CO_2 Capture Project

Material selection for CO_2 transportation

Marion Seiersten and Kjell Ove Kongshaug
Institute for Energy Technology

Funded by the CO_2 Capture Project and the Research Council of Norway

October 10, 2003

This presentation was prepared with the support of the Research Council of Norway /Klimatek under Award No. 144737/228. Any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the Klimatek.

www.co2captureproject.org

Our project

- Corrosion of carbon steel
  - Increase design confidence by establishing corrosion mechanism at high CO_2 pressures
    - Mechanisms for CO_2 dissolution in water.
    - Electrochemical reaction mechanisms.
  - What are the effects of glycol at high CO_2 pressures.
  - Can inhibitors be used, and if so what types are most effective.

Our project cont.

- Corrosion of other steels and CRAs
  - Effect of process chemicals and other components.
- Determine the water solubility in CO_2 – LPG mixtures
  - Find solubility curves
  - Make a fundament for improved EOS for CO_2-LPG
- Most importance given to corrosion of C-steel

Why corrosion in CO_2 systems?

- Water
  - CO_2 and water form carbonic acid which is corrosive.
  - Water may condense/precipitate from the CO_2 phase.
  - Accidental/unforeseen water carry over.
- Contaminations
  - H_2S
  - Well chemicals
  - SO_x and NO_x
  - Process chemicals

(H_2S, Well chemicals:) CO_2 separated from natural gas

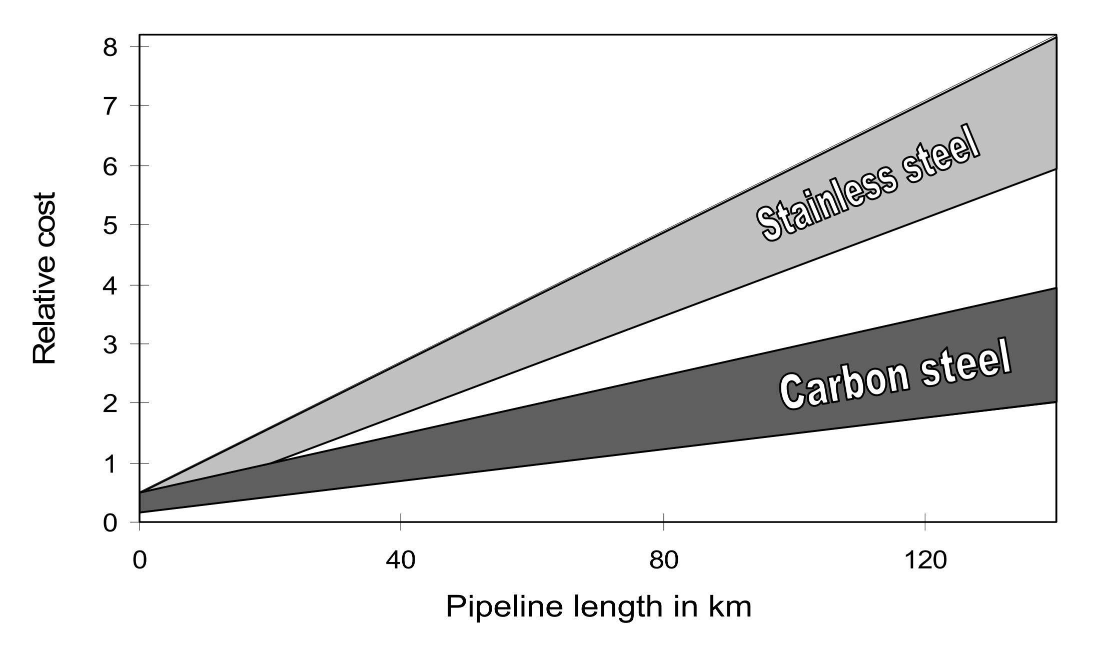
(SO_x and NO_x, Process chemicals:) CO_2 separated from exhaust gas

The need of corrosion assessments

- Nearly 30 years of experience with carbon steel pipelines for CO_2 transportation. The corrosion problems have been small. Why bother about corrosion?
- Because:
  - Until now all CO_2 transportation pipelines have been dry, in the future some will be wet.
    - Combined transportation of liquid CO_2, condensate and free water using an existing low alloy C-steel pipeline has been considered in the North Sea and the corrosion experiments showed that it may be feasible (Sven M. Hesjevik et al., CORROSION NACE, 2003).
  - The data that are available is insufficient for corrosion assessments at CO_2 pressures above 20 bar.

How can this work reduce CO_2 transportation costs?

- Because it may make it possible to:
  - Reduce drying requirements when carbon steel is used.
  - Combine hydrate and corrosion inhibition and use green inhibition methods.
  - Replace corrosion resistant alloys with carbon steel.



Benefits to modelling

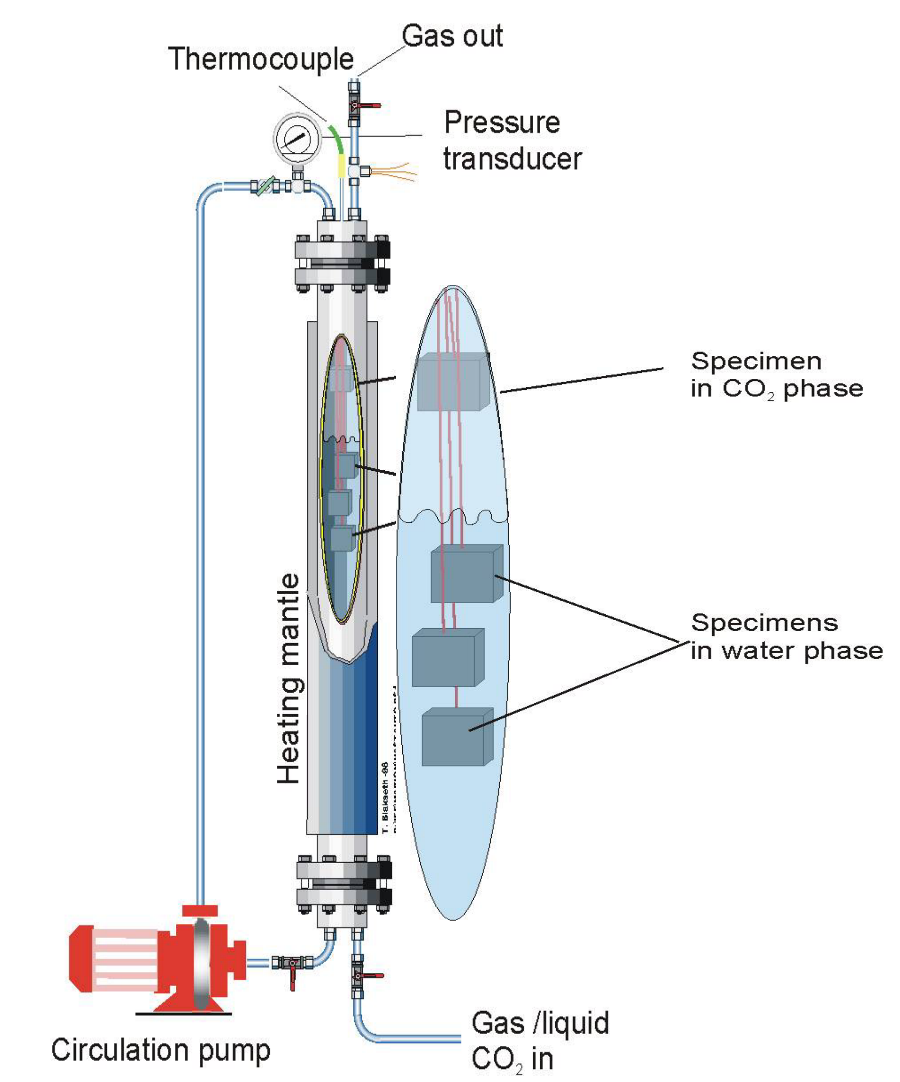
- The project contributes to the development of reliable corrosion models that can be used at high CO_2 pressures.
- Why corrosion modelling?
  - To be able to select the best material for the job.
  - Select cost effective corrosion mitigation.
  - Calculate corrosion allowances.

CO_2 corrosion models

	Developed by	T/°C min	T/°C max	P_{max} / bar	P_{CO2} / bar min	P_{CO2} / bar max
de Waard	de Waard and coworkers (Shell, IFE) Published	0	140			10
HYDROCOR	Shell	0	150	200		20
Cassandra 98	BP		140	200		10
NORSOK	Hydro, Saga, Statoil (IFE data)	20	150	1000		10
CORMED	Elf		120			
LIPUCOR	Total	20	150	250		50
KSC Model	IFE (JIP)	5	150	200	0.1	20
Tulsa model	University of Tulsa	38	116			17
PREDICT	InterCorr International	20	200			100
Ohio model	Corrosion in Multiphase Systems Center at Ohio University	10	110	20		20
SweetCor	Shell	5	120		0.2	170

CO_2 corrosion models

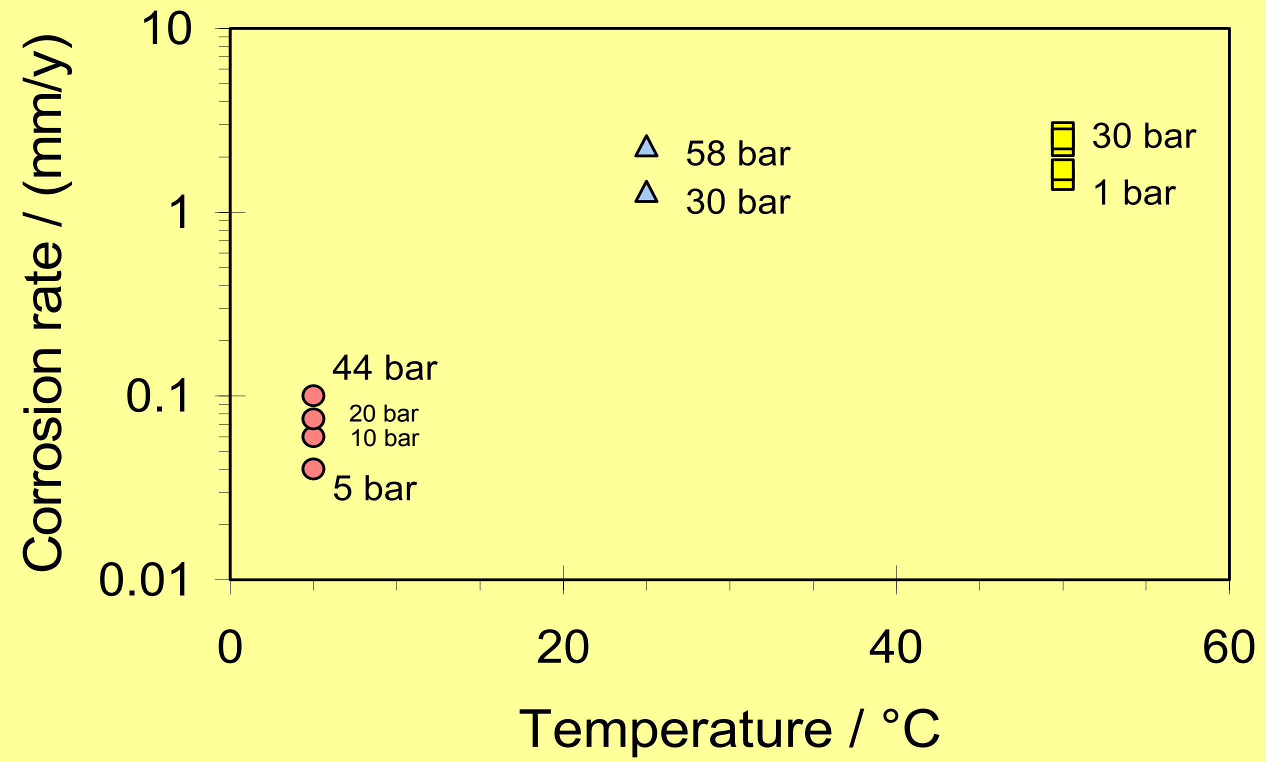
- An assessment of corrosion models carried out by IFE (R. Nyborg, JIP 2000) showed that:
  - With two exceptions the models are restricted to CO_2 partial pressures lower than 50 bar, most of them are only valid at $p_{CO2}<20$ bar.
  - A few cases (mostly dry) are included in SweetCorr.
  - The high pressure part of PREDICT is not well documented.
- There are a need for corrosion data at high CO_2 pressures.



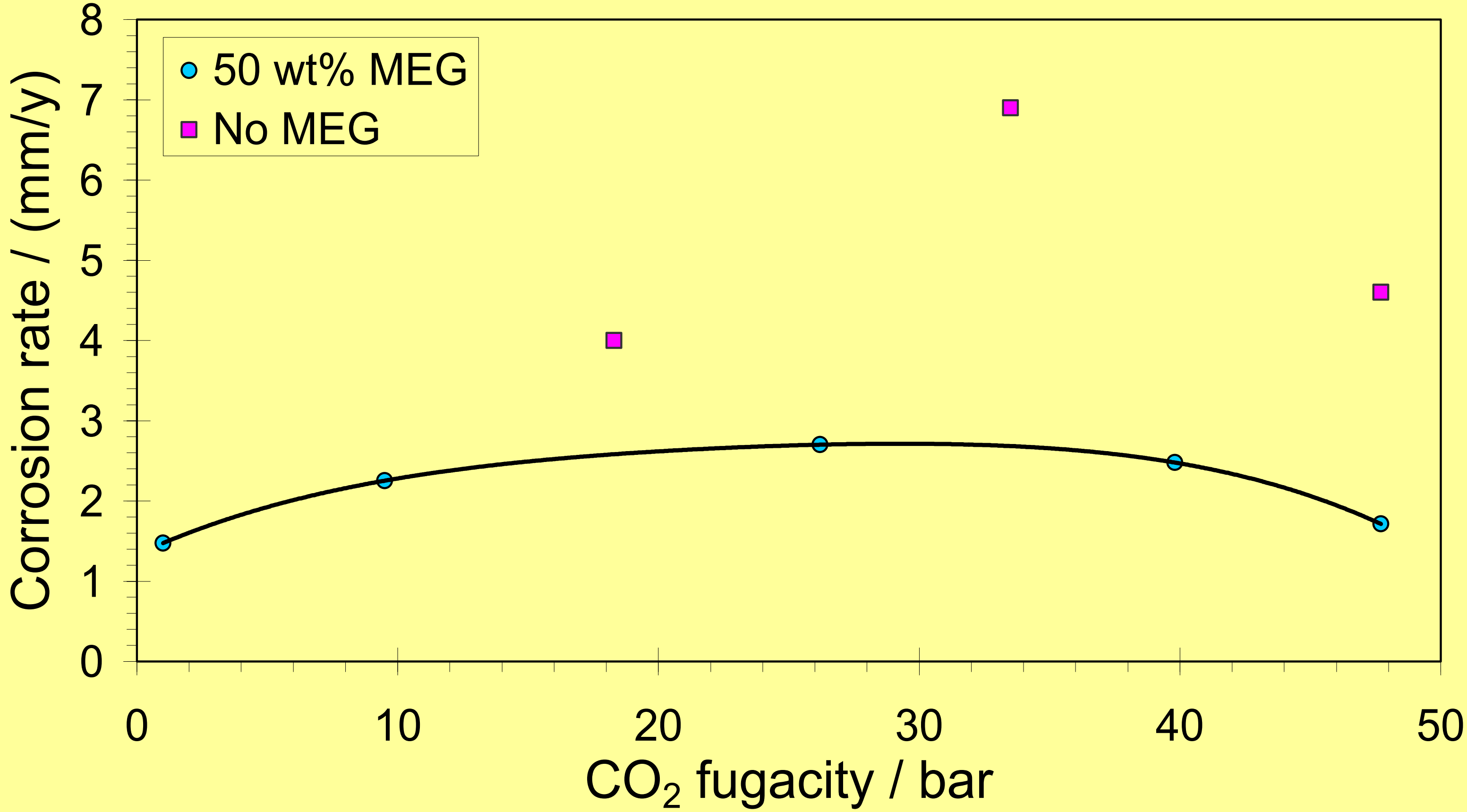
Experiments

- Temperature: 5, 25 and 50 °C.
- CO_2 pressure: 5-80 bar.
- Solution:
  - Distilled water
  - Hydrate inhibitor: Mono Ethylene Glycol (MEG), 0 / 50 wt%.
  - Salt: 1% NaCl.
- Material: Carbon steel X-65
- Test duration: 5-20 days.
- Till now: 20 experiments in the project.

Results – 50 wt% MEG (Monoethylen glycol)

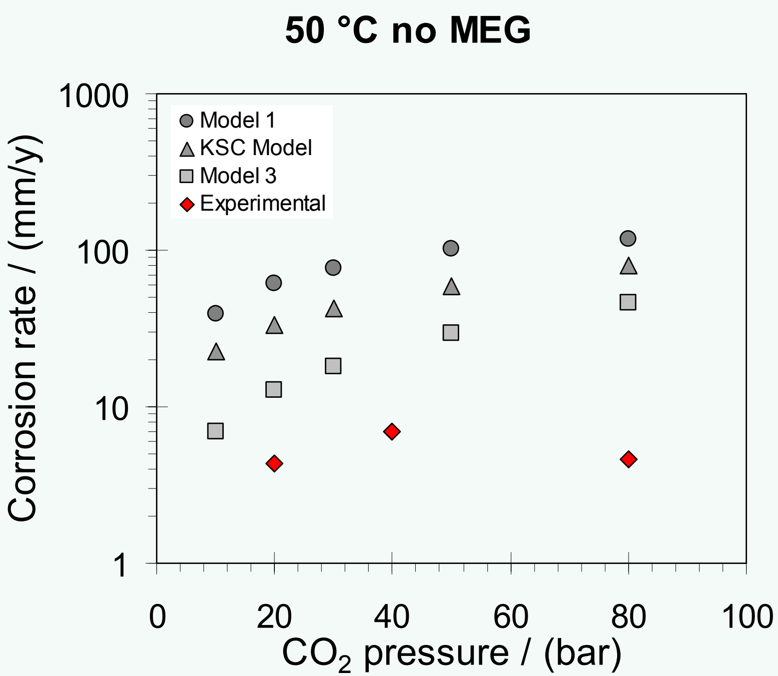


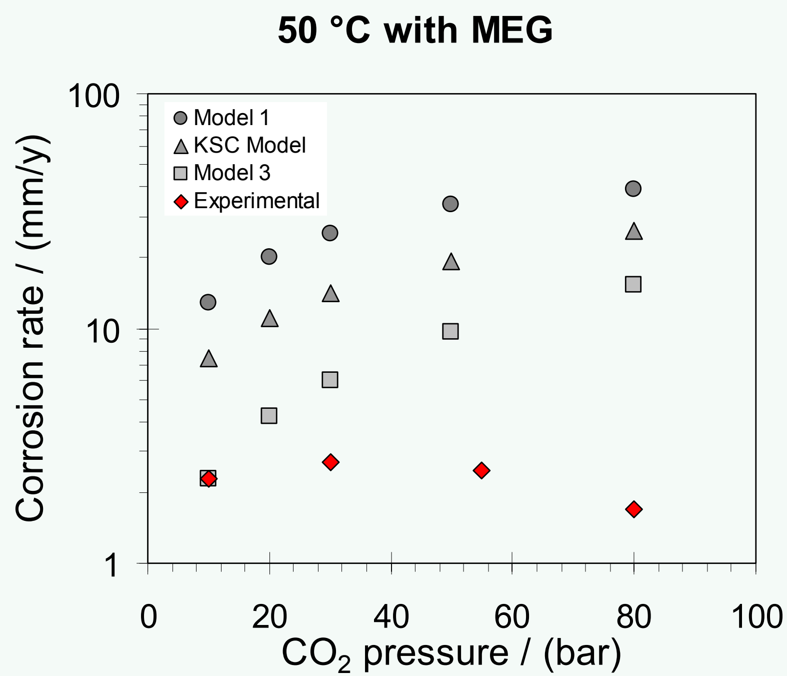
Results 50 °C



Corrosion rate / (mm/y)
8
7
6
5
4
3
2
1
0
50 wt% MEG
No MEG
0
10
20
30
40
50
CO2 fugacity / bar

Comparison with model calculations

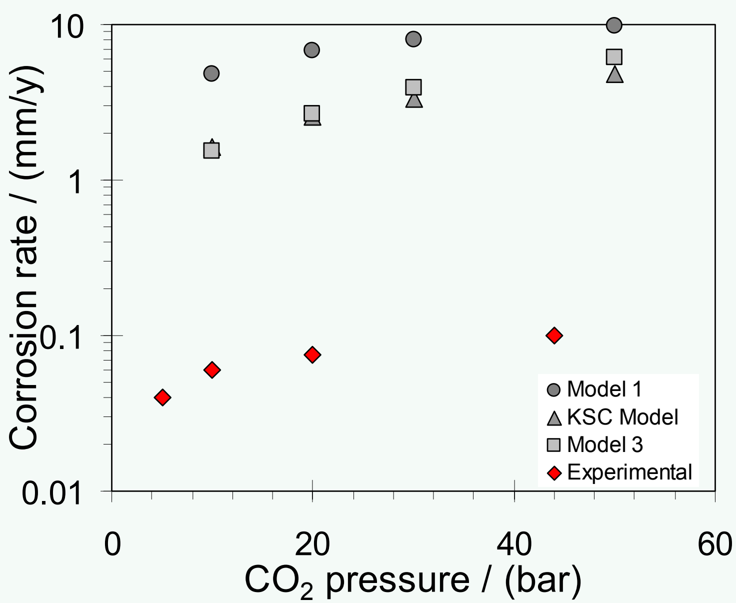




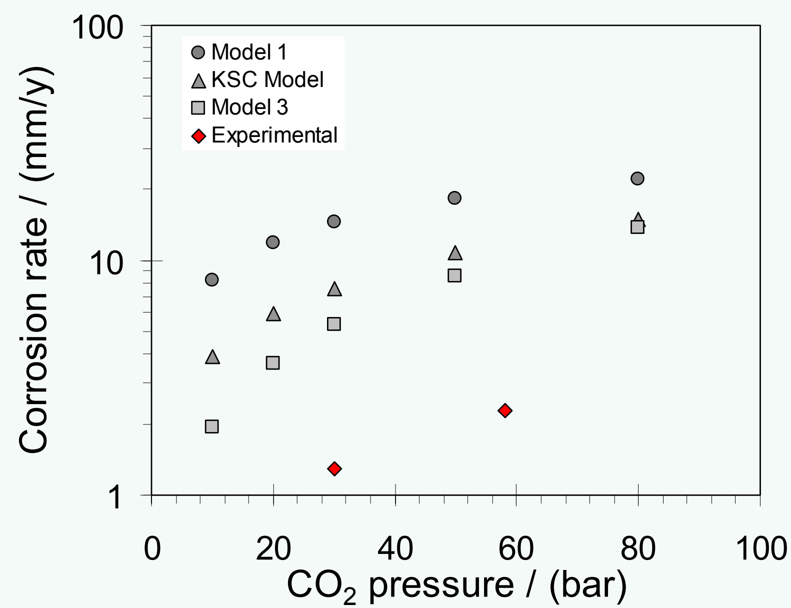
Measurements compared to model extrapolations (the models are not verified at p_{CO2}>20 bar

Comparison with model calculations, cont.

5 °C 50% MEG

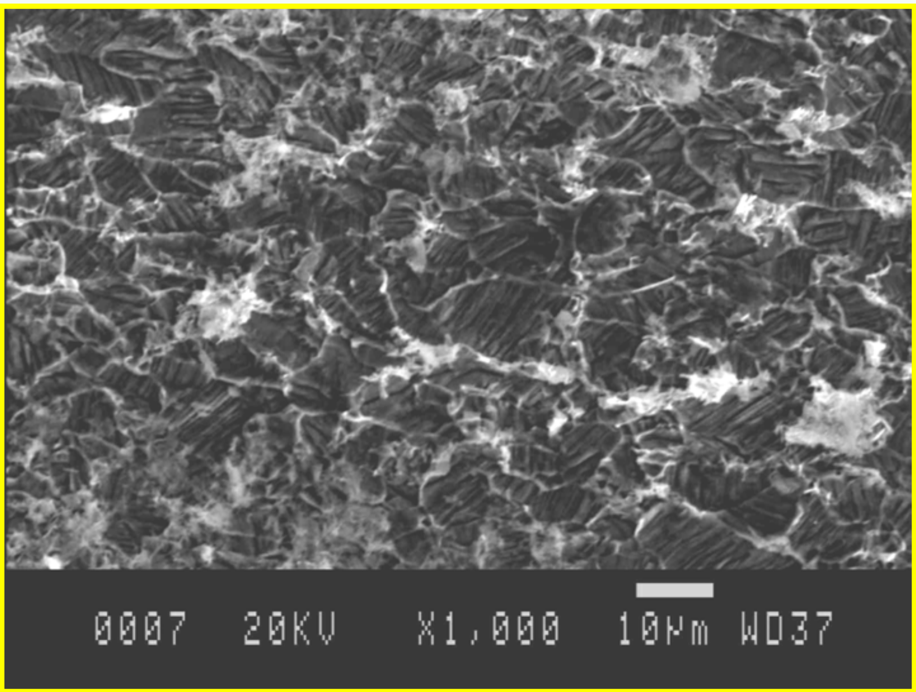


25 °C 50% MEG

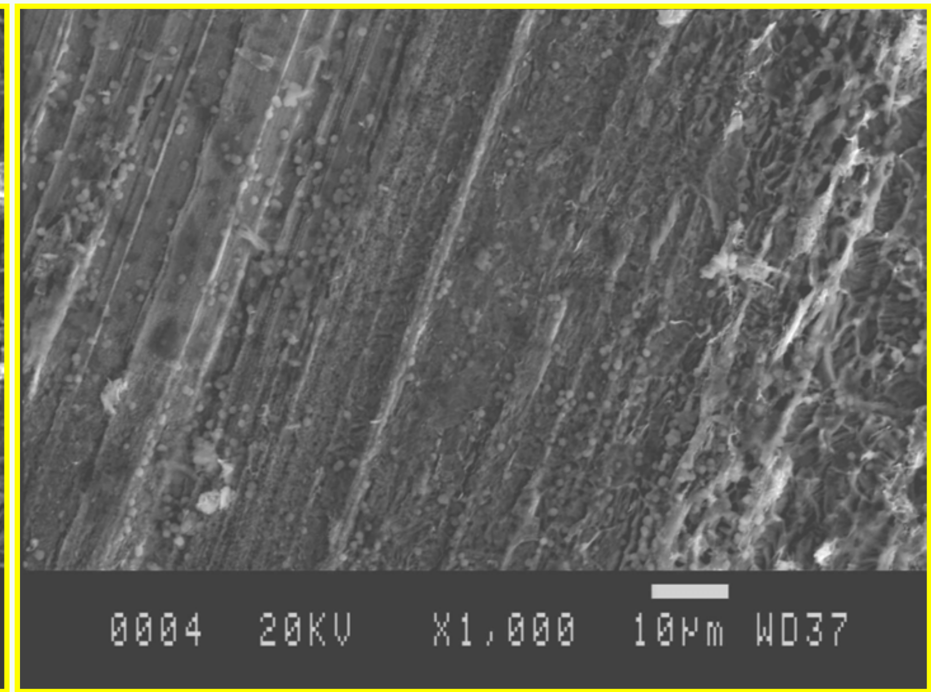


Measurements compared to model extrapolations (the models are not verified at p_{CO2}>20 bar

Typical surfaces



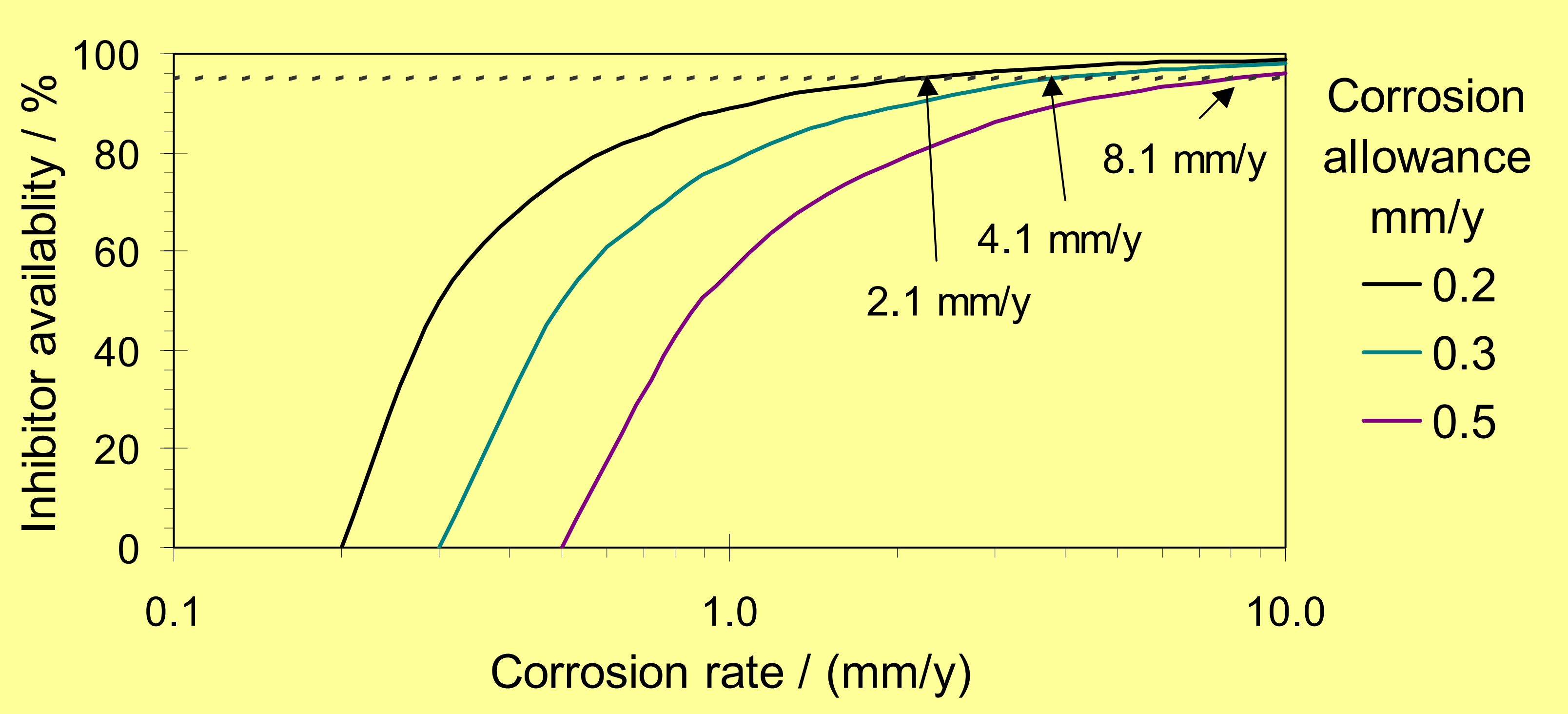
5°C, 44 bar CO_2



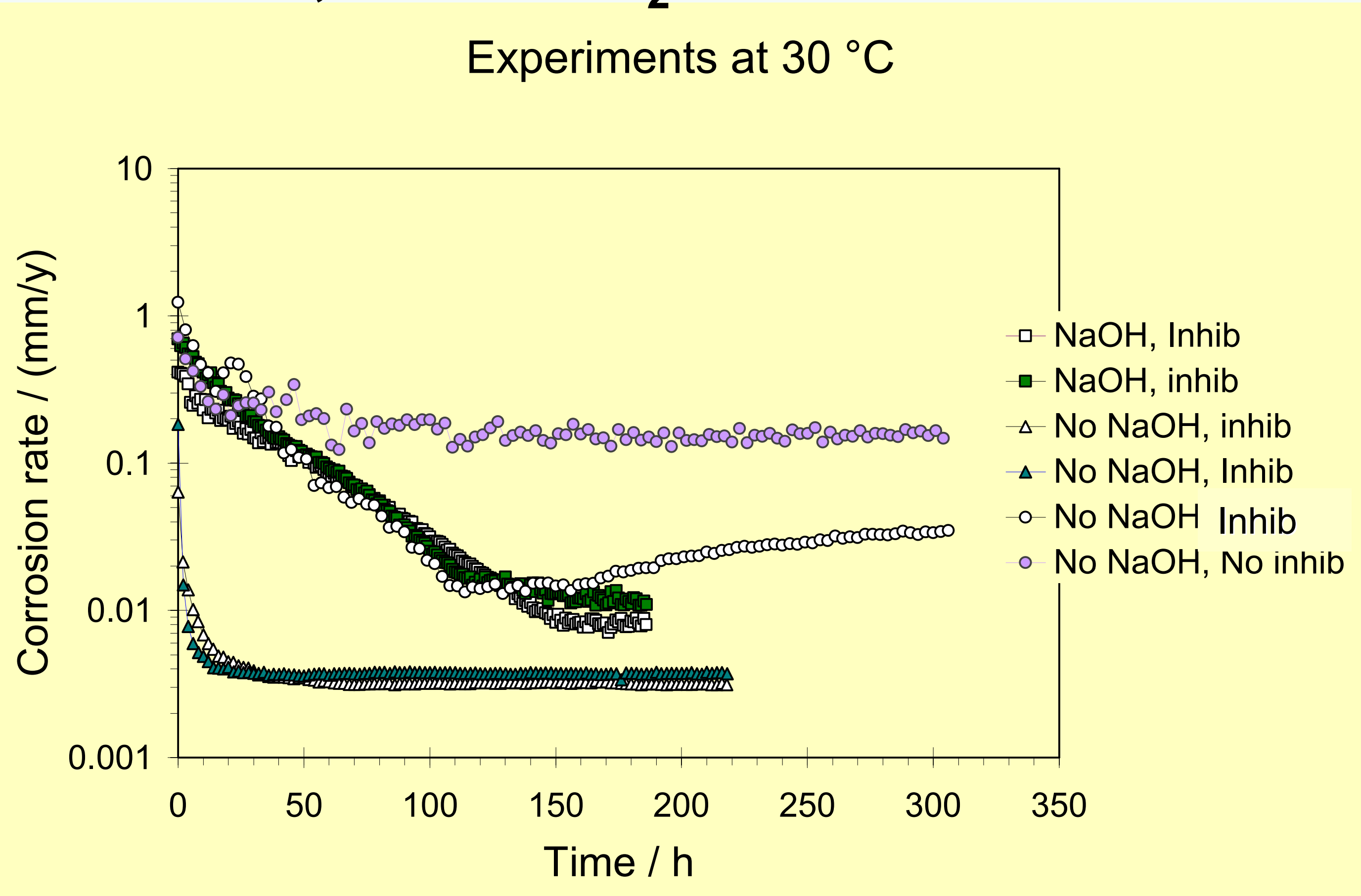
5°C, 35 bar CO_2

No pitting observed on any of the test specimens.

Consequences of the findings



Possible to achieve 0.1 mm/y with inhibitor? Results – 30°C, 72 bar CO_2



Conclusions

- The results show that the maximum corrosion rate for carbon steel (X-65) at 5 to 50 °C and CO_2 pressure 10 to 80 bar in 50 wt% MEG is 3 mm/y.
- The corrosion rate without MEG is maximum 7 mm/y at 50 °C and 10-80 bar.
- At 50 °C, the corrosion rate has a maximum as function of CO_2 pressure at about 30-40 bar both with and without MEG.
- Consequences of the findings:
  - It is possible to inhibit corrosion in wet CO_2 pipelines below 50 °C, but the inhibitor availability must be high.

Acknowledgement

- Thanks to Klimatek and CCP for supporting the project.
- Thanks to Statoil that allowed the use of data from Statoil granted investigations in this project.