FYP II Final Oral Presentation

Application of corrosion prediction models to optimize material selection in offshore facilities

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Project Background

Corrosion study - Exploration & Production (E&P) business.

Different philosophies of CO_2 corrosion prediction models (ECE4 & MULTICORP).

Parameters: partial pressure of CO_2, H_2S content, high temperature, pH, iron content and flow velocity.

Predicted corrosion (design & operation)– assessed (what parameters are crucial).

Influence on material selection and total project cost.

Problem Statement

PETRONAS employs ECE4 and MULTICORP.

Design of project's facilities - integrity and costs.

Proper corrosion prediction is important.

Material selection and project life cycle.

Economic feasibility.

..a multinational O&G company once experienced a **failure** by not taking into consideration one of the parameters.

Paper 05551, CO2 Corrosion Prediction Model-Basic Principles

Objectives

Study the corrosion predictions from both ECE4 and MULTICORP.
(design & operation phase)

Discuss important parameters to come out with the best possible accuracy of predicted corrosion.

Proper material selection process - economical aspect maximized for profit optimization.

ECE 4

Alloy Selection

…from input data pH is calculated…consider the suitability of 8 corrosion resistant alloys (CRAs)

..identify materials which are safe or unsafe in stated conditions.

Life-Cycle Cost Analysis

Used to give rough indication of relative cost between CRA and carbon steel.

Important aspect in corrosion evaluation…obtain a realistic estimate of the actual pH value in the water phase.

..if formation water is produced, it is important to obtain good water analysis data…bicarbonate and organic acids.

The actual pH value must be calculated from the CO_2 and H_2S partial pressure, temperature, bicarbonate content in the water.

Norsok

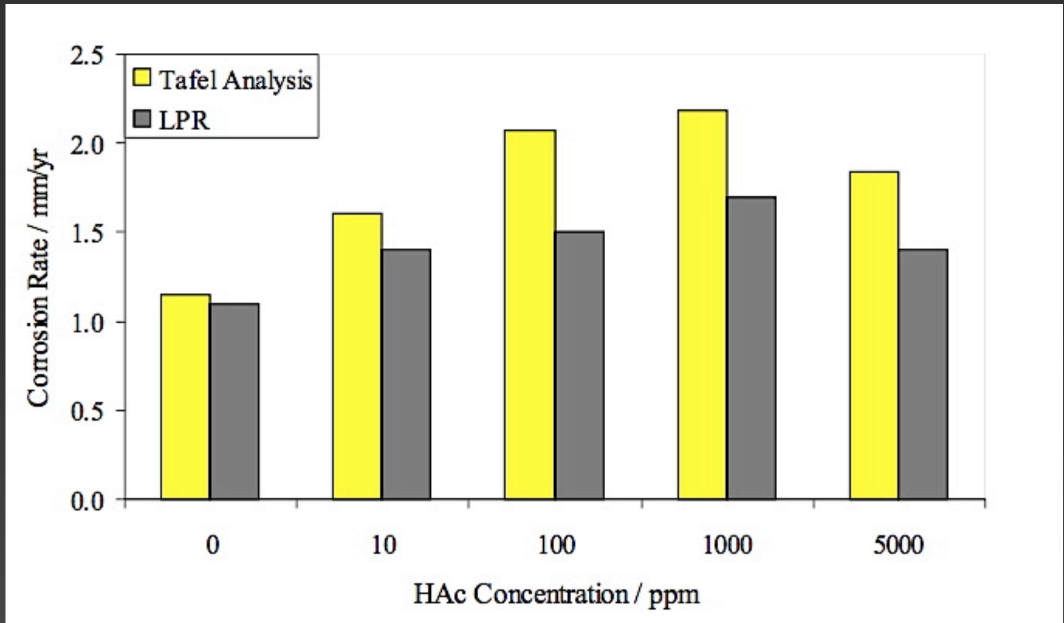
Model the effects of fluid flow rate since it proved that flow rate influences CO_2 corrosion.

More severe in conditions with high content of organic acids. Not suitable for used in produced water environment.

Uncertainties.

The Effect of Cl^- and Acetic Acid on Localized CO_2 Corrosion in Wet Gas Flow.
Paper No. Paper 03327, Corrosion in Multiphase Systems Center Institute for Corrosion and Multiphase Technology Ohio University

Localized attack in CO_2 corrosion of mild steel is always associated with the formation and breakdown of protective iron carbonate film.



CR is not significantly affected by HAc at room temperature but at high temperature environment.

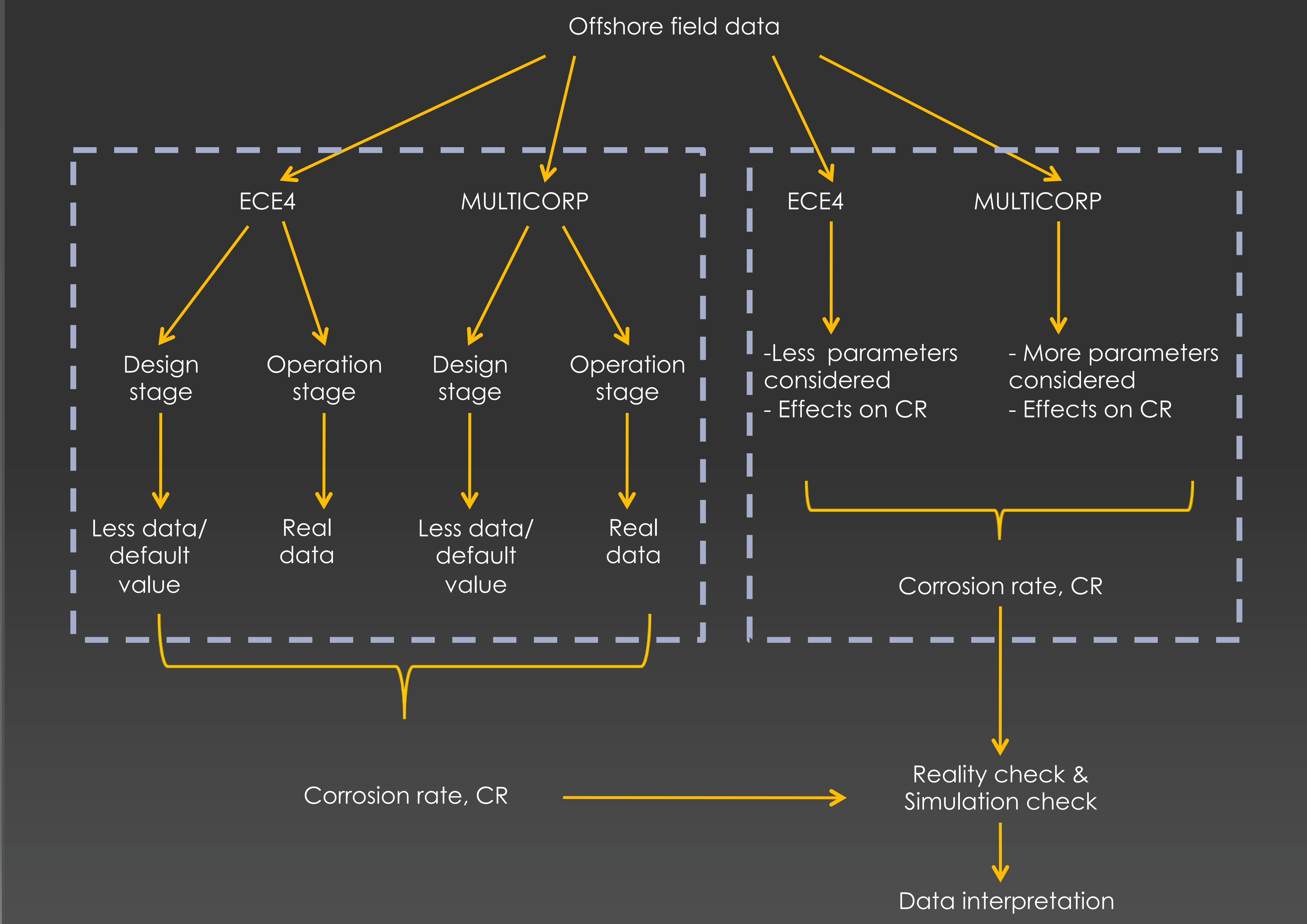
Methodology

Gather field data.

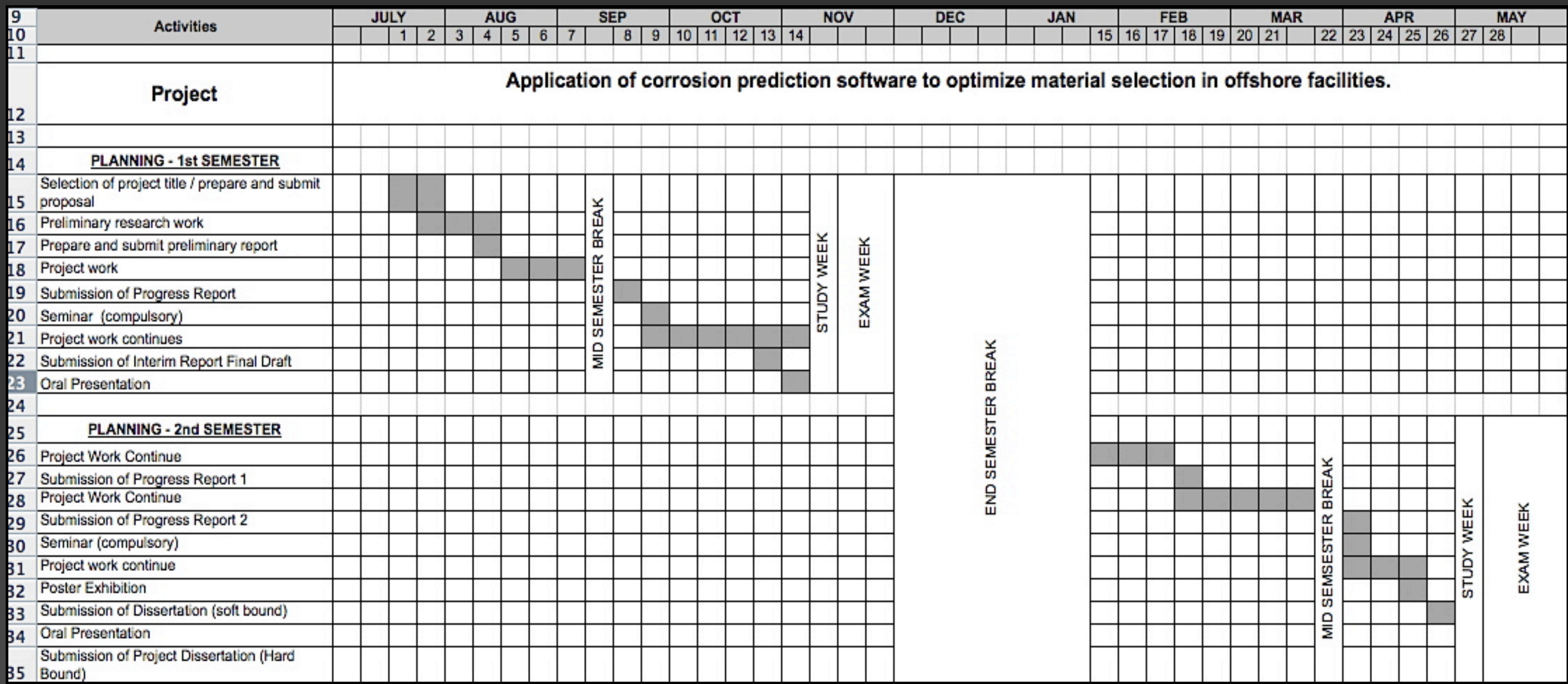
Two outputs that are desired to be found:

-To compare corrosion predicted from two different models (ECE4 & MULTICORP) by using same well data.

-To compare corrosion predicted in design and operational stage using field data.


Offshore field data
ECE4
MULTICORP
Design stage
Operation stage
Design stage
Operation stage
Less data/ default value
Real data
Less data/ default value
Real data
Corrosion rate, CR
ECE4
MULTICORP
-Less parameters considered
- Effects on CR
- More parameters considered
- Effects on CR
Corrosion rate, CR
Reality check & Simulation check
Data interpretation

Gantt Chart

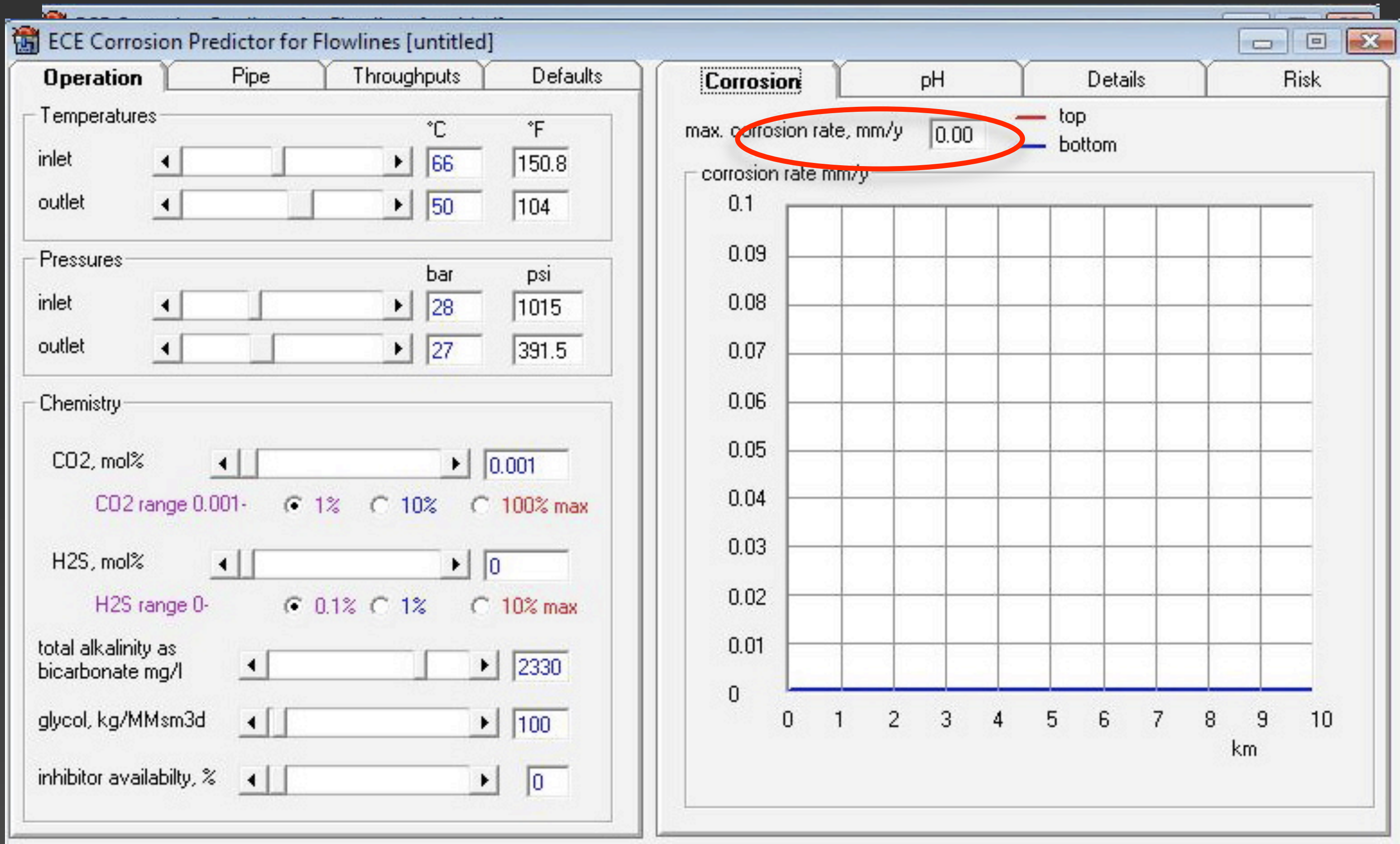


Activities
JULY AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Project
Application of corrosion prediction software to optimize material selection in offshore facilities.
PLANNING - 1st SEMESTER
Selection of project title / prepare and submit proposal
Preliminary research work
Prepare and submit preliminary report
Project work
Submission of Progress Report
Seminar (compulsory)
Project work continues
Submission of Interim Report Final Draft
Oral Presentation
PLANNING - 2nd SEMESTER
Project Work Continue
Submission of Progress Report 1
Project Work Continue
Submission of Progress Report 2
Seminar (compulsory)
Project work continue
Poster Exhibition
Submission of Dissertation (soft bound)
Oral Presentation
Submission of Project Dissertation (Hard Bound)
MID SEMESTER BREAK
STUDY WEEK
EXAM WEEK
END SEMESTER BREAK
MID SEMSESTER BREAK
STUDY WEEK
EXAM WEEK

ECE4

Results

Design and operational stage comparison output.

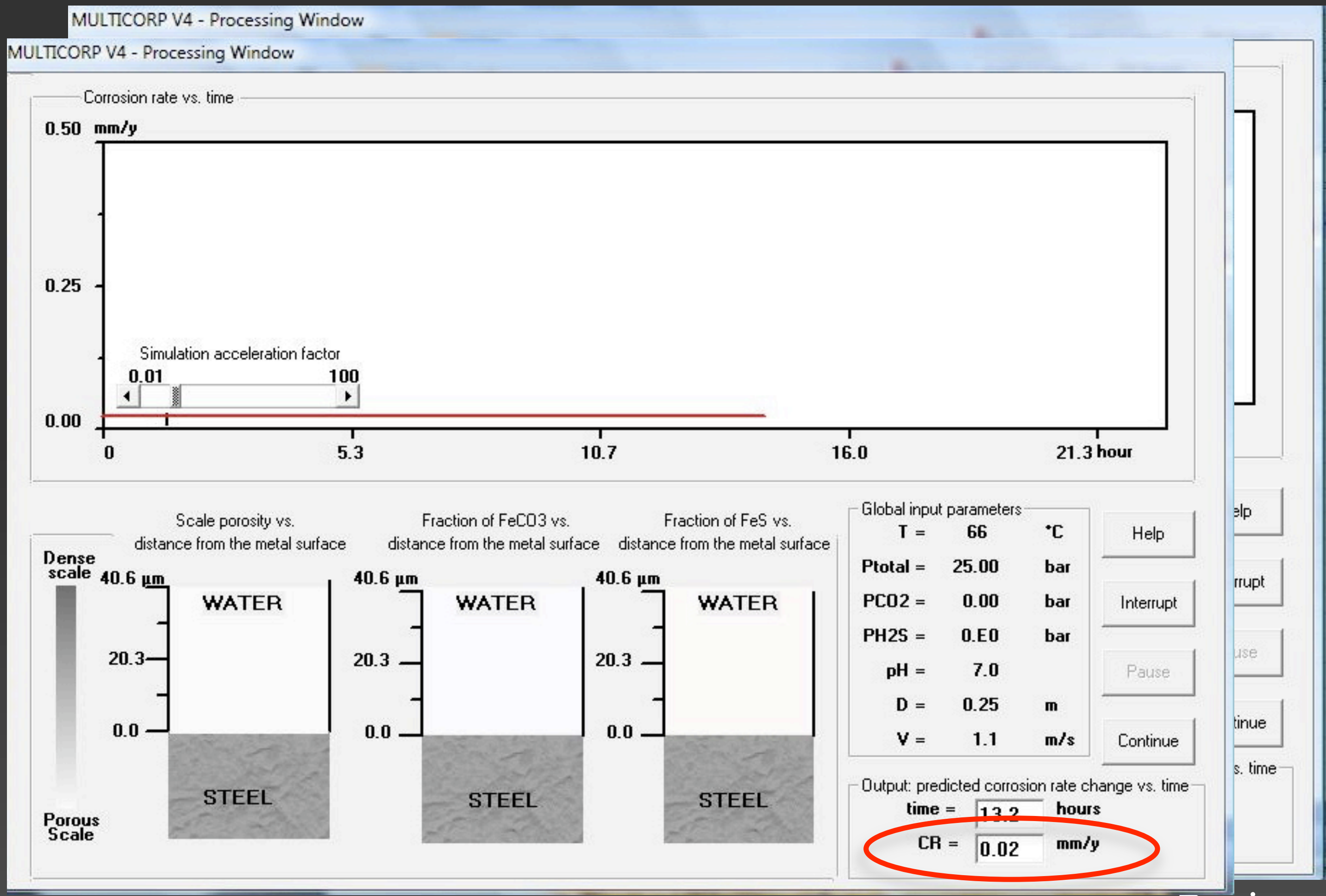


Design = 0 mm/yr

Operational = 0 mm/yr

MULTICORP

Design and operational stage comparison output.



Design = 0.13 mm/yr

Operational = 0.02 mm/yr

Discussions

Design and operation stage predictions. (ECE4)

Field	Corrosion rate, mm/year (ECE4)	
	Design	Operation
Field B	0	0
Field J	0.250	0.160

Design and operation stage predictions. (MULTICORP)

Field	Corrosion rate, mm/year (MULTICORP)	
	Design	Operation
Field B	0.130	0.020
Field J	0.080	0.018

ECE4 - B Field		
Parameters	Value	
	Design	Operation
Temperature (deg C)		
Inlet	70	66
Outlet	30	50
Pressure (bar)		
Inlet	20	28
Outlet	7	27
CO_2 mol %	0.04	0.001
H_2S mol %	-	0
Production flow rates		
Crude (m^3/day)	435	1000
Gas (MMscfd)	0.2	0
Water (m^3/day)	2390	2660
API gravity	30	39
Alkalinity as bicarbonate (ppm)	-	2330
Water cut (%)	85	68
Corrosion rate (mm/y)	0	0

MULTICORP – B Field		
Parameters	Value	
	Design	Operation
Temperature (deg C)		
Inlet	70	66
Outlet	30	50
Pressure (bar)		
Inlet	20	28
Outlet	7	27
CO_2 mol %	0.04	0.001
H_2S mol %	-	0
Production flow rates		
Crude (m^3/day)	435	2186.3
Gas (MMscfd)	0.2	0
Water (m^3/day)	2390	512
API gravity	30	39
Alkalinity as bicarbonate (ppm)	0	3600
Sulphates (ppm)	0	98
Chlorides (ppm)	0	13000
Water cut (%)	85	68
Oil density (kg/m^3)	780	793.7
Oil viscosity ($N.s/m^2$)	-	0.0013
Velocity (m/s)	-	1.158
Corrosion rate (mm/y)	0.13	0.02

For field J, data from offshore ultrasonic test shows 0.1 mm thickness loss (after 7 years of service). Initial thickness =12 mm.

CR estimated = 0.014 mm/y

Reliability of models with values from ultrasonic test.

ECE4 = 0.16 mm/y	MULTICORP = 0.018 mm/y
(>100 percent difference)	(+- 29 percent difference - operation)

MULTICORP produces more accurate result due to its consideration of few critical factors e.g. presence of carbonates, sulphates and velocity of fluids.

comparisons:

Parameters	ECE4	MULTICORP
CO_2 mole %	✓	✓
H_2S mole %	✓	✓
O_2 in water	–	–
Acetic acid in water	–	✓
Pressure	✓	✓
Temperature	✓	✓
Gas flow rate	✓	✓
Oil flow rate	✓	✓
Water flow rate	✓	✓
Internal diameter	✓	✓
Pipe length	✓	✓
Bicarbonates	–	✓
Sulphates	–	✓
Chlorides	–	✓
Dissolved iron in water	–	✓
API gravity	✓	✓
Oil density	–	✓
Oil viscosity	–	✓
Water density	–	✓
Water viscosity	–	✓
pH	✓	✓
CO_2 partial pressure	–	–
Oil velocity	–	✓
Water velocity	–	✓
Water cut	✓	✓

← MULTICORP takes into consideration the effect of acetic acid in water.

← Bicarbonates, sulphates, chlorides effects.

← Oil & water density and viscosity.

← Oil & water velocity.

CO_2/H_2S

In CO_2/H_2S corrosion of mild steel, both iron carbonate and iron sulfide layers can form on the steel surface.

Only CO_2 presence – pH dependence is small. IF water is present, form H_2CO_3 – corrosive to alloy and CS.

No H_2S, at high temperature, high pH – form $FeCO_3$ (protective layer).

Flow rate

Corrosion rate increases with velocity. Strips away protective films.

pH

Dissolved CO_2 or H_2S that contribute significantly to a lower pH.

CO_2 corrosion mechanism - different to that of strong acids like HCl.

CO_2 corrosion direct reduce of H_2CO_3 to HCO_3^- rather than reduction of H^+ ions (carbonic acid corrosion much more corrosive).

Effect of acetic acid:

Corrosion rate increases gradually with the concentration of acetic acid.

Corrosion rate is higher at higher temperature.

Reaction is retarded by an increase in pH due to less hydrogen ions being available for reduction.

The undissociated acetic acid in the solution affects corrosion.

Under low condensation rate, presence of acetic acid (low concentrations) is enough to almost double the corrosion rate.

CO_2 corrosion of mild steel is always associated with the formation and breakdown of protective iron carbonate films.

The chemical and electrochemical equation involves in the CO_2 corrosion in the presence of acetic acid:

Water dissociation
$H_2O_{(l)} \longleftrightarrow H^+_{(aq)} + OH^-_{(aq)}$

Carbon dioxide dissolution
$CO_{2\,(g)} \longleftrightarrow CO_{2(aq)}$

Carbon dioxide hydration
$CO_{2\,(aq)} + H_2O_{(l)} \longleftrightarrow H_2CO_{3\,(aq)}$

Carbonic acid dissociation
$H_2CO_{3\,(aq)} \longleftrightarrow H^+_{(aq)} + HCO_3^-{}_{(aq)}$

Bi-carbonate ion dissociation
$HCO_3^-{}_{(aq)} \longleftrightarrow H^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

Acetic acid (HAc) dissociation
$CH_3COOH_{(aq)} \longleftrightarrow H^+_{(aq)} + CH_3COO^-_{(aq)}$

Proton reduction
$2H^+_{(aq)} + 2e^- \rightarrow H_{2\,(g)}$

Carbonic acid reduction
$2H_2CO_{3\,(aq)} + 2e^- \rightarrow 2HCO_3^-{}_{(aq)} + H_{2\,(g)}$

Undissociated acetic acid
$2CH_3COOH_{(aq)} + 2e^- \rightarrow 2CH_3COO^-_{(aq)} + H_{2\,(g)}$

Iron oxidation
$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$

Iron carbonate precipitation
$Fe^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow FeCO_{3\,(s)}$

Water corrosivity increased by dissolved gases, acids, salts, strong bases, entrained abrasives, high temperature, fluctuating pressure, cavitation, or impingement.

Fast-moving water carry dissolved metal ions away from corroding areas before the dissolved ions can be precipitated as protective layers.

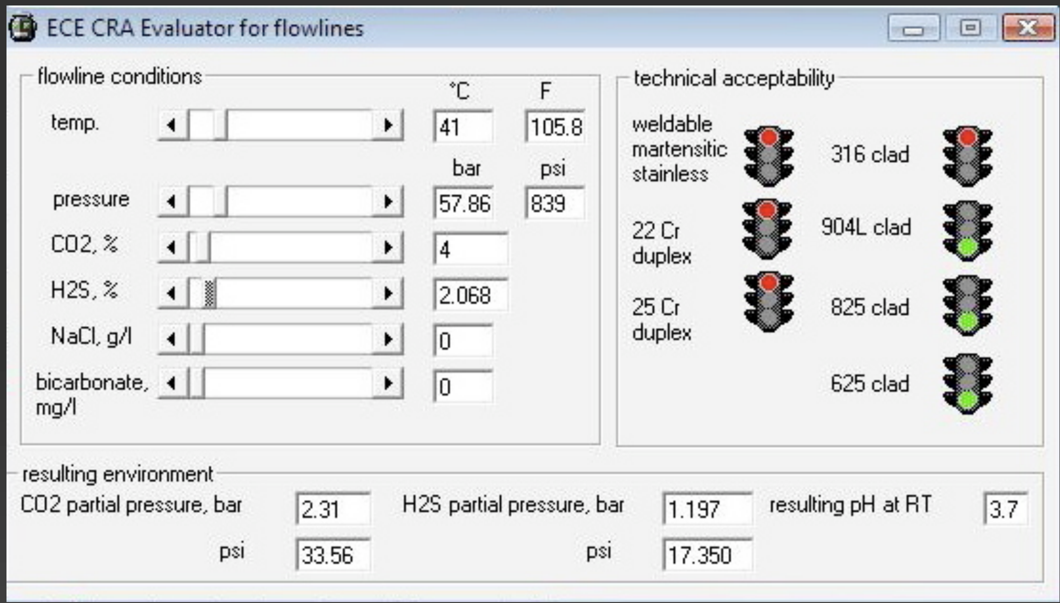
Erosion-corrosion - a combination of pitting and erosion.

Particles in a liquid or gas have effect on a metal surface - removal of protective surface films (protective oxide films).

Temperature increases, the protective films may become more soluble and/or less resistant to scouring.

Turbulent condition can cause an increase in corrosion rates or new forms and modes of corrosion.

ECE4 CRA Evaluation Tool



Even at low temperature (around 40°C), one by one material starts to fail its technical acceptability in the case of H_2S presence in CO_2 environment.

Conclusions

Amount (required) data used during the design and operation stage were dissimilar. Influence predictions.

Presence of CO_2, H_2S, free water, acetic acid and presence of carbonate content in the production highly affect the corrosion prediction.

Other factors; Inhibition type, flow velocity, flow type, pH, temperature etc.

ECE4 CRA evaluation tool make ease material selection process. Predicted CR.

MULTICORP considers critical parameters. Result more accurate.

Many more factors that can affect the corrosion prediction. Big impact to the material selection process and the overall life cycle of the project.

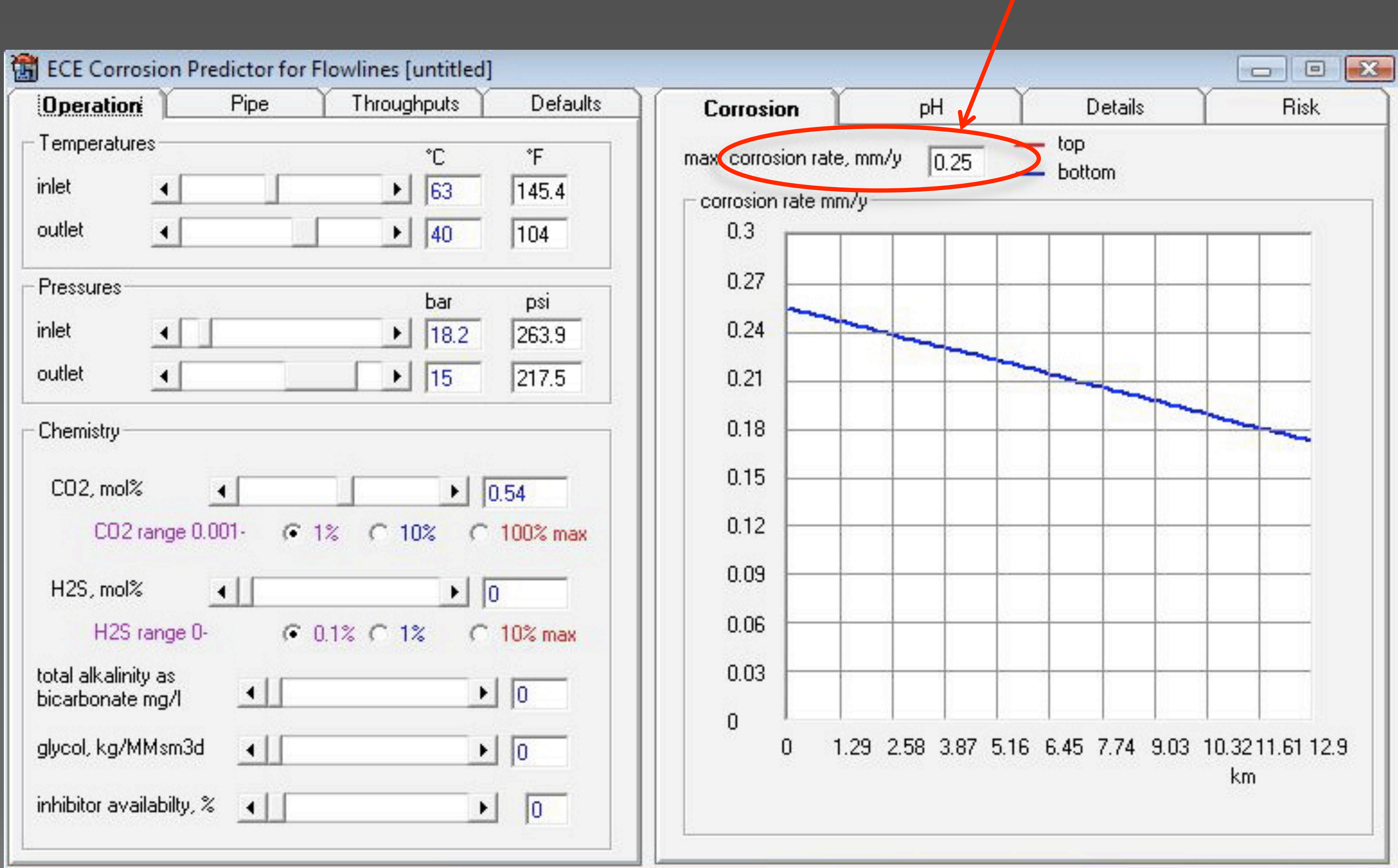
Recommendations

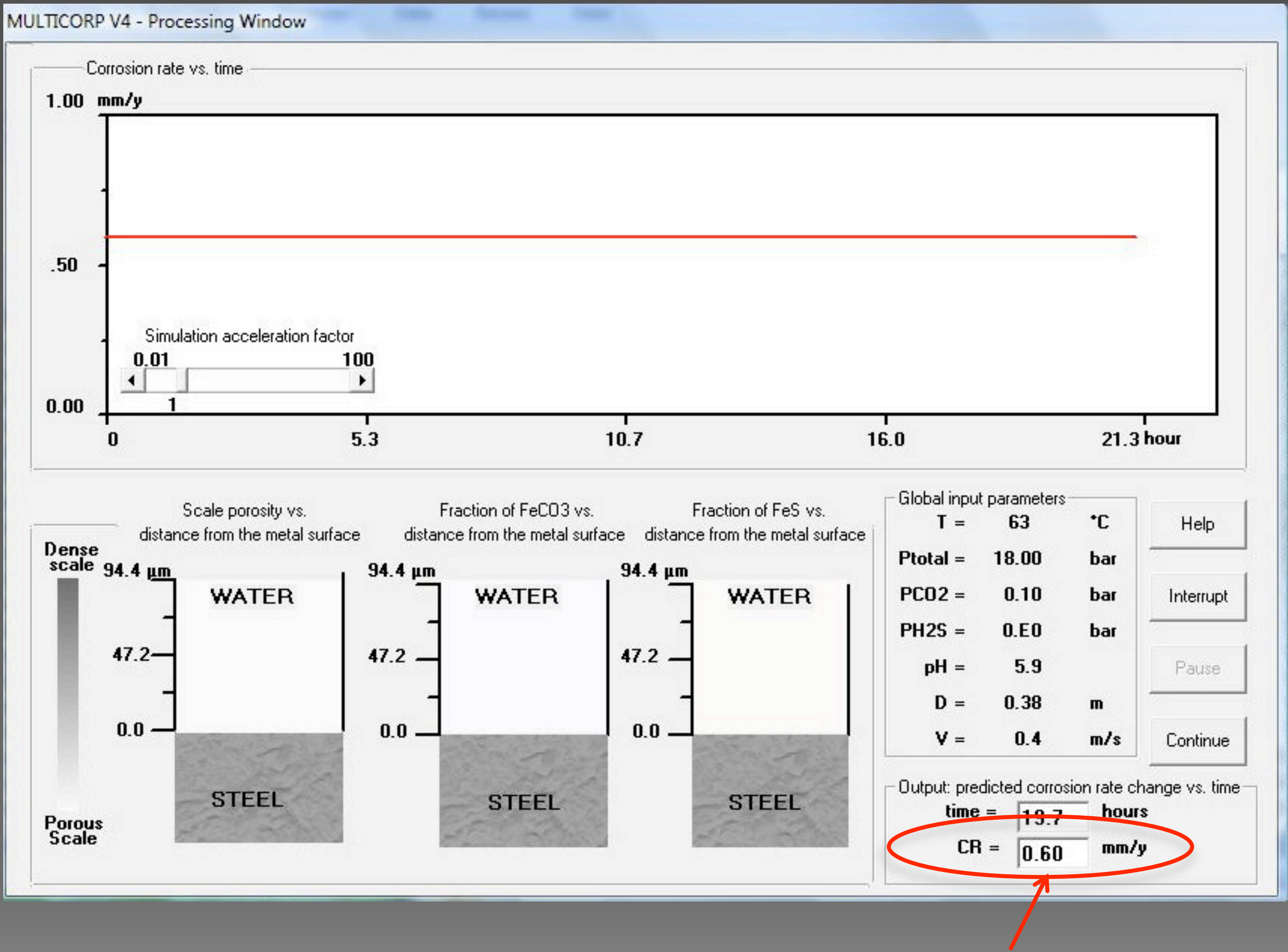
Study further other factors that can affect the corrosion prediction besides that were discussed above.

Model different field data using both ECE4 and MULTICORP considering more parameters.

Understanding the proper functions of the models and knowing the vital input data could help PETRONAS less rely on the consultant to perform the corrosion prediction and this could assist in producing outputs with a more accurate result in selecting materials.

ECE4 CR = 0.25 mm/yr





MULTICORP CR = 0.6 mm/yr