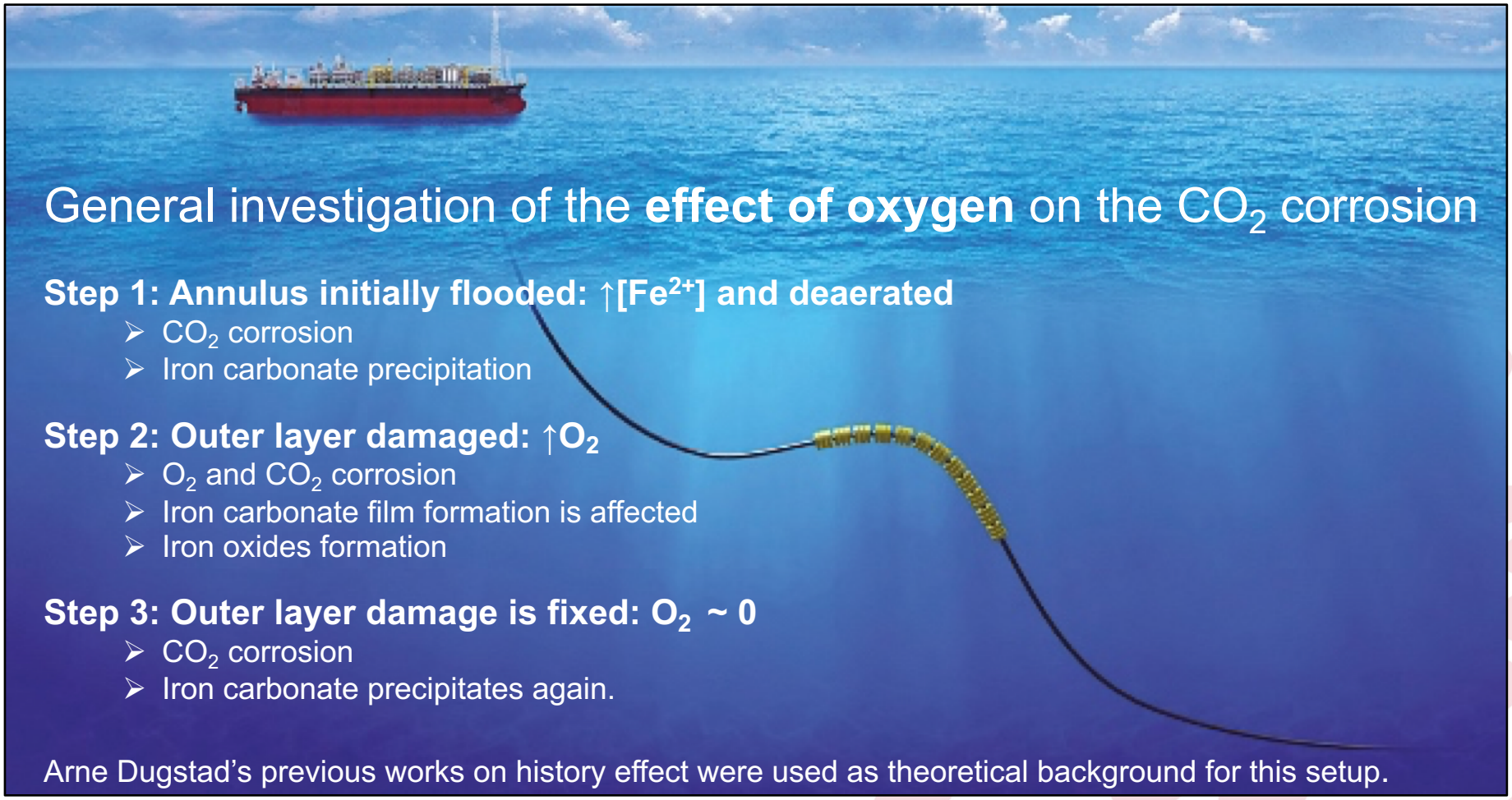
What conditions would we like to simulate in this work?



General investigation of the **effect of oxygen** on the CO_2 corrosion

Step 1: Annulus initially flooded: ↑[Fe^{2+}] and deaerated

- CO_2 corrosion
- Iron carbonate precipitation

Step 2: Outer layer damaged: ↑O_2

- O_2 and CO_2 corrosion
- Iron carbonate film formation is affected
- Iron oxides formation

Step 3: Outer layer damage is fixed: O_2 ~ 0

- CO_2 corrosion
- Iron carbonate precipitates again.

Arne Dugstad's previous works on history effect were used as theoretical background for this setup.

Adapted from http://www.petrobras.com.br/data/files/7F/C2/09/90/F7F6B4101E4E24B446CD61A8/tecnologias-presil-risers.jpg

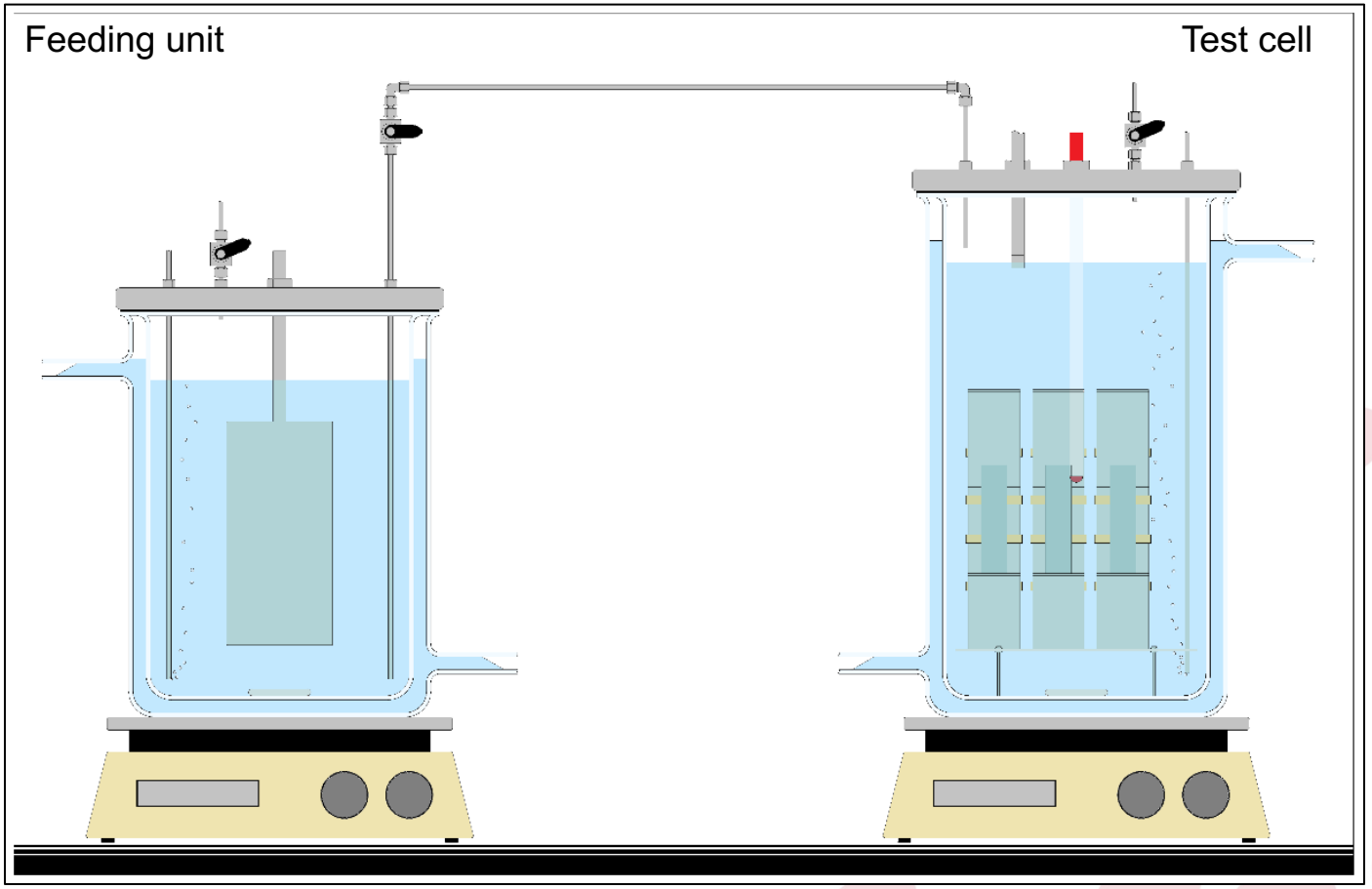
Test Parameters

Test 1: 30 days – **Finished**

Step 1	Step 2	Step 3
0.1bar CO_2 25°C Seawater ~2000ppm Fe^{2+}	0.1bar CO_2 0.2bar O_2 25ºC Seawater	0.1bar CO_2 25°C Seawater ~2000ppm Fe^{2+}

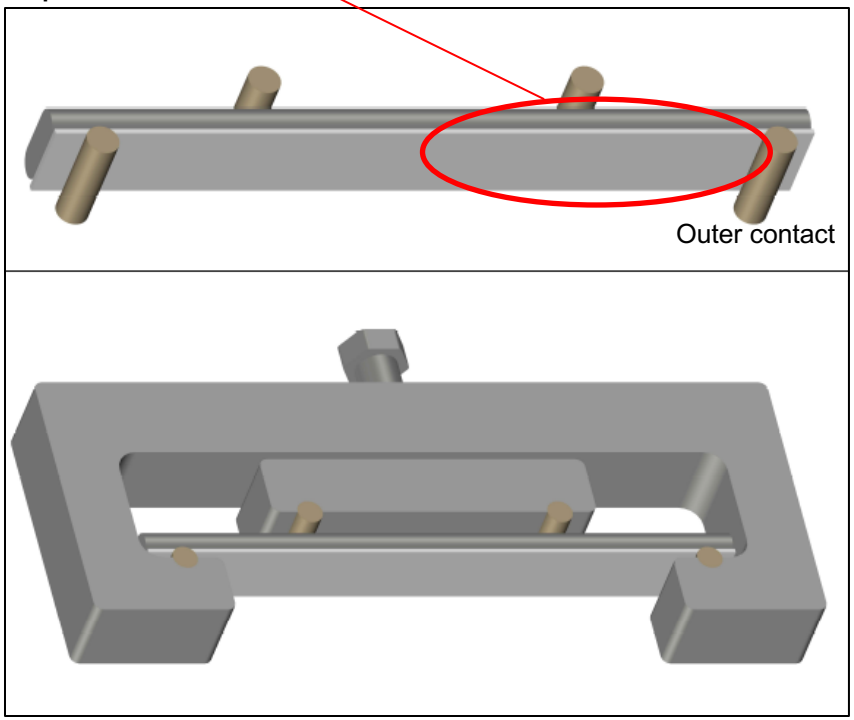
Test 2 and 3: 90 and 180 days – **On going**

Experimental Setup

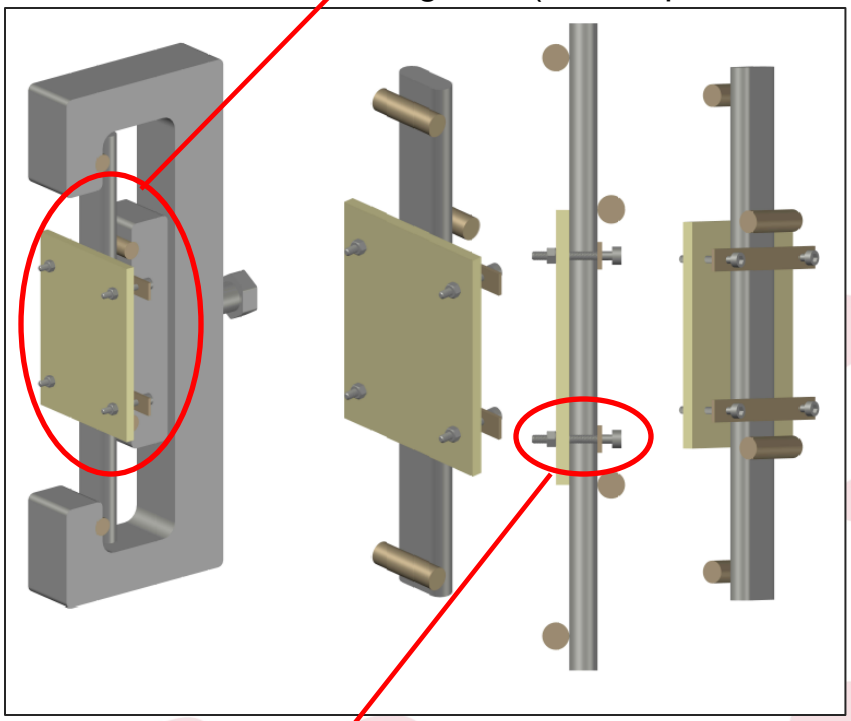


Configuration of creviced specimens

TEFLON: Low friction coefficient → sliding during the deformation process → difficult a uniform contact



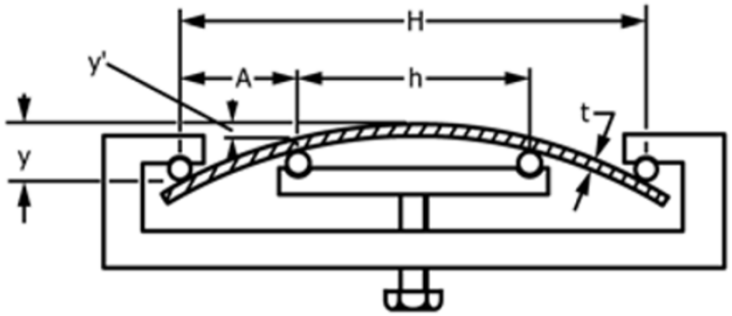
PA11: Higher friction coefficient. Covering only the region A (central portion of



Nuts and bolts to facilitate the adjust the gap between polymer and specimen before loaded

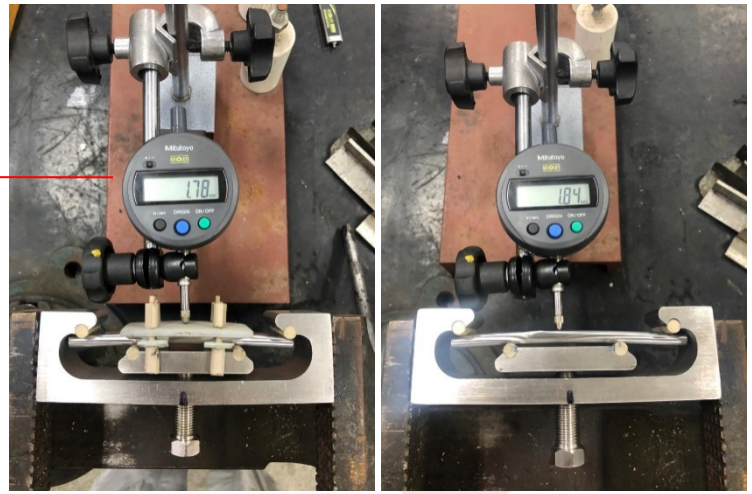
The four-point bend tests

Test specimens were loaded to 90% YS.
Creviced specimens had their deflection measured already with the polymer tape.



$$\sigma = \frac{12 \cdot E \cdot t \cdot y}{(3 \cdot H^2 - 4 \cdot A^2)} \quad \therefore \quad y = \frac{\sigma \cdot (3 \cdot H^2 - 4 \cdot A^2)}{12 \cdot E \cdot t}$$

Dial indicator



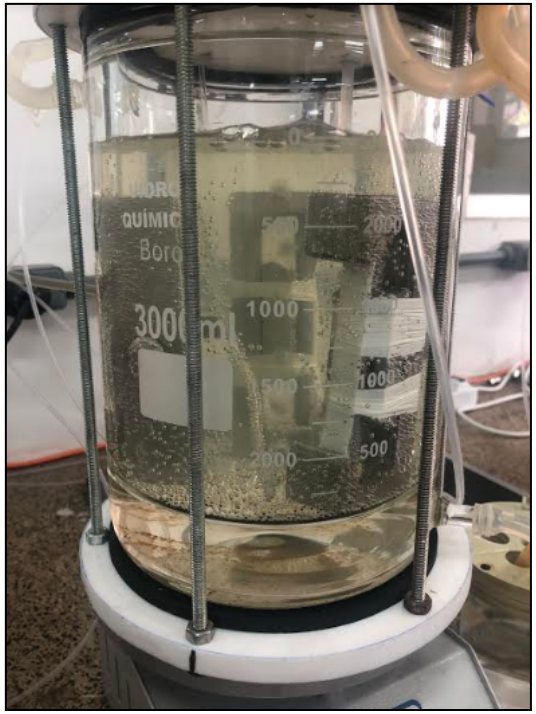
y	deflection
σ	stress on the outer fiber (convex surface)
H	distance between outer supports
A	distance between inner support and closest outer support
E	Young's modulus (usually E=210GPa for steels)
t	specimen thickness

INPUT		OUTPUT
%Y.S.	Y.S.	σ
(MPa)	(MPa)	(MPa)
90	1085	976.5

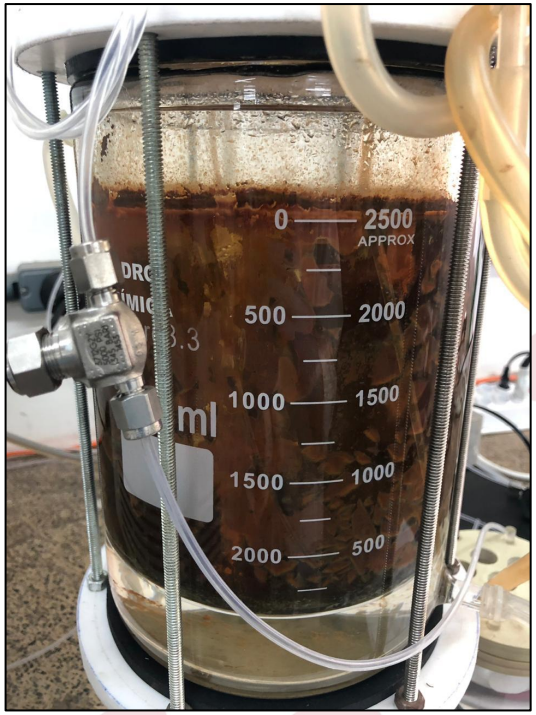
INPUT				OUTPUT
H	A	E	t	y
(mm)	(mm)	(GPa)	(mm)	(mm)
100	23	210	5.88	1.84

Test 1. TEFLON polymer layer
(1 month)

Test cell aspects according to the variations of the test environment.



Step 1



Step 2

Test 1. Results

(1 month)

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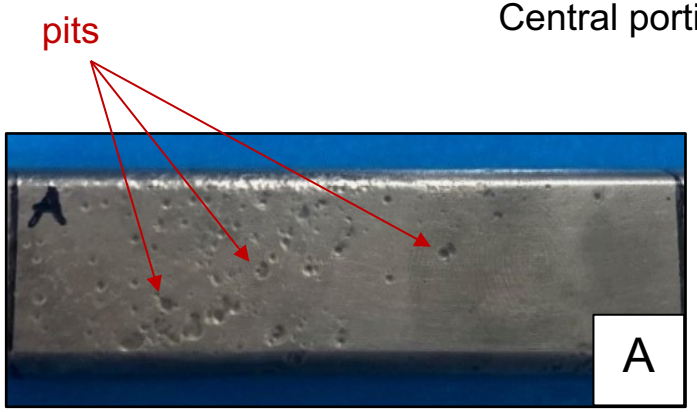
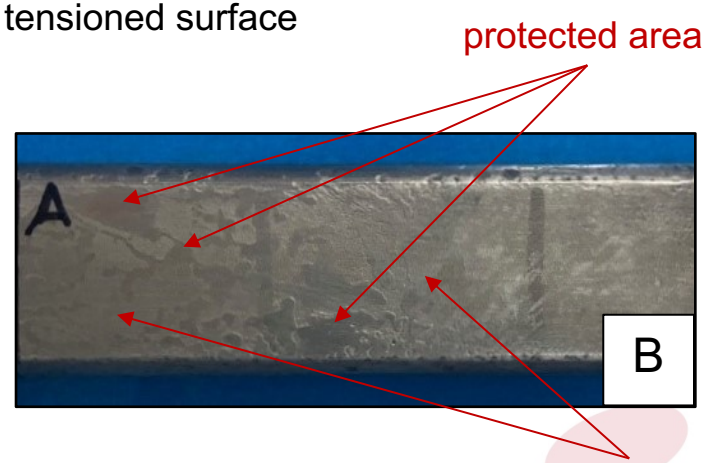
Surface analysis – Macroscopic and SEM

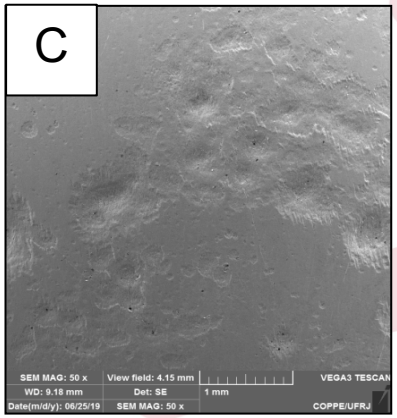
Central portion of the tensioned surface

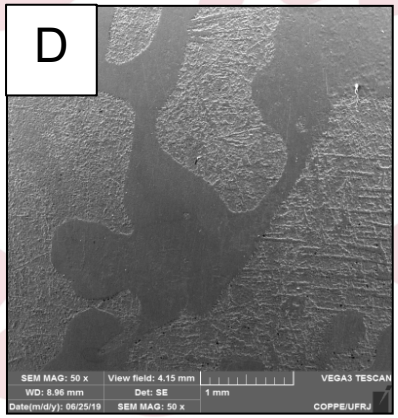




Macroscopic analysis: (A) Bare specimen
(B) creviced specimen

SEM analysis: (C) Pitted area: Bare specimen
(D) Protected regions and uniform corrosion: creviced specimen





Test 1. Results

(1 month)

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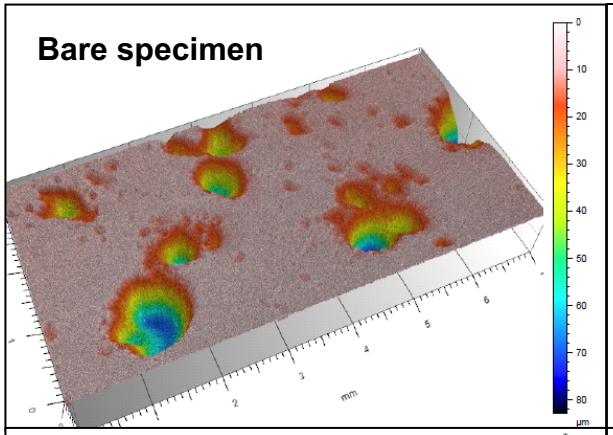
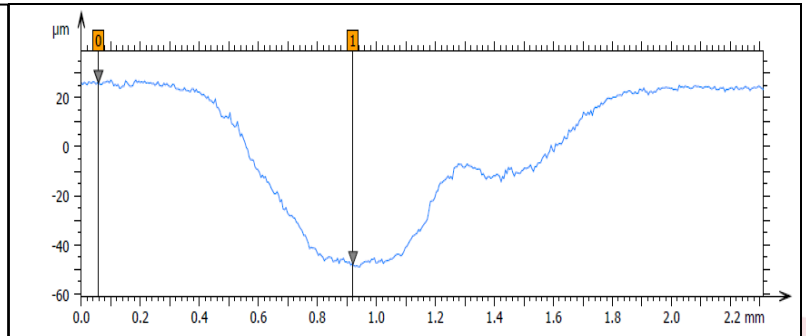
Surface analysis – Confocal microscopy

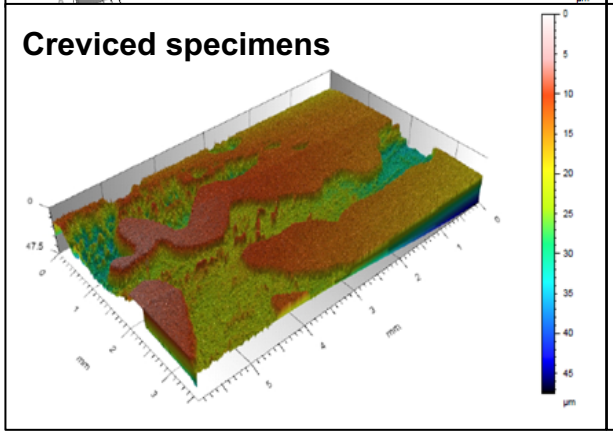
Bare specimen

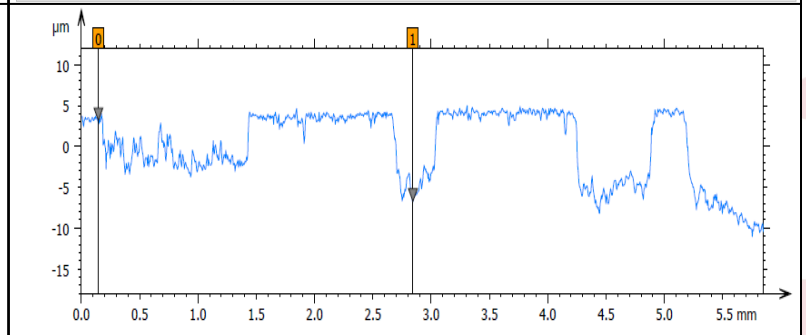




Parameters	0-1	Unit
Horizontal distance	0.863	mm
Height difference	-73.8	µm

Creviced specimens





Parameters	0-1	Unit
Horizontal distance	2.70	mm
Height difference	-9.89	µm

Test 1. Results

(1 month)

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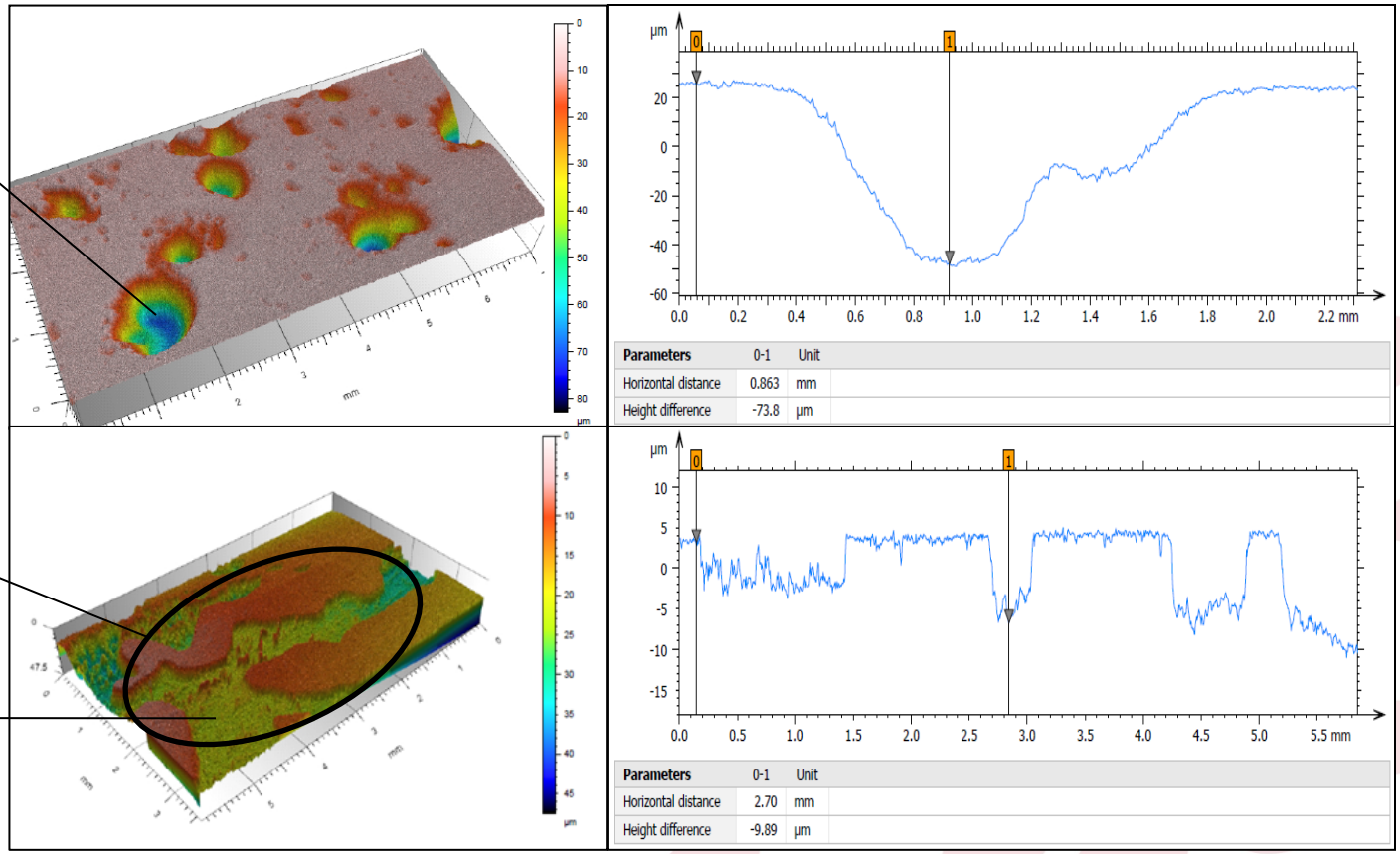
Surface analysis – Confocal microscopy

Round and deep

Inert polymer tape → prevent localised corrosion

Significant uniform corrosion (cover the entire central portion)



Main conclusions of Test 1

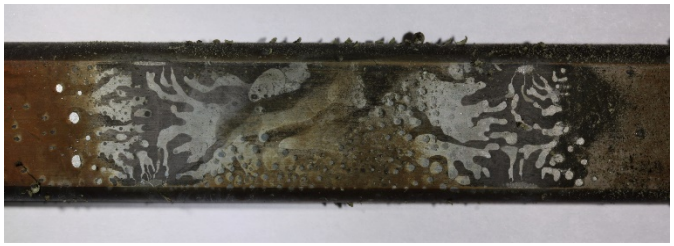
- No cracks were observed.
- Pitting was observed in the specimen tested without crevice.
- The polymer tape on the surface of the steel prevented pitting.
- Severe uniform corrosion was observed under the polymer tape.

Test 1.2. Setup at IFE (Norway)

Experiment	01.1
Status	Finished
Polymer	Teflon
Duration	1 month
Cracks	No

Before cleaning

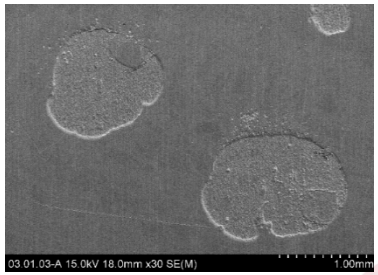
Bare specimen

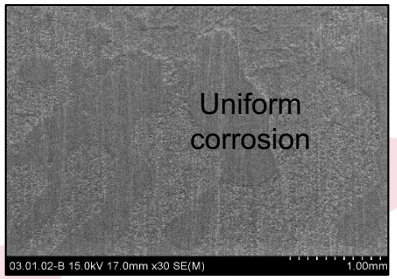


Creviced specimen

No pitting – iron carbonate film

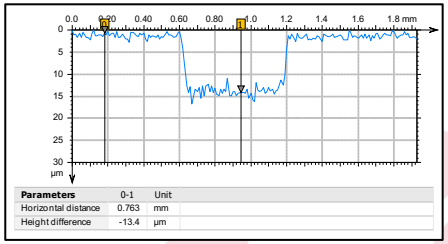
Localised attacks resulted from CO_2 bubbles retained at the surface of the bare specimen.

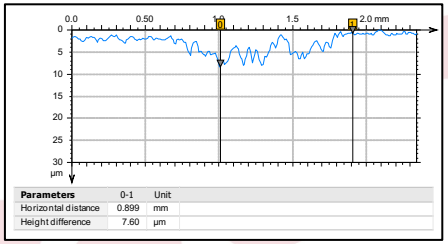




Bare specimen

Creviced specimen





Main conclusions of Test 1.2

- No cracks were observed.
- No pitting was observed in the specimen tested without crevice.
- Localised attacks resulted from CO_2 bubbles retained at the surface of the bare specimen. As they were large and shallow, did not caracterise pitting.
- The bare specimens were relatively protected by the iron carbonate film and almost did not corrode.
- Uniform corrosion was observed under the polymer tape, although not as severe as in the specimens exposed to oxygen.

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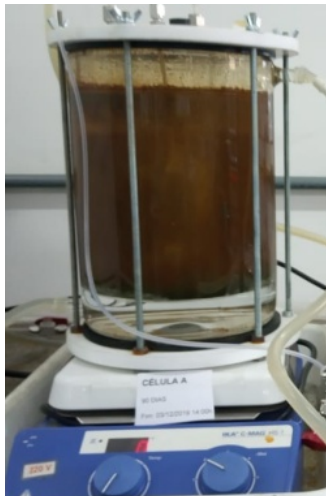
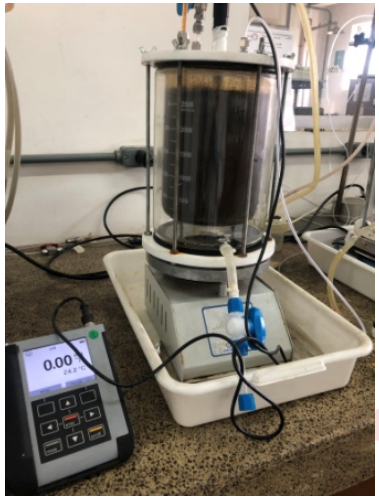
Tests 2 and 3. PA11 polymer layer

Tests 2 and 3. PA11 polymer layer

Test cell aspects according to the variations of the test environment.





A: first day of experiment, **with only CO2 and N2** in the gas mixture. **Before heavy precipitation of iron carbonate.**
B: gas mixture is changed and **oxygen reacts** to the dissolved iron and **disrupts the iron carbonate films**.
C: test cell after the test solution was drained at the **end of step 2, and before step 3** started.
D: test cell **during step 3.**

References

COELHO, P. P. S. (2013) *Estudo da susceptibilidade à corrosão sob tensão em atmosfera de H_2S das armaduras de tração de dutos flexíveis* (in Portuguese). M.Sc. Thesis, Federal Centre of Technological Education Celso Sukow da Fonseca, Rio de Janeiro, Brazil.

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Thanks for your attention!