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Galvanic effects of scales and inhibition in CO_2 corrosion

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Overview

- Objectives of research
- Introduction to galvanic corrosion
- Properties of corrosion product scales
- Experimental setup
- Results and Discussion
- Conclusions

Objectives

To determine:

- The galvanic effect of magnetite (and other) scales on CO_2 corrosion of mild steel
- The effect of cathode to anode surface area ratio on galvanic corrosion
- The effect of flow (mass transfer)
- The effectiveness of corrosion inhibitors on galvanic corrosion control

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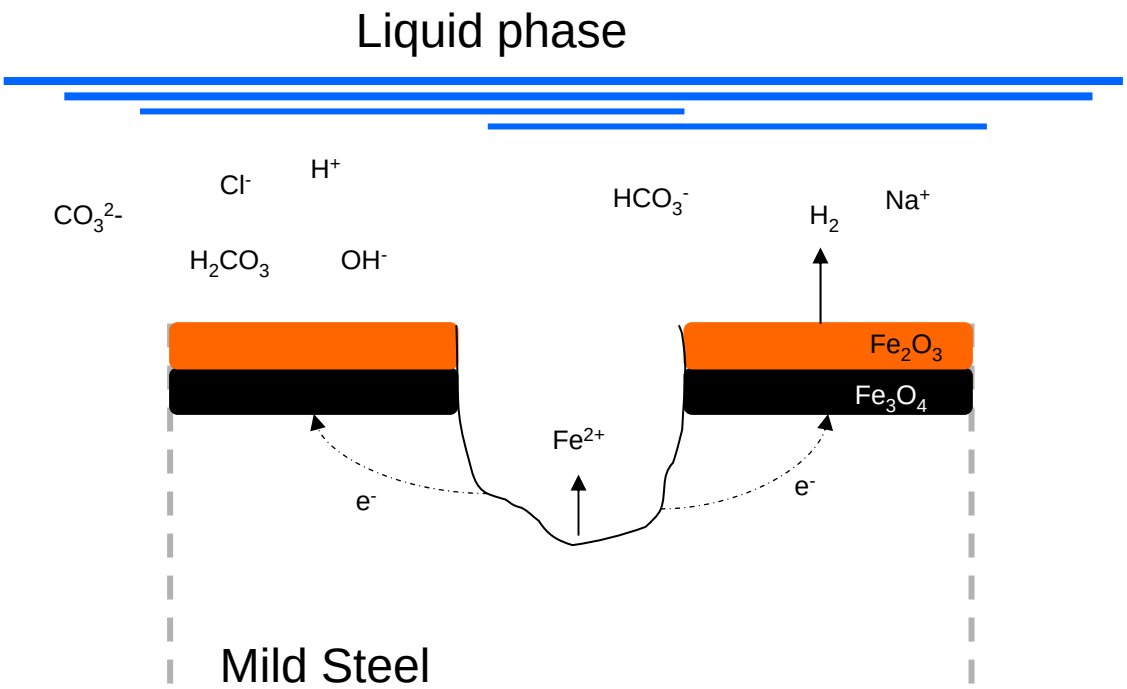
Galvanic corrosion in the oil and gas industry

- Pipelines corrode at an accelerated rate (~5mm/yr)
- Patches of black corrosion scale found on the corroded pipelines
- Operating conditions in a particular platform in the North West Shelf:
  - pH : 6.5
  - Temperature : 55 ^{o}C
  - CO_2 partial pressure : 0.3 bar

Galvanic corrosion



Anodic reaction:

$$Fe \rightarrow Fe^{2+} + 2e^-$$

Cathodic reactions:

$$2H^+ + 2e^- \rightarrow H_2$$

$$2H_2CO_3 + 2e^- \rightarrow H_2 + 2HCO_3^-$$

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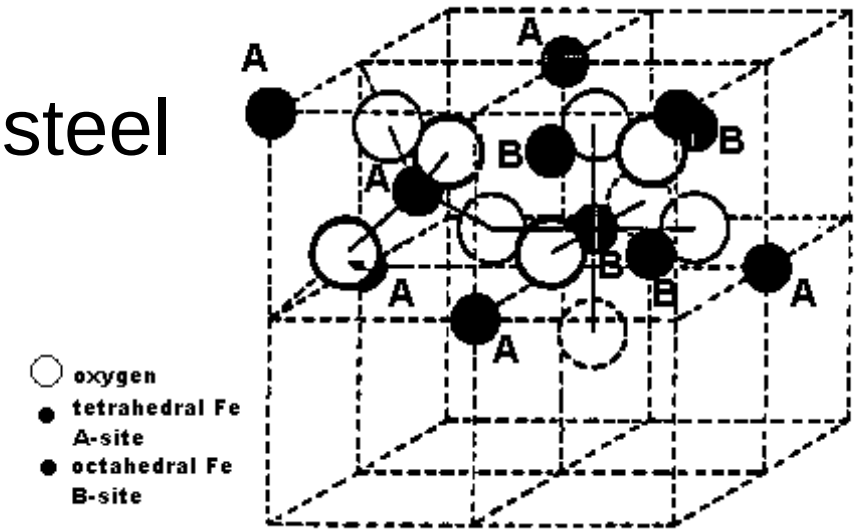
Properties of corrosion scales

Table 1: Electronics properties of iron corrosion products

Products	**Chemical code**	**Electronic property**	**Band gap (eV)**
Goethite	α-FeOOH		2.1
lepidocrocite	γ-FeOOH		2.06
Hematite	Fe_2O_3	n-type semiconductor	2.2
Magnetite	Fe_3O_4	n or p type semiconductor	0.1
Maghemite	γ-Fe_2O_3	n-type semiconductor	2.03
Wüstite	FeO	p-type semiconductor	2.3
Pyrite	FeS_2	Conductor	1.2
Troilite	FeS	p-type semiconductor	0.1
Greigite	Fe_3S_4		0

Properties of Magnetite

- Iron (II) oxides and Iron (III) oxides
- High conductivity of 100 to 1000 Ωcm^{-1}
- Unique octahedral structure that allows the holes to migrate easily from Fe^{2+} and Fe^{3+} on the sharing edge
- More noble than mild steel



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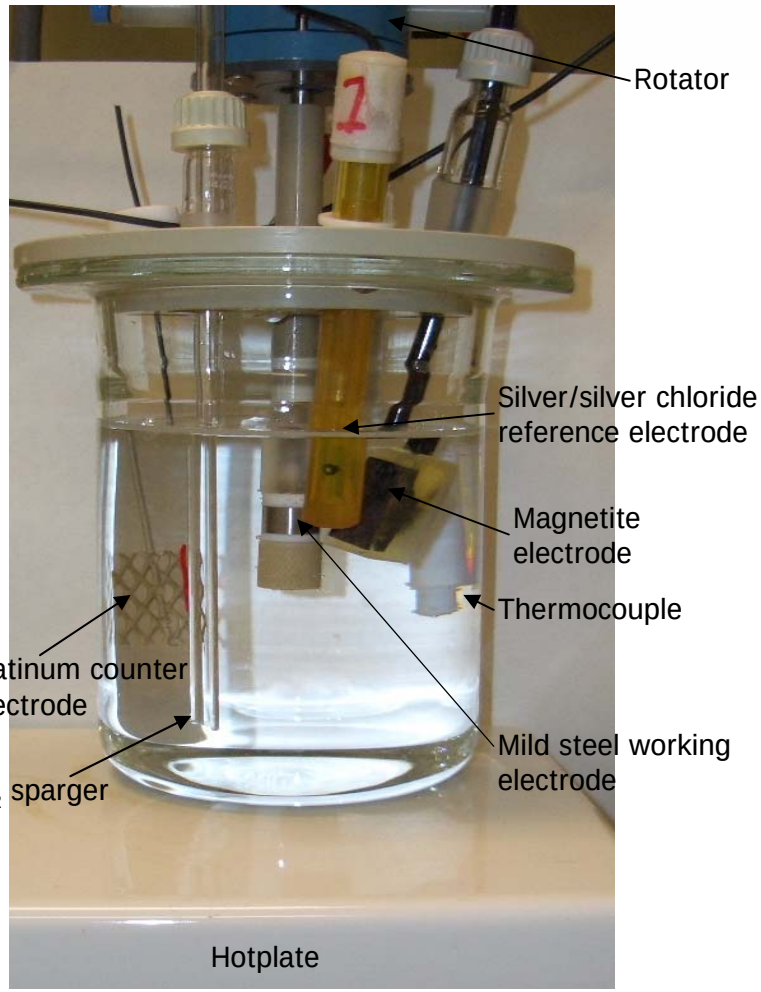
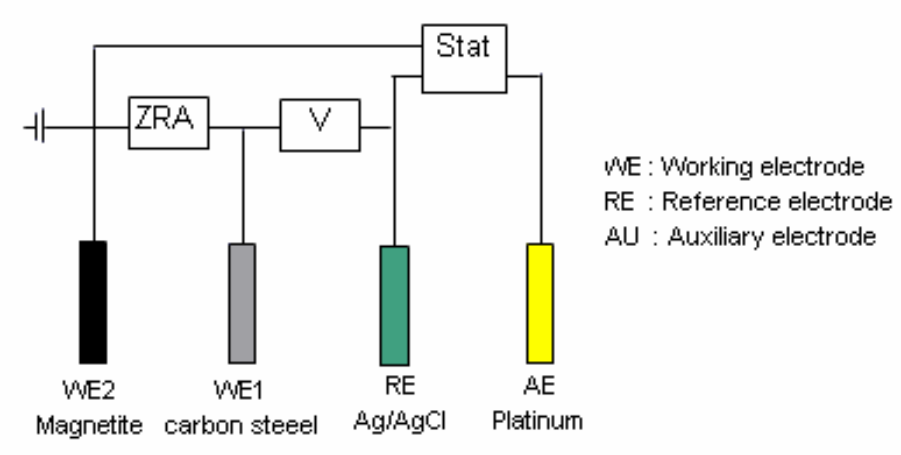
Experimental setup (1)



- Mild steel electrode size : 3.05 cm^2, 1.20 cm^2 and 0.66 cm^2
- Magnetite electrode size: 4.9 cm^2
- Test Conditions:
  - solution : 1L of 3% NaCl +100 ppm $NaHCO_3$
  - Temperature : 30^oC
  - Pressure : 1atm CO_2
  - Rotation : 1000 rpm

Experimental setup (2)

- ACM Gill 12 potentiostat with a built in ZRA
  - Linear polarisation measurement on the mild steel
  - Galvanic current and potential measurement on the couple



Results and Discussions

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Surface Area Ratio

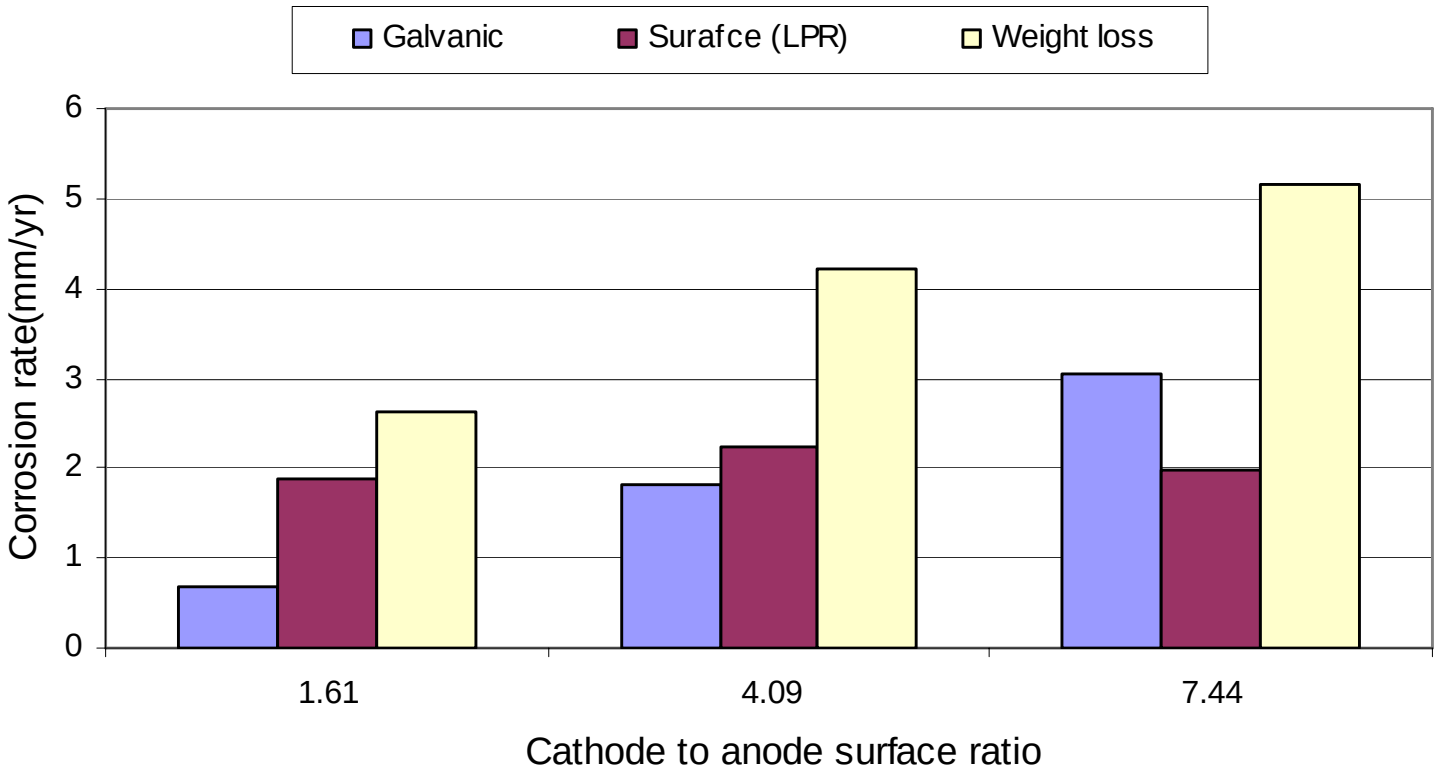

Figure I : Self corrosion and galvanic corrosion rates for different mild steel surface areas galvanically coupled to magnetite

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Mixed potential

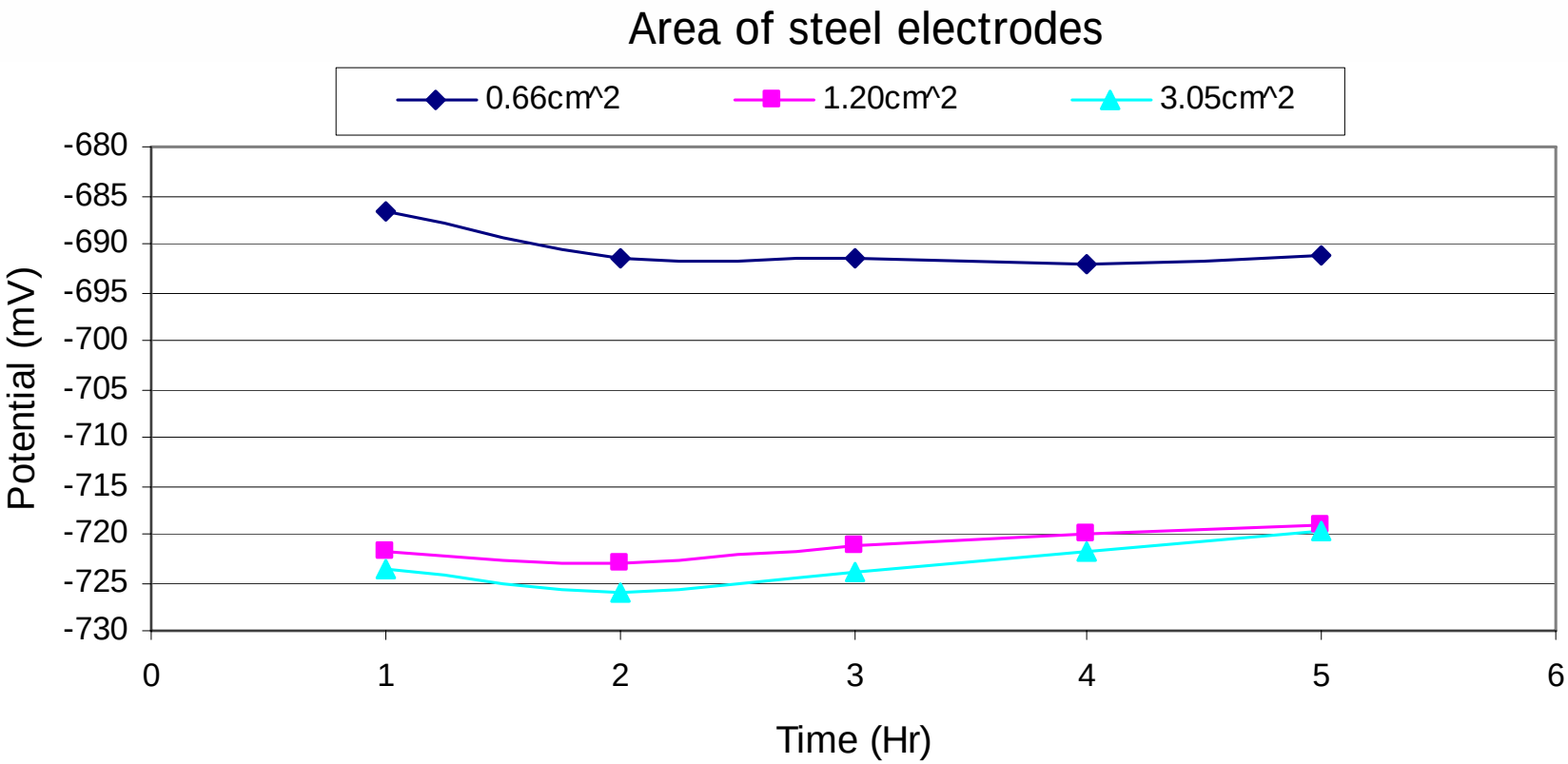

Figure II : Mixed potential of magnetite / mild steel coupling with different mild steel surface area and uncoupled mild steel potential

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Effect of corrosion inhibitor on mild steel

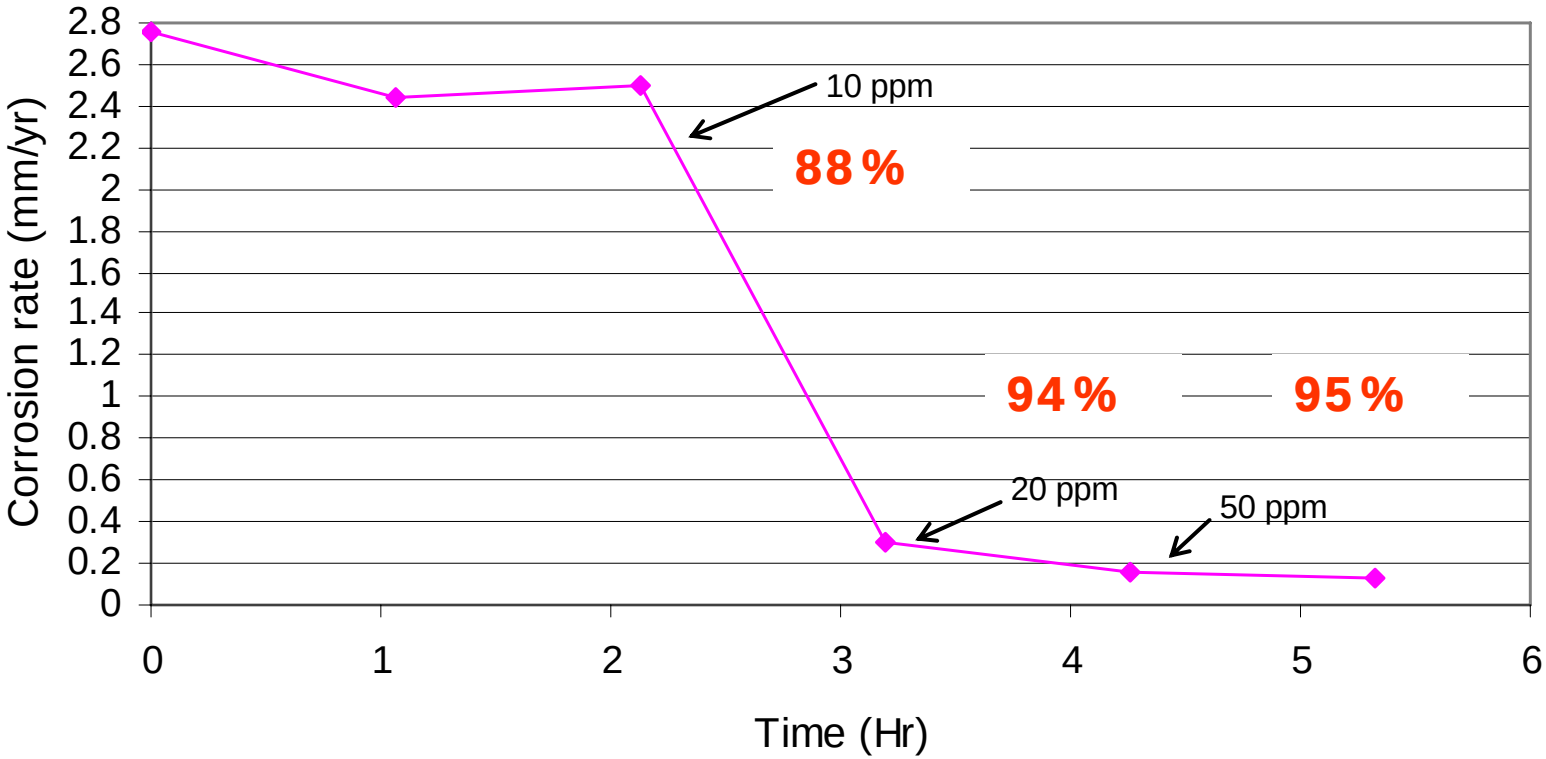

Figure III : Self corrosion rate of a 1.2 cm^2 mild steel electrode with the addition of corrosion inhibitor 1

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Inhibitor effect on galvanic corrosion

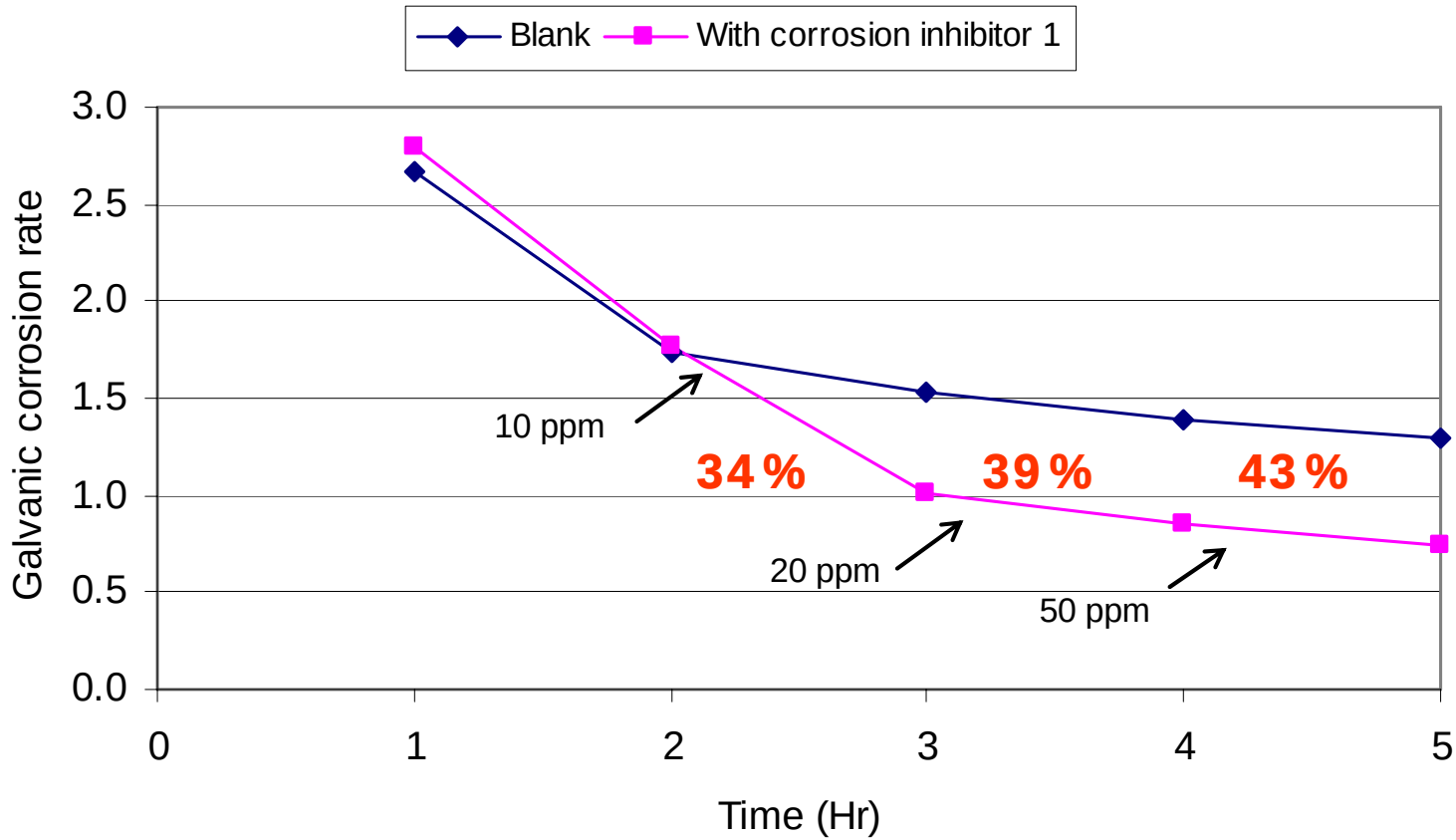

Figure IV : Galvanic corrosion rate of 1.2 cm^2 mild steel electrode with the effect of corrosion inhibitor

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Inhibitors effect on self corrosion

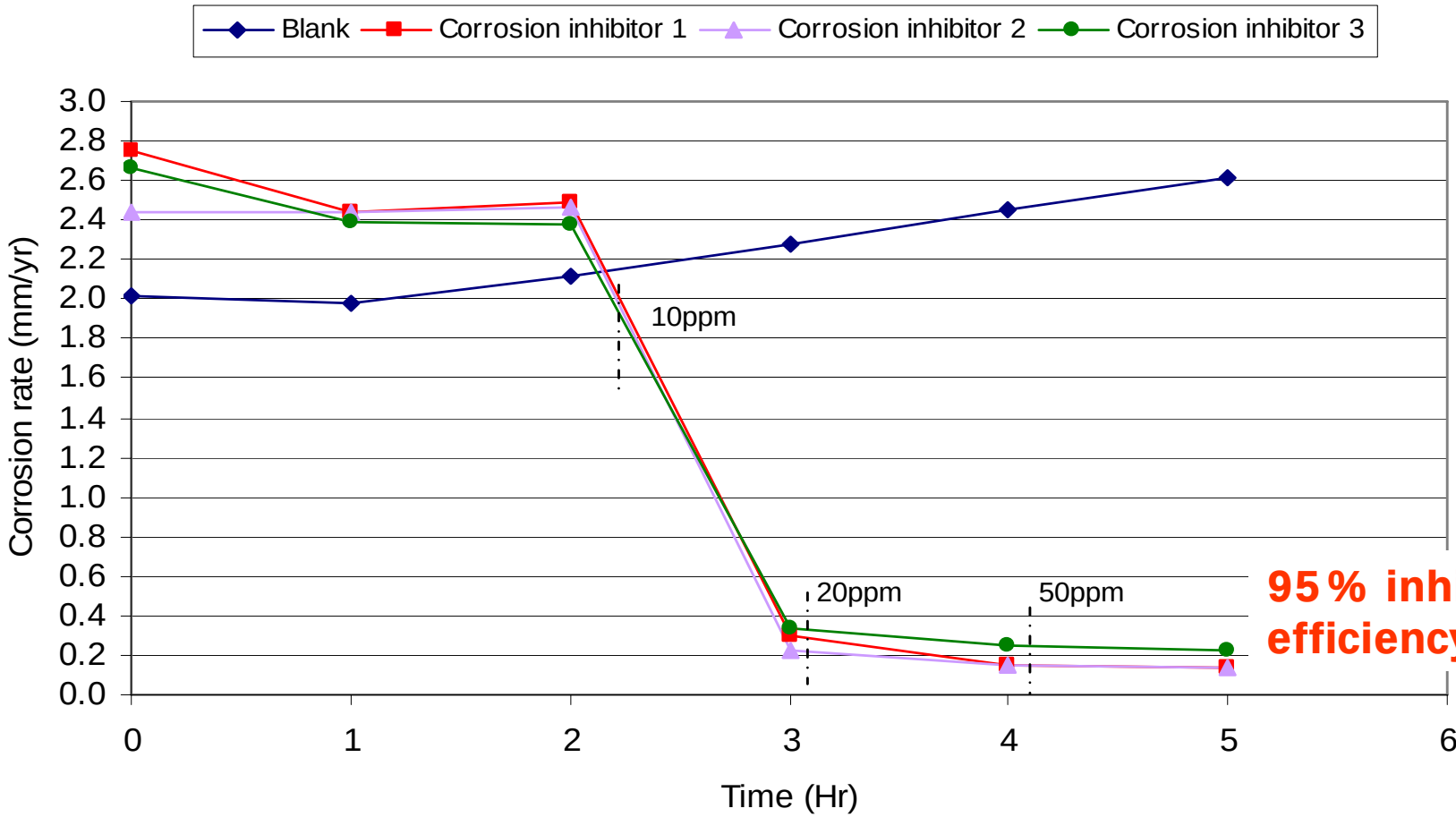

Figure V : Self corrosion rate of a 1.2 cm2 mild steel electrode with the addition of corrosion inhibitors

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Inhibitors effect on galvanic corrosion

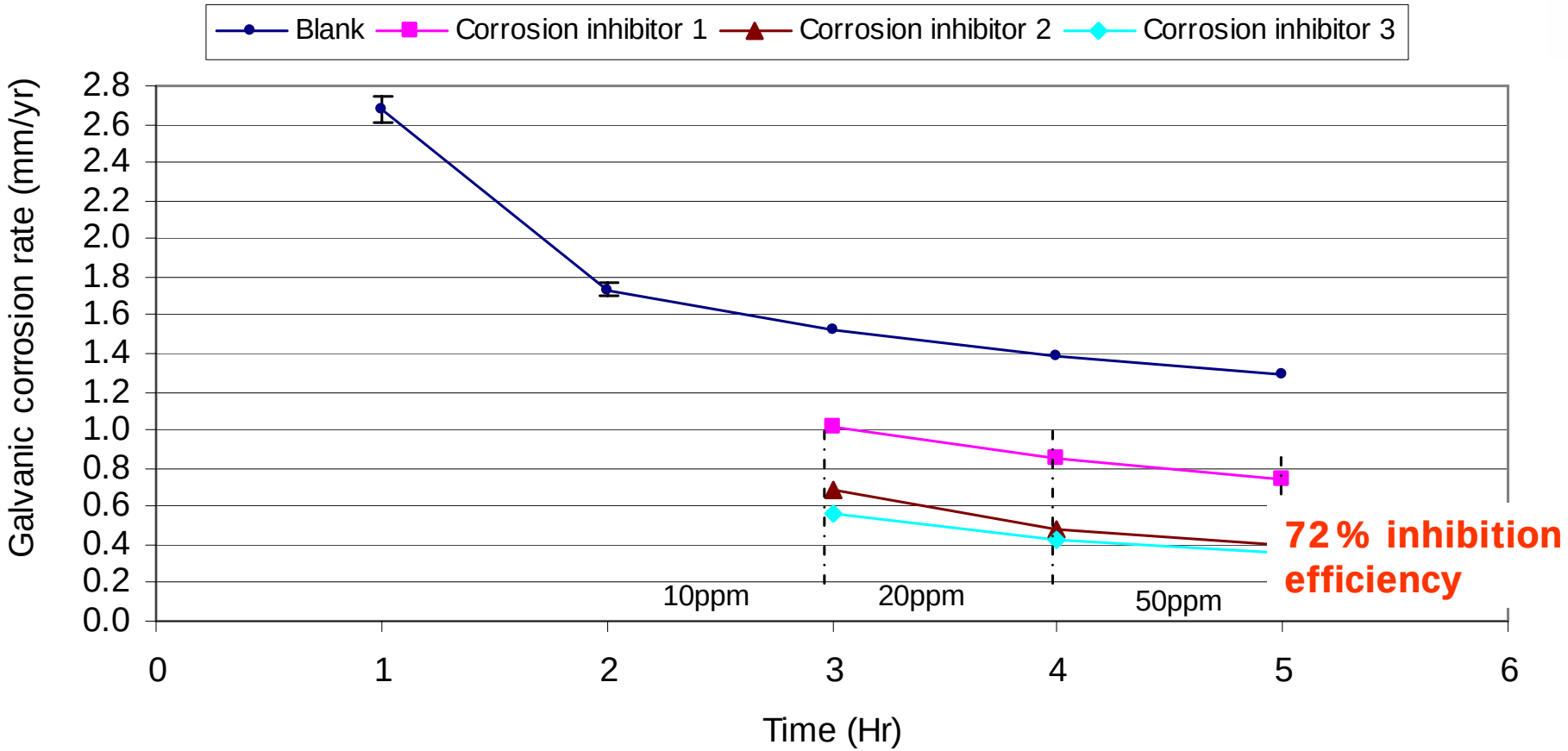

Figure VI : Galvanic corrosion rate of 1.2 cm^2 mild steel electrode with the effect of different corrosion inhibitors

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Conclusions

- Coupling of magnetite with mild steel causes galvanic corrosion
- The galvanic couple is limited by cathodic reaction
- Increasing the ratio of cathode to anode surface area accelerates the galvanic corrosion on the mild steel
- A corrosion inhibitor that reduced self corrosion was not as efficient at reducing galvanic corrosion from magnetite scale
- The efficiency of corrosion inhibitors at reducing galvanic scale corrosion varies