INSTITUTO DE PESQUISAS TECNOLÓGICAS

COMUNICAÇÃO TÉCNICA

Nº 178795

Characterization of on situ preferential weld corrosion in low-conductivity sweer corrosion media for subsea pipelines using SVET and immersion tests

Zehbour Panossian
Gislaine Maria Bragagnolo Nunes
Bruno de Barros Andrade
Marcos Luiz Henrique
Rodrigo da Silva Marques
Thales R. Gomes
Petronio Zumpano Junior
Ilson Palmieri Baptista

Palestra apresentada no LATINCORR & INTERCORR 2023, Rio de Janeiro . 25 slides.

Instituto de Pesquisas Tecnológicas do Estado de São Paulo S/A - IPT
Av. Prof. Almeida Prado, 532 | Cidade Universitária ou
Caixa Postal 0141 | CEP 01064-970
São Paulo | SP | Brasil | CEP 05508-901
Tel 11 3767 4374/4000 | Fax 11 3767-4099

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ABRACO
ASSOCIAÇÃO BRASILEIRA DE CORROSÃO

LatinCORR & InterCorr 2023

November 5-8, 2023 | Rio de Janeiro, Brazil

AMPP

Characterization of In Situ Preferential Weld Corrosion in Low-Conductivity Sweet Corrosion Media for Subsea Pipelines Using SVET and Immersion Tests

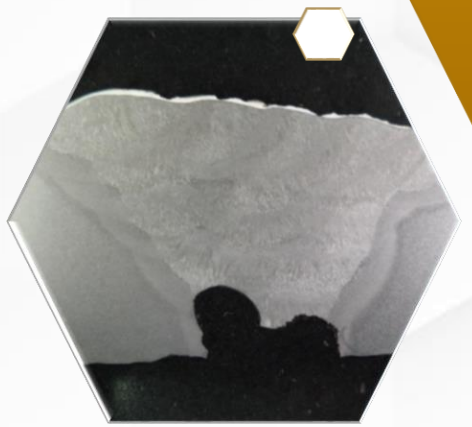
Juliana Lopes Cardoso

Zehbour Panossian, Gislaine M. B. Nunes, Bruno de B. Andrade, Marcos L. Henrique, Rodrigo da S. Marques, Thales R. Gomes, Petronio Zumpano Jr., Ilson P. Baptista

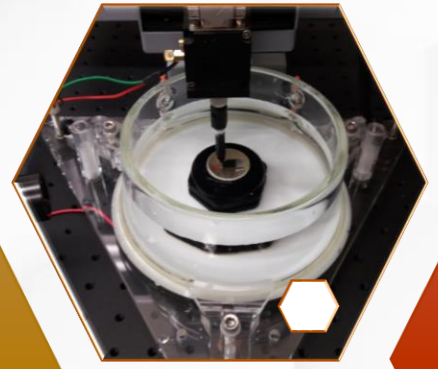
Summary

INTRODUCTION

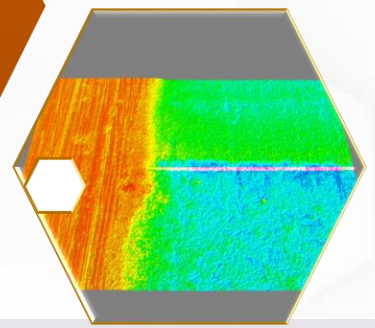
Welded Joint in gas exportation pipeline



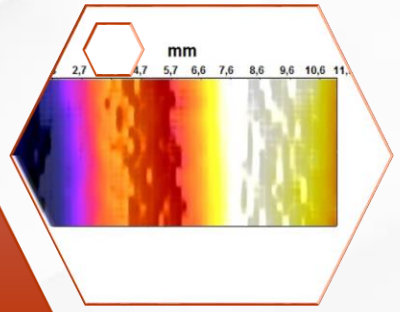
METHODOLOGY
- Materials
- Techniques and tests



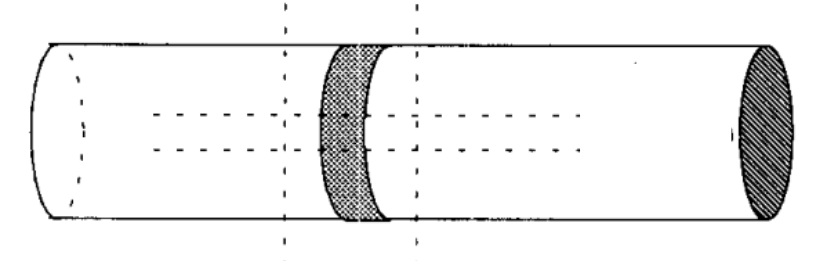
RESULTS

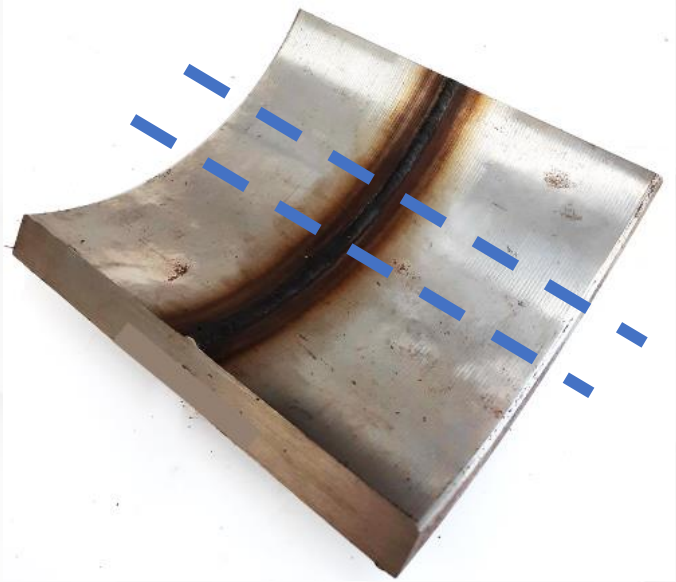


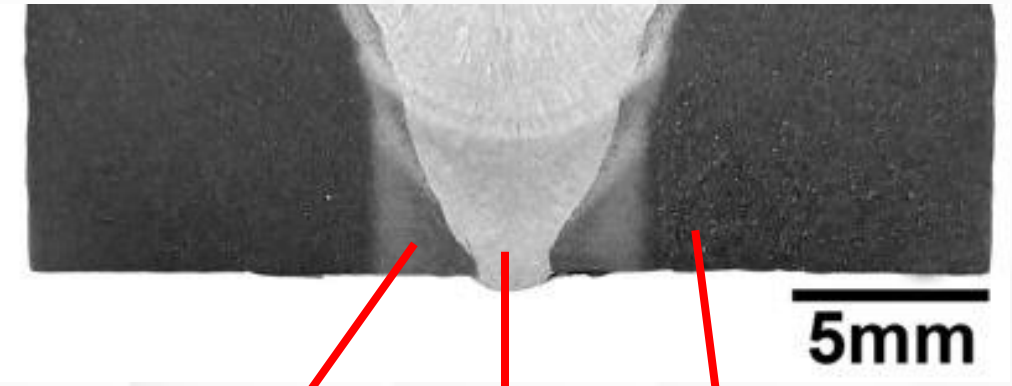
CONCLUSIONS



What is a welded joint and PWC?







Heat affected zone
HAZ

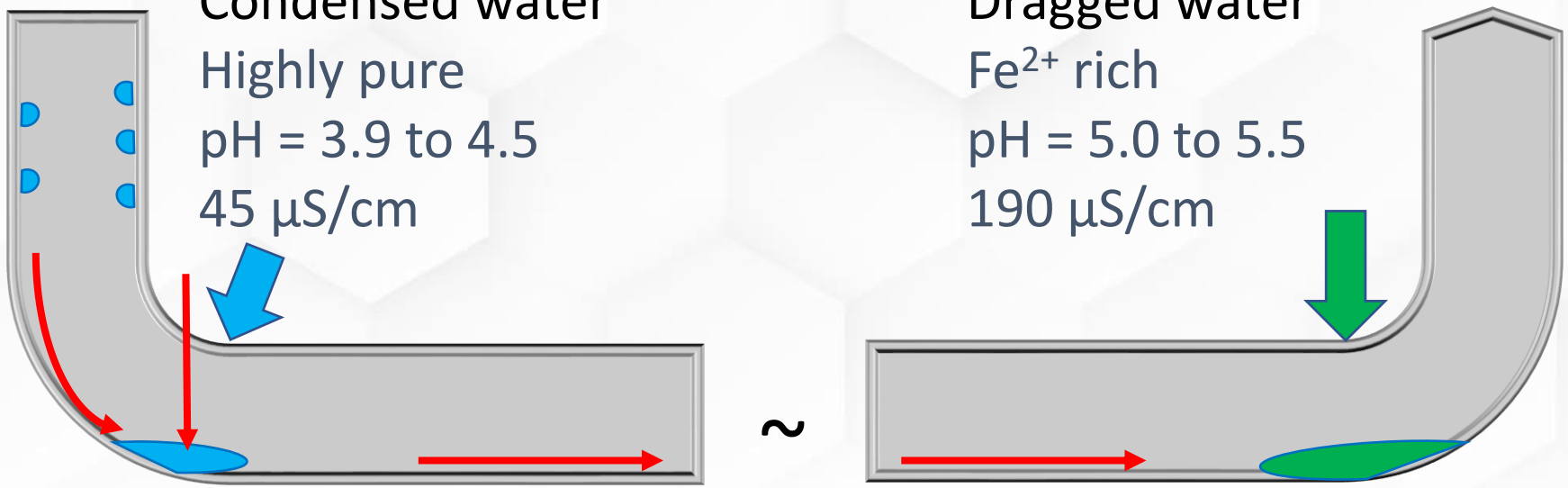
Weld metal
WM

Parent metal
PM

The problem: gas-exportation pipe corrosion

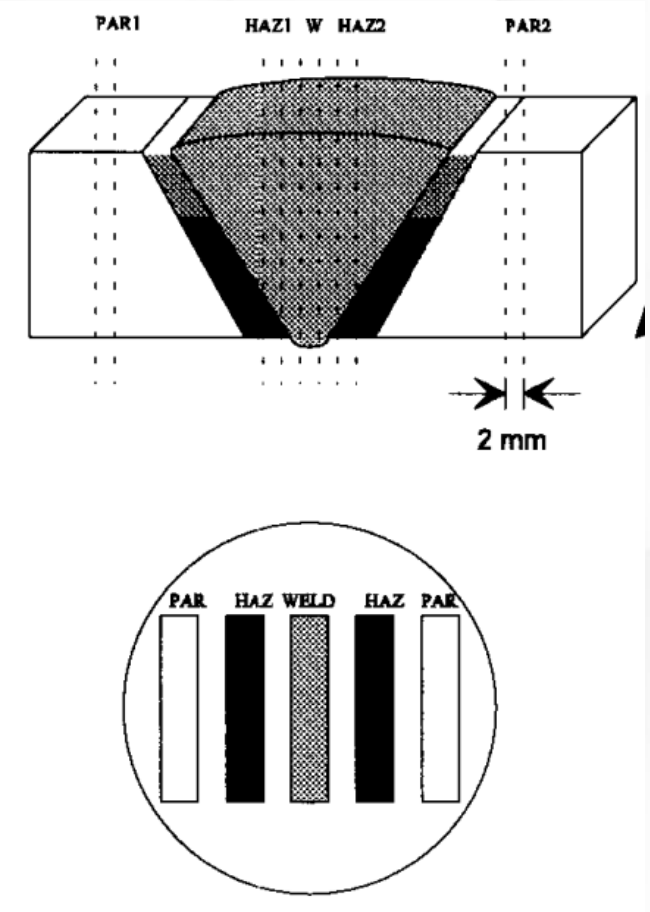
- Fails in moisture removal in triethylene glycol (TEG) plants
- PWC was observed in gas exportation in contact with low conductivity CO_2 condensed water

From production
After treatment



Gas-transportation pipeline

Literature review



Olsen; Sundfaer; Enerhaug, 1997

- Parts of a weld are challenging to separate:
  - Uneven and irregular borders;
  - Narrow regions;
  - Heterogeneous.

Literature search

- Keywords used:
  - "scanning vibrating electrode technique" AND "joint" AND "carbon dioxide"

Scopus

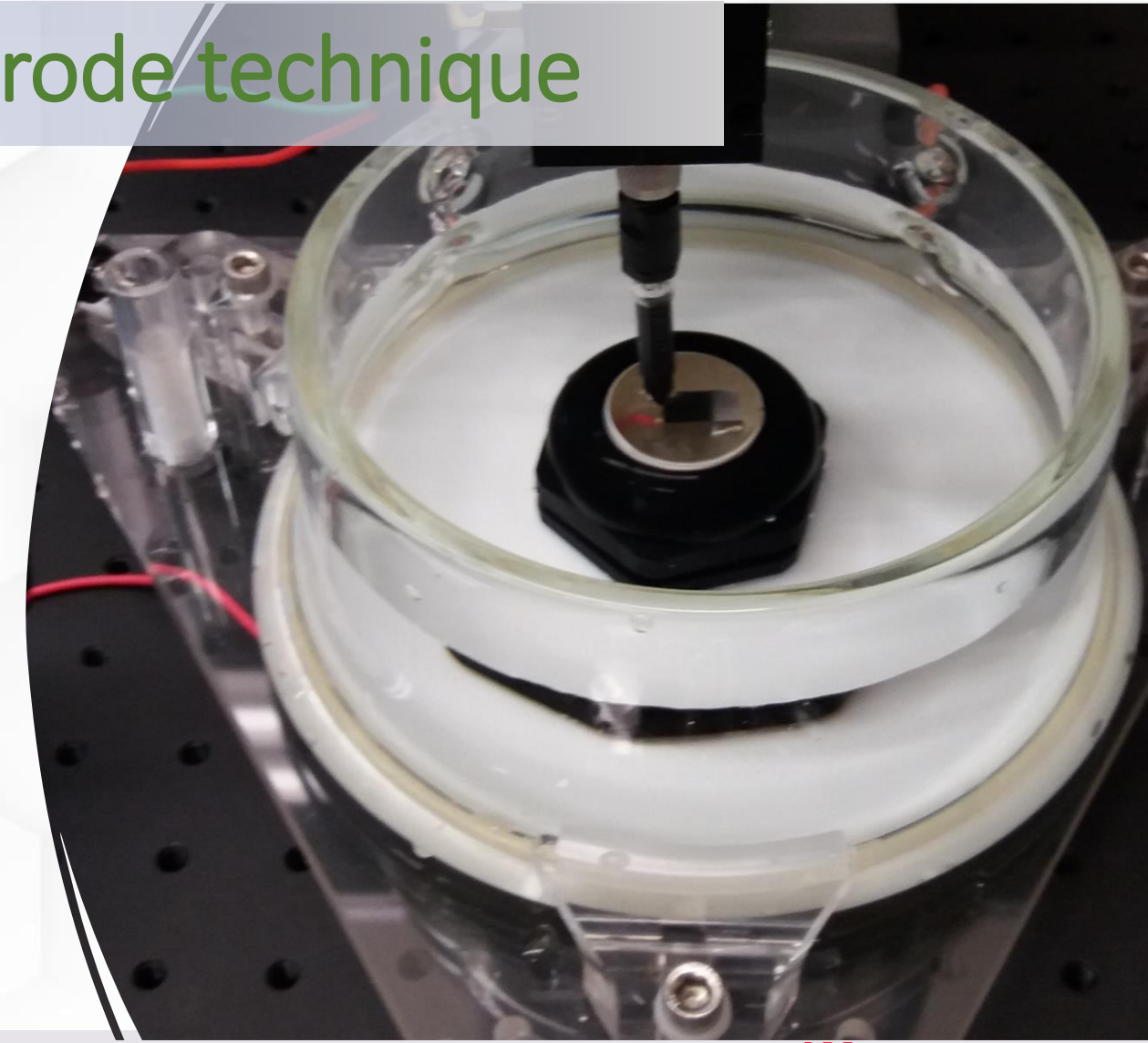
scanning vibrating electrode technique: **696 results**
scanning vibrating electrode technique AND joint: **29 results**
scanning vibrating electrode technique AND joint AND carbon dioxide: **1 result**

Clarivate Web of Science™

scanning vibrating electrode technique**: 651 results**
scanning vibrating electrode technique AND joint: **31 results**
scanning vibrating electrode technique AND joint AND carbon dioxide: **0 results**

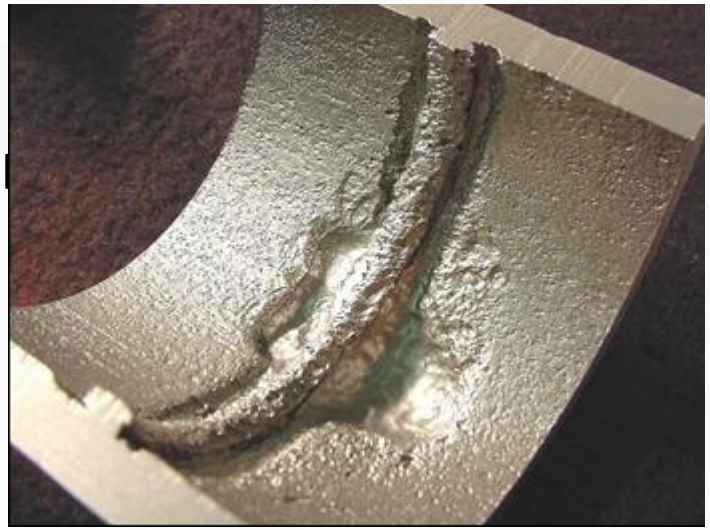
SVET - Scanning vibrating electrode technique

- Electrochemical techniques for evaluating galvanic current typically require disconnection of the anode and cathode.
- SVET can solve this problem by allowing the mapping of cathodic and anodic regions on coupled metallic surfaces.
- SVET limitation is using a low conductivity medium to avoid the signal overlap from adjacent regions.
  - Condensed and dragged water are suitable.



Goal

- To find out a criterium for the selection of parent metal and welding consumables for gas-transportation pipelines (condensed water and dragged water, which are low-conductivity media).
- To establish laboratory facilities to test 79 different circumferential joints
- To identify the PWC phenomenon in low conductivity
  understanding the overall processes:
  - Immersion test;
  - SVET-technique test.



Source: Raman. T. J. Study of Preferential Weld Corrosion in X52 Mild Steel with the Presence of Acetic Acid. Dissertation . Universiti Teknologi PETRONAS. 2016.

Materials / Parent metals

- Seven different parent metals

Parent Metal	Welding process	Most abundant relevant alloy element, in descending order
8” DNVGL SMLS 450	GTAW / GMAW	Si
10” DNVGL SMLS 450	GTAW / GMAW	Cr + Si
12” DNVGL SMLS 450	GTAW / GMAW	Ni + Si + Cu
20” DNVGL SAW 450	GTAW / GMAW / SAW	Ni + Si + Cr + Cu
24” DNVGL SAW 450	GTAW / GMAW / SAW	Si + Cr
8” Forged	GTAW / GMAW	Ni + Cr + Si
20” Forged	GTAW / GMAW / SAW	Ni + Si + Cr + Cu

Materials / Welding processes and consumables

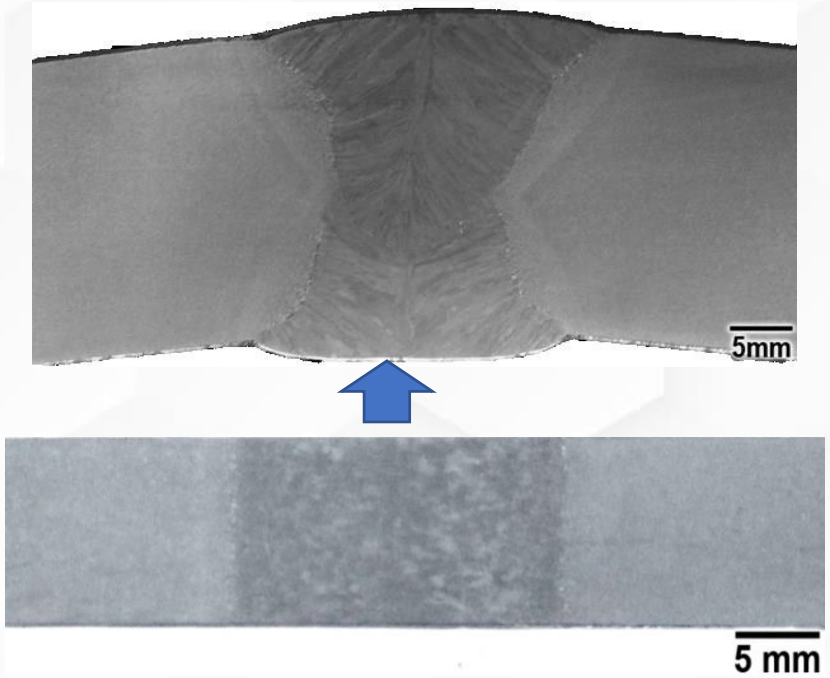
- Most abundant relevant element of the consumable for each welding process

GTAW	GMAW	SAW
↓ Si	↓ Si	Si
↑ Si	↑ Si	Ni + Si
Ni + Si	Ni + Si	Ni + Cr + Si + Cu
Si + Cr + Ni	Ni + Si + Cu	-x-
Ni + Si + Cu + Cr	Si + Cu + Cr + Ni	-x-

Total of 79 welded joints

Materials / Specimens

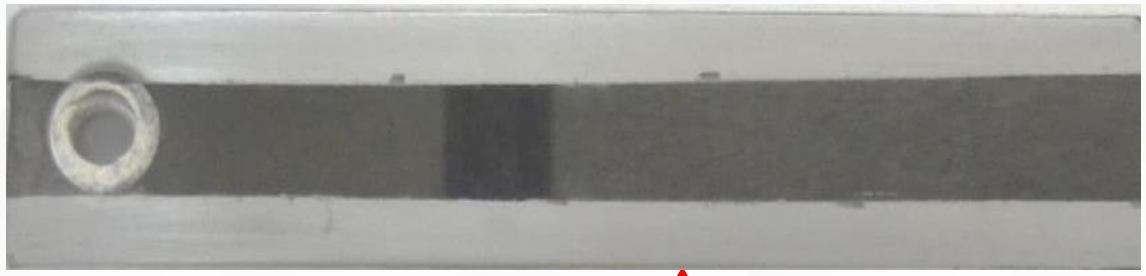
- Immersion samples:



Sample ready to test

470 Scotch tape to protect the surface
This area was used as a reference for thickness-loss measurement

Sample after the test



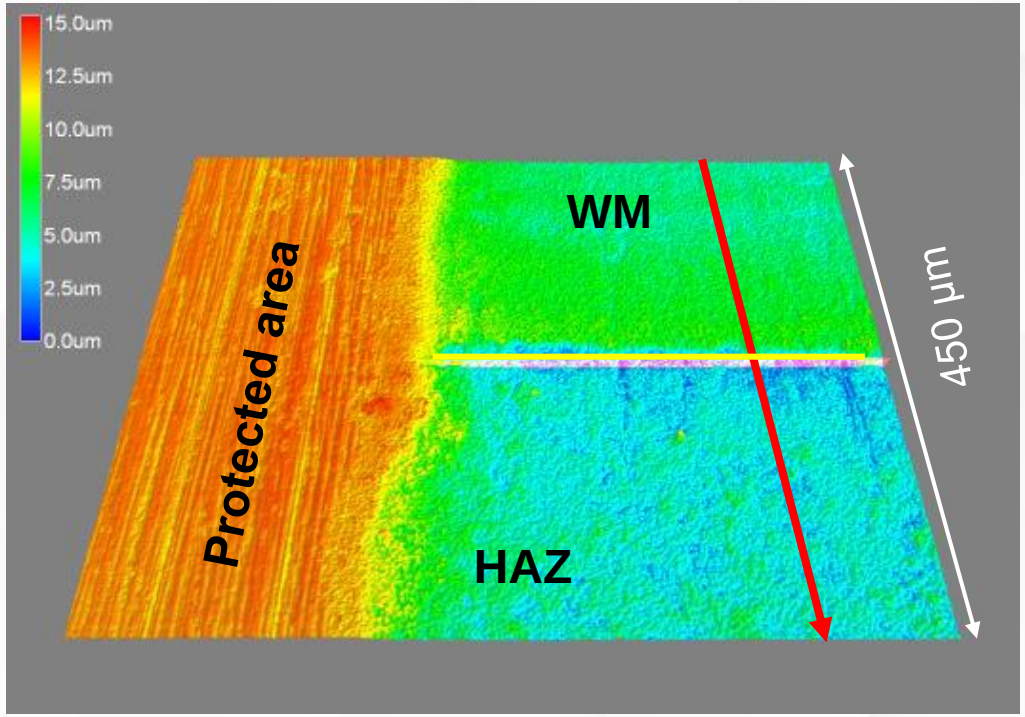
Non-corroded area (reference)

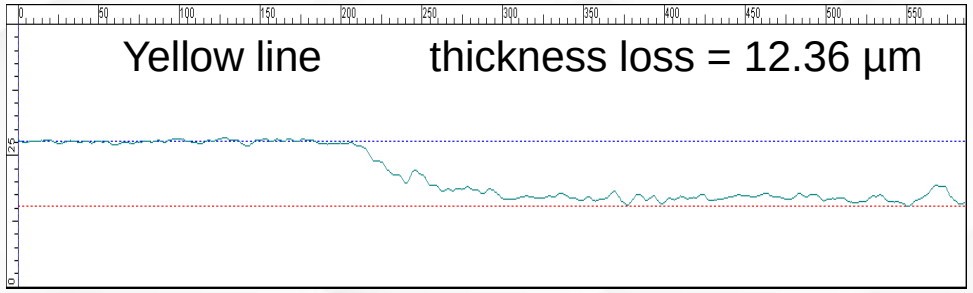
Tests conditions

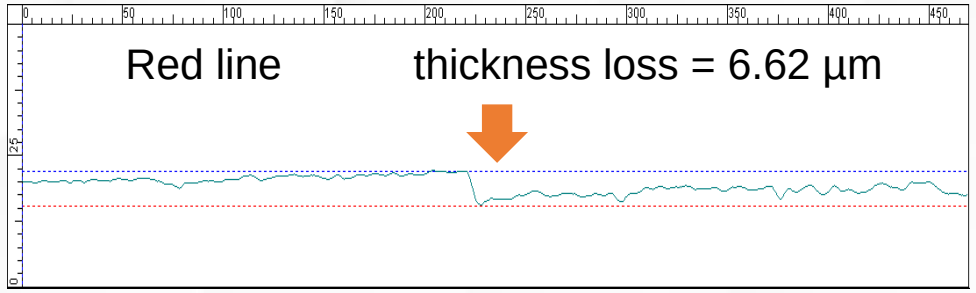
Immersion tests duration:

- 48 h (condensed water);
- pH control to 3,9 (initial) to 4,5 (max.);
- 120 h (dragged water);
- pH from 5,0 (initial) to 5,5 (max.).

Identification of PWC occurrence by confocal microscope



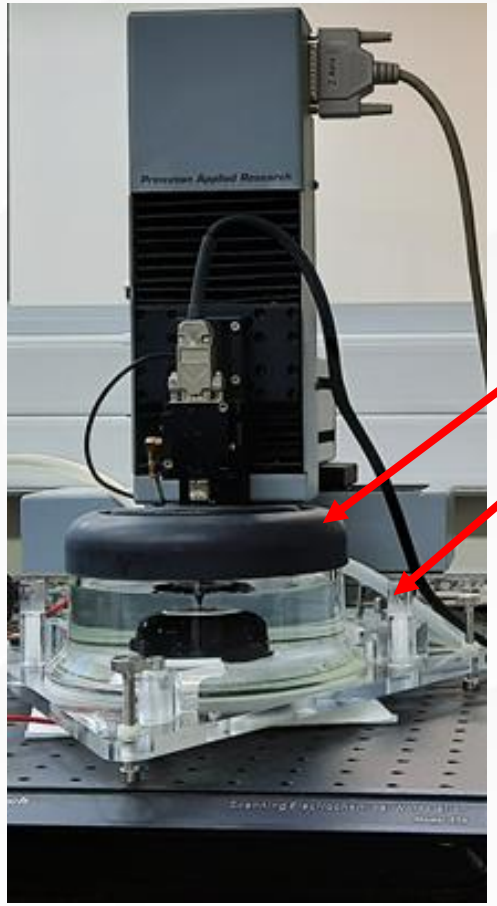




Light HAZ preferential attack close to HAZ/WM fusion line: the galvanic action is restricted to the distance less than 100 µm from fused line (FL) because of the low conductivity of the condensed water.

Tests conditions

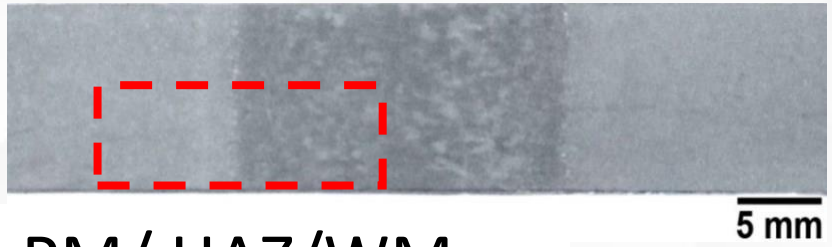
- CO_2 environment



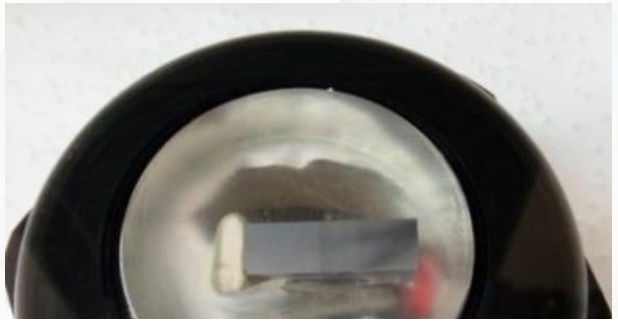
Cap

CO_2 Injection to maintain the atmosphere

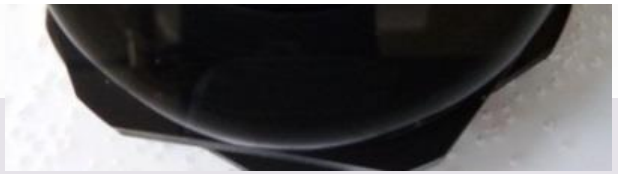
- Girth welds =
  SAW (wider)/ GTAW / GMAW (narrower)



PM/ HAZ/WM



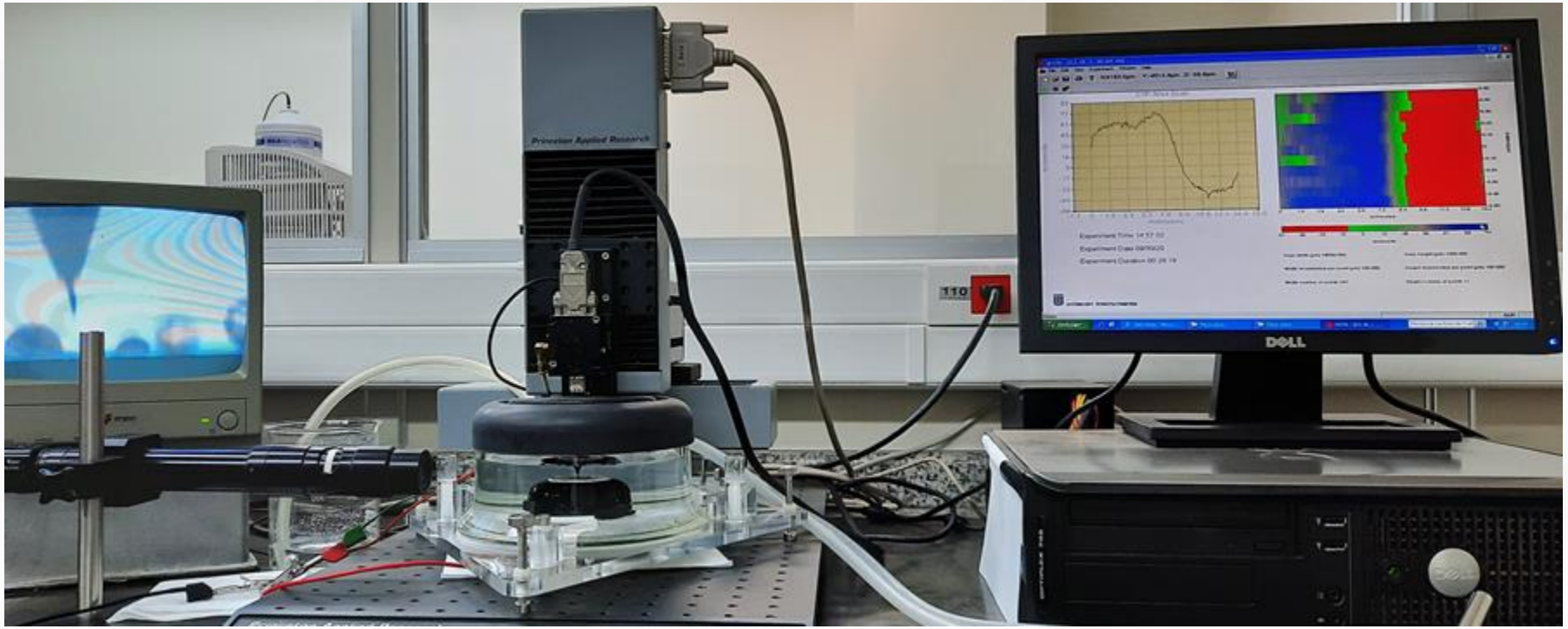
PM/ HAZ/WM



PM - 25 mm^2
HAZ - full length
WM - 25 mm^2

Tests conditions

- 20 h of immersion in test solution before the measurement to establish the galvanic corrosion.



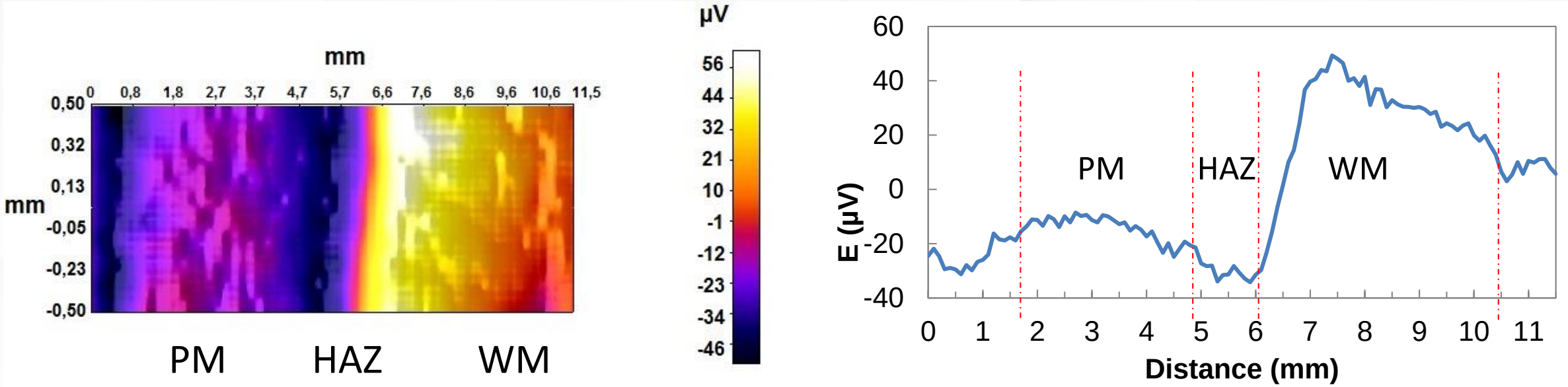
Scan rate = 100 µm/s

µm/point = 100
(X and Y direction)

The position of the tip depended on the signal intensity, about 1 µm

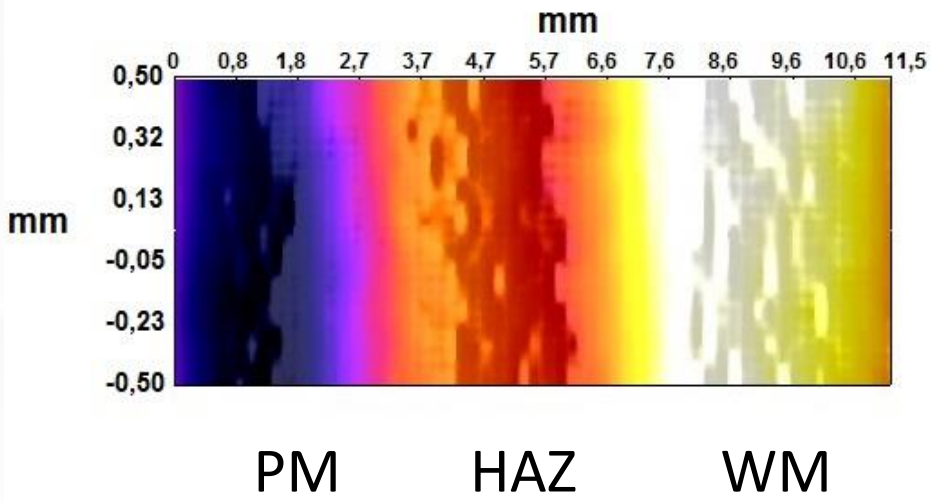
Results

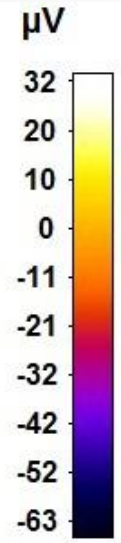
- Result from a GTAW welded joint immersed in condensed water, parent metal 20” DNVGL SAW 450 and consumable ↑ Si.
- WM is an anodic region, HAZ is the most cathodic part.

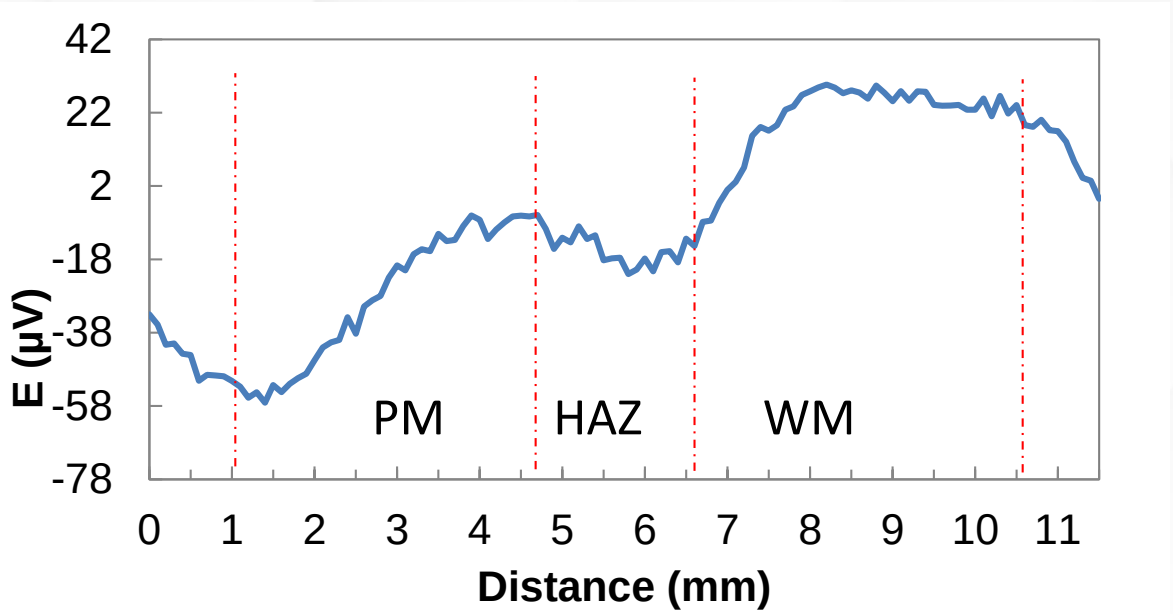


Results

- Result from a GTAW welded joint immersed in dragged water, parent metal 20” DNVGL SAW 450 and consumable ↑ Si.
- WM is the anode, PM is the most cathodic part.

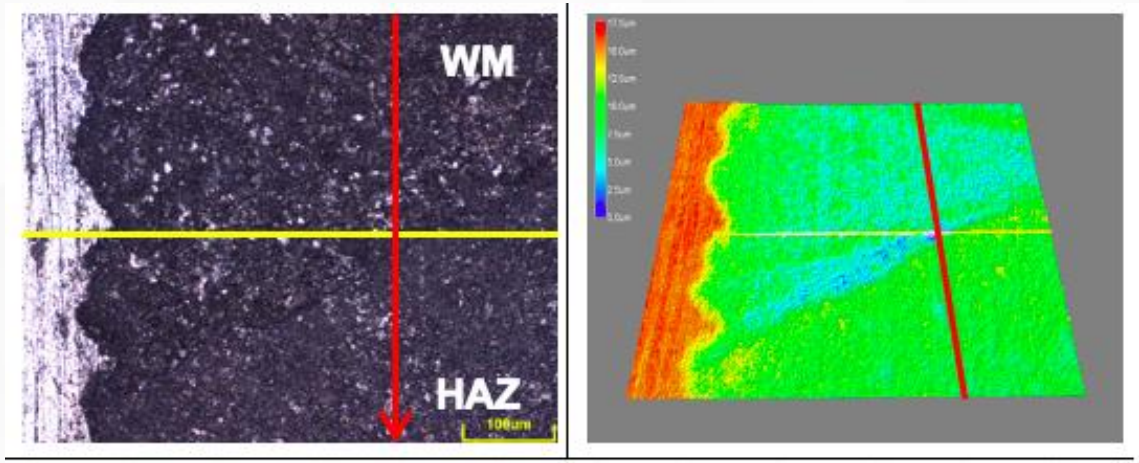




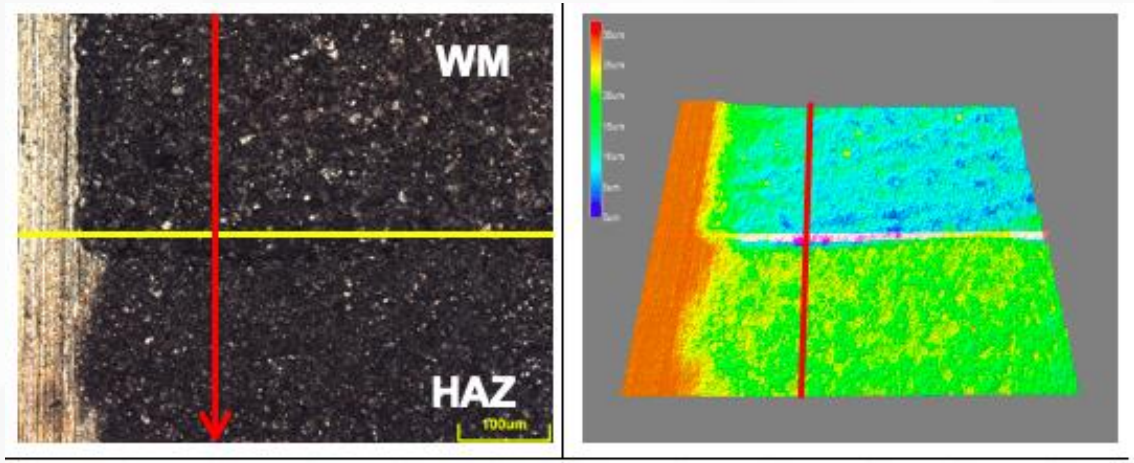


Results – immersion tests

- Condensed water

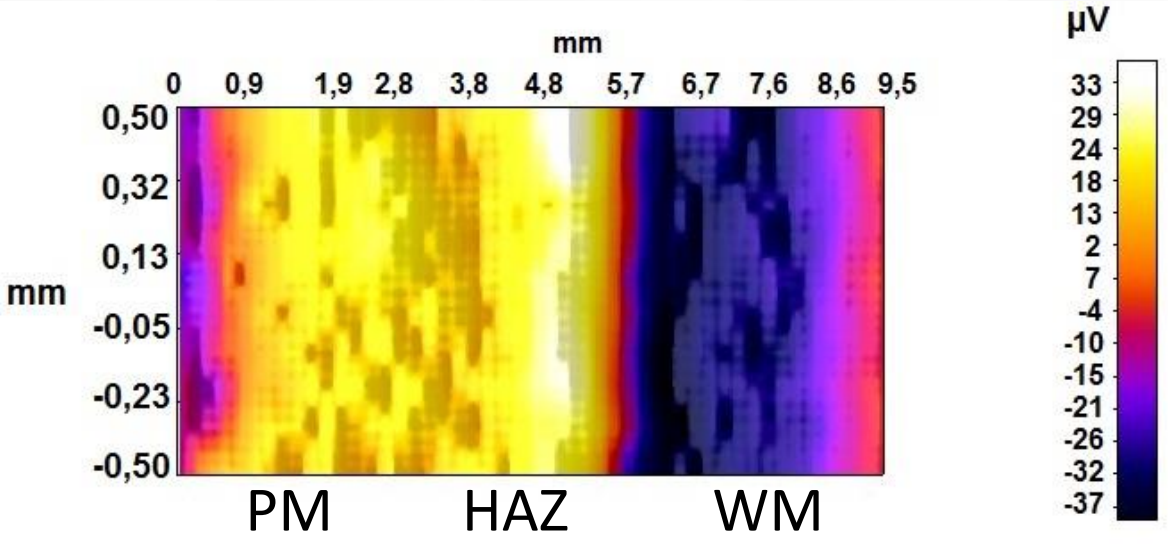


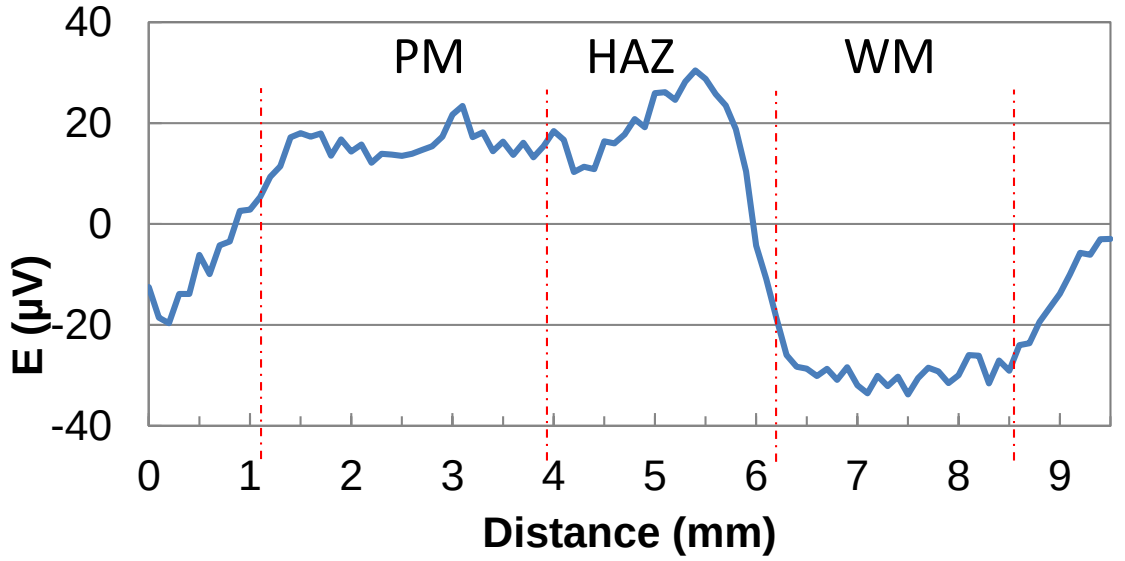
- Dragged water



Results

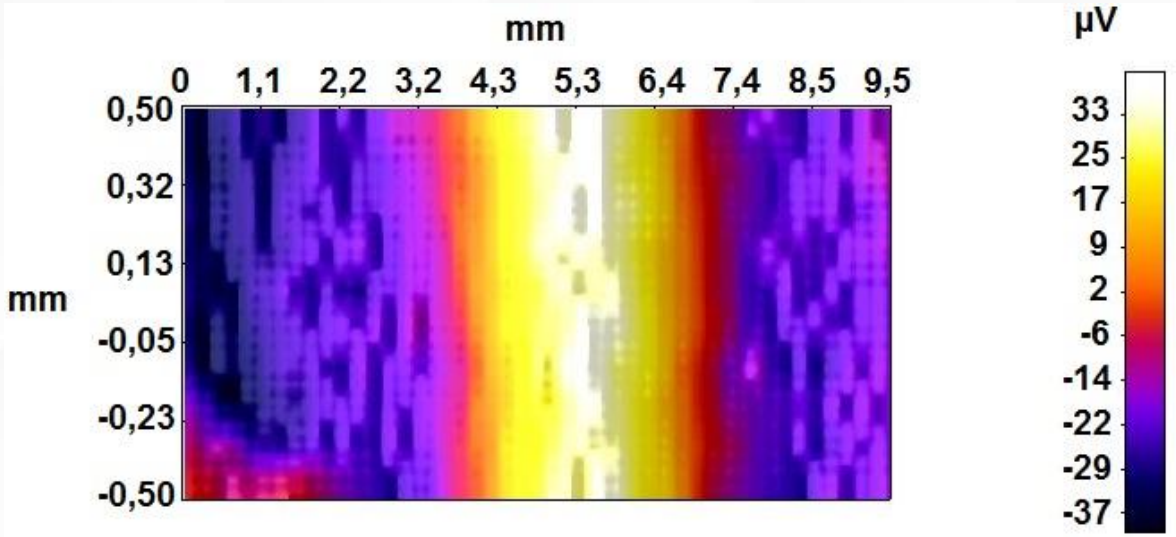
- Result from a GMAW welded joint immersed in condensed water, parent metal 20” DNVGL SAW 450 and consumable ↑ Si.
- WM is a cathodic region, HAZ and PM are the anode.

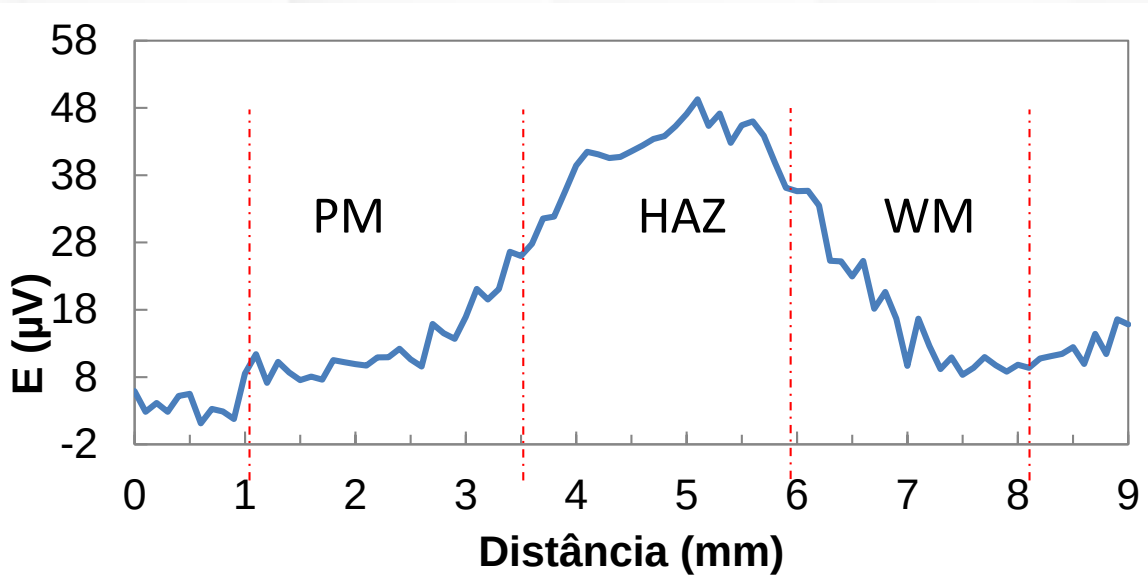




Results

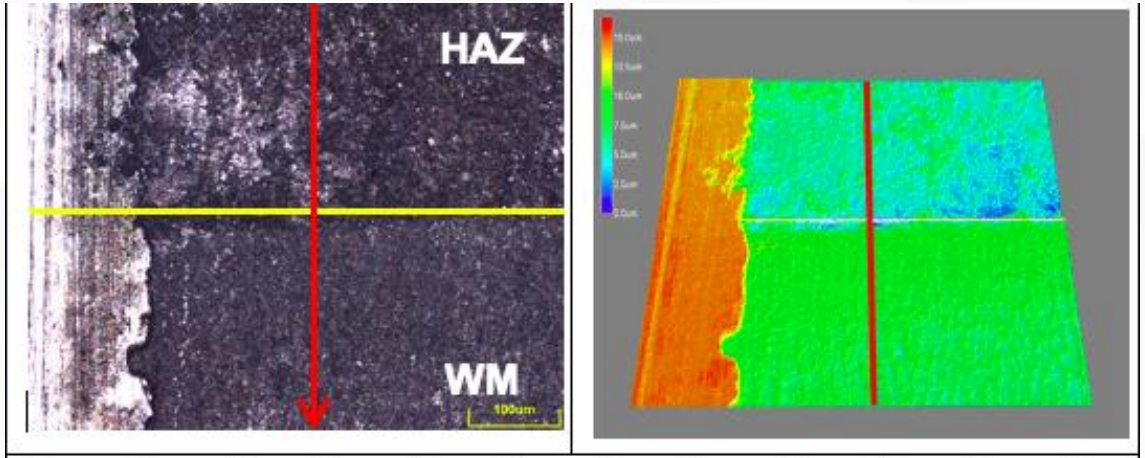
- Result from a GMAW welded joint immersed in dragged water, parent metal 20” DNVGL SAW 450 and consumable ↑ Si.
- HAZ is the anode, PM and WM are cathodic regions.

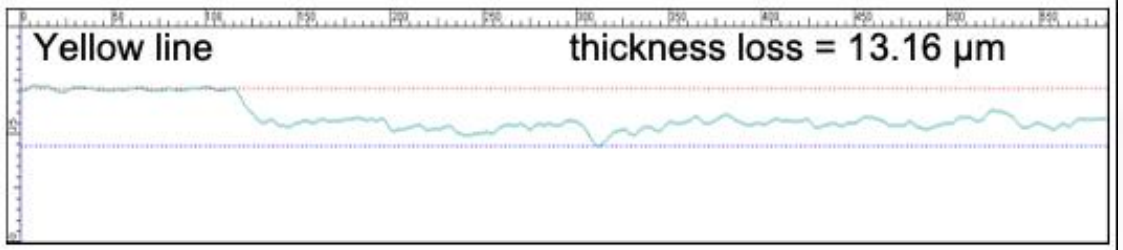


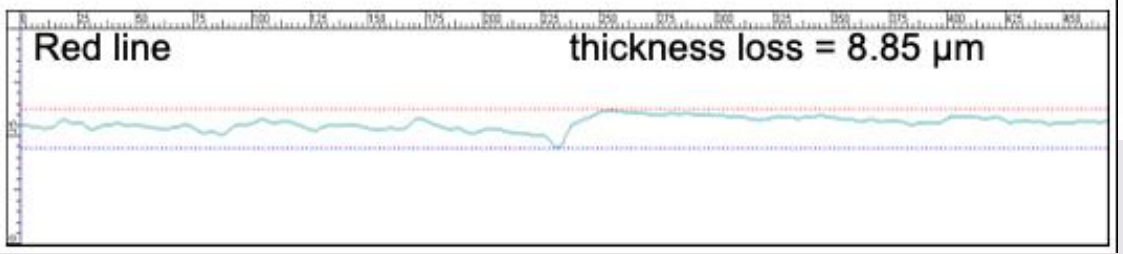


Results – immersion tests

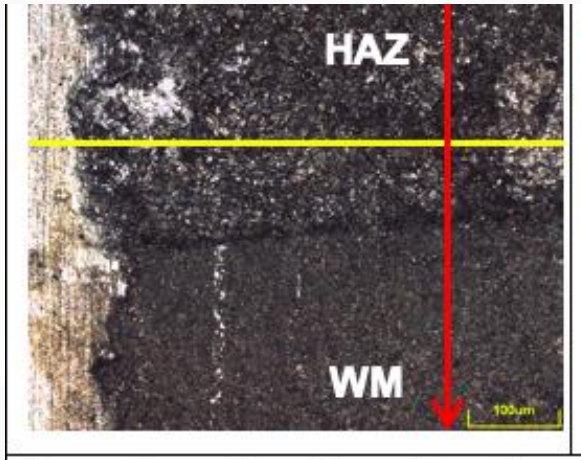
- Condensed water

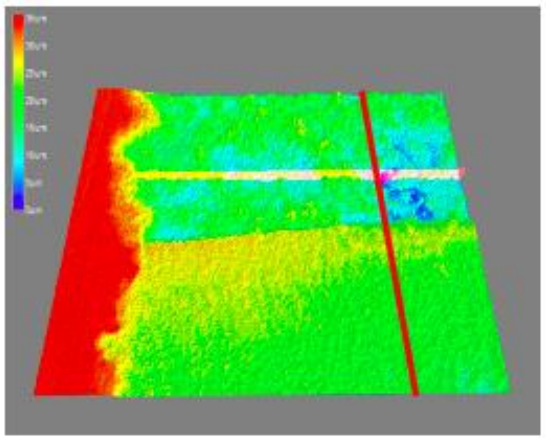


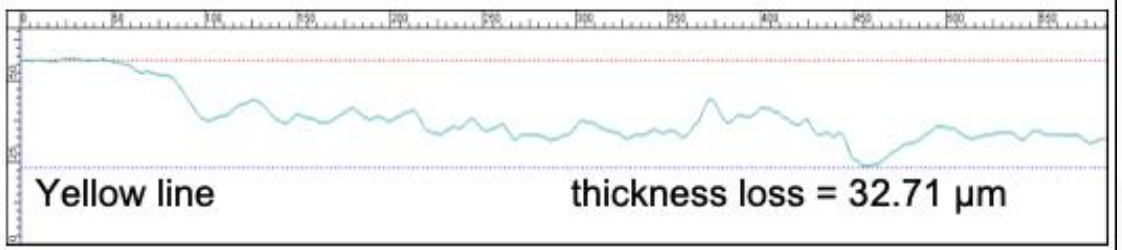


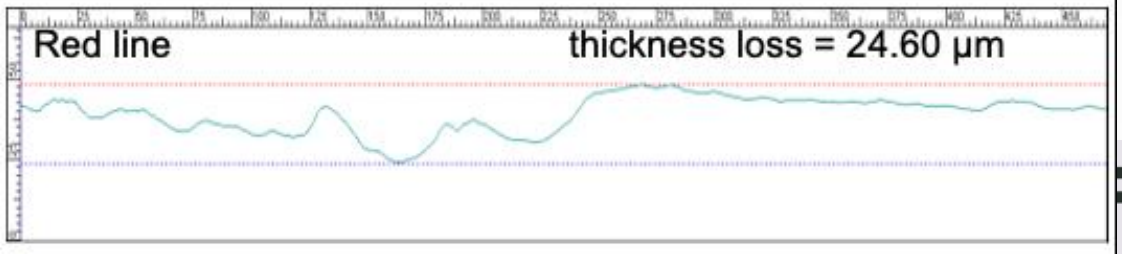


- Dragged water









Conclusions

- SVET indicated the PWC, a pronounced and concentrated material loss.

- The anodic and cathodic regions were preserved, as it was used the welded joint with all its parts together.

Thank you for your attention!

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SÃO PAULO GOVERNO DO ESTADO SÃO PAULO SÃO TODOS

fipt fundação de apoio ao instituto de pesquisas tecnológicas

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Dra. Juliana Lopes Cardoso
jcardoso@ipt.br
+55 11 3767-4805
Laboratory for Corrosion and Protection