<u>EUROPEAN FEDERATION OF CORROSION</u>
<u>Working Party 13 - Corrosion In Oil & Gas</u>

MOM of the Stockholm Business Party Meeting
Thursday 9th September 2011
9:00 – 13:00,
Stockholm International Fair
Room 3

1. Post meeting note:

The Antikor prize for the best lecture by a young presenter was awarded to M. Hörstemeier (Salzgitter Mannesman Forschung GmbH) for the following paper:

"Sulfide Stress cracking Resistance of High Strength Low Alloy Steels for High H_2S Pressure Wells".

Professor Muratov of Antikor awarded a certificate and a cash prize to Michaela.

T. Chevrot, Chairman of WP13 opened the meeting at 9:00 and welcomed the members of WP13 attending the meeting.

2. General Information

EFC WP13 Chairmanship

Thierry Chevrot, current Chairman, is now moving position within TOTAL and as agreed during the last meeting in Moscow, he is replaced by Michel Bonis (TOTAL) as WP13 chairman as of 11/09/2011.

Jean Kittel (IFP Energies Nouvelles) will remain as vice-chairman.

It is suggested that Shell could take over the chairmanship of WP13 in 2014, provided that a suitable candidate is identified.

Eurocorr 2012

Eurocorr 2012 conference will be held 9th to 13th September, 2012 in Istanbul. The following sessions / workshops will be organized:
:

- A joint workshop on Microbial Induced Corrosion, jointly organized by WP 10 and WP13,

- Sour service session: Organized jointly with NACE TEG 374X “Materials for Oil & Gas” represented by Bob Badrak (NACE).
- Corrosion inhibition and monitoring session: Organized jointly with NACE STG 61 “Corrosion and scale inhibition” represented by Mohsen Achour (NACE).

The traditional prize offered by, Antikor for the best paper by a presenter less than 35 years old will also be awarded during the conference.

NACE 2012 – Salt Lake City

Corrosion 2012 will be held in Salt Lake City 11th to 15th March 2012. Two joint sessions between NACE and EFC will be organized:

- TEG 374x / WP13 on Materials in Oil & Gas: subjects for informal discussions should be sent to Richard Thompson RMTH@chevron.com or to Michel Bonis Michel.bonis@total.com
- STG61 WP13 on corrosion and scale inhibition: subjects for informal discussions should be sent to Mohsen Achour (Mohsen.H.Achour@conocophillips) or to Michel Bonis Michel.bonis@total.com

Joint work with WP 15 “Corrosion in the refinery industry”

A call for joint work on further revision of the following EFC greenbooks was made by J. Kittel on behalf of F. Ropital, cheirman of WP15:

- EFC N°46: “Amine Unit Corrosion in Refineries”
- EFC N° 55: “Corrosion Under Insulation (CUI) Guidelines”

Anybody who would like to participate or get more information on the above should contact francois.ropital@ifpen.fr

3. Progress of active Working Groups

“Recommended Practice for Pipeline Corrosion Management in Oil and Gas production and Transportation”, T. Chevrot, TOTAL

Thierry Chevrot announced that the work on this document was now completed and would be published as a greenbook before the end of the year at best. He also took the opportunity to thank again all participants and reviewers for their motivation and hard work which resulted in the document being written in less than two years.

<u>Post meeting note:</u> The document will be published and available around February 2012 as EFC N° 64.

Laboratory testing of materials to qualify clear brine fluids for use in wells, J. Martin, BP

T. Chevrot emphasized that the draft of this document (see Appendix 1) is currently not suitable for publication by EFC. This is due to:

- The move of the working group's chair, which somehow stalled progress,
- The six pages document is too general and would need to be more detailed to enhance its value to users.

It is decided that the work carried out for the last three years on this topic should not be lost. Therefore, a working group will be formed again to take this work forward and present a version suitable for publication by EFC in 2012.

T. Cassagne (TOTAL), J. Martin (BP), and P. Nice (Statoil) are in charge of reviving the working group.

4. Environmentally Assisted Cracking

CEFRACOR - Corrosion in O&G industries Committee (CIPG) - Subgroup WG 5, J. Kittel, IFP Energies Nouvelles

Jean Kittel gave a few results and preliminary conclusions obtained from the work carried out within the Centre Français de l'Anticorrosion (CEFRACOR).

The presentation in Appendix 2 shows that environmental cracking test results greatly depend on materials sampling, specimen and solution preparation, and test procedure. Some gaps in the current Internationla Standards have been evidenced and need to be studied further.

This French working group would like to share these results with other EFC members and organize a workshop to define the way forward.

Working Group on 4 point bend testing – Status, S. Bond, TWI

Stuart Bond gave a presentation on similar work discussed for the last two years, but focused on test method NACE TM 0177 (See Appendix 3).

In particular, issues with mechanical properties determination, load, edge effects, testing at high temperature, and acceptance criteria have been raised and need to be discussed with a larger group of WP13 members before EFC 16 and EFC 17 may be revised.

Conclusion on environmental cracking

It is felt that the data and facts given in both presentations need to be shared and discussed with all interested parties. S. Bond will set up a meeting during which all interested parties will be invited to bring available data for sharing. The name and contact details for people who are interested were taken.(about 15 people).

The next step will be defined following this initial meeting.

5. Internal Corrosion

Corrosion in Dense Phase CO2 Transport and Storage
A.Dugstad, Institutt for Energy Technology (IFE)

Arne Dugstad presented some of the questions which are rising from work being currently carried out at IFE with regards to pipelines for CO_2 transport.

In particular the need to define safe operating windows for such pipelines before CO_2 capture plants are designed was reminded to all as this is not always the case in reality.

Arne also identified significant gaps in studies carried out up to now:

- Few studies for $p(CO_2) > 50$ bar
- Less than 10 publications presenting data with flue gas impurities
- Not much focus on corrosion in the CO_2 Capture community
- CO_2 transport studies have mainly been focused on Enhanced Oil Recovery (EOR), therefore using CO_2 without contaminants.
- What is the effect of impurities on the water limit for no/acceptable corrosion and what are the consequences of accidental water ingress?

IFE and DNV embarked on the CO2-Pipetrans phases 1&2 Project (2007- 2012) to answer some of these gaps. IFE also started the KDC JIP (2011 – 2014) on dense phase CO_2 and impurities. Both projects are presented and discussed in Arne’s presentation in Appendix 4.

6. Corrosion Control by Chemicals

Oil Soluble Inhibitors – Developing an Acceptable Testing Methodology
S. Turgoose, Intertek

During the joint NACE/EFC meeting at Corrosion 2011 in Houston it was agreed that there were no universally accepted testing protocols for oil soluble inhibitors.

Following this, a working team (composed of Andrew MacDonald – Clariant , Alyn Jenkins – MISWACO, Mohsen Achour – ConocoPhillips, Yolanda De-Abreu – Nalco, and Graeme Dicken – Intertek CAPCIS acting as leader) was set up to develop guidelines for testing Oil Soluble Corrosion Inhibitors.

A questionnaire has been circulated amongst specialists to seek some initial input into the thinking and viewpoints relating to the selection of oil soluble products for service and their selection process. Steve presented a summary of the answers very few answers obtained (see Appendix 5). It was decided that the questionnaire should be re-formulated and tht it should be forwarded to Working Party 1, “Corrosion & Scale Inhibition” in order to increase the number of respondents.

Alternative Solutions to Biocides for MIC and Souring Control
M. Bonis, TOTAL

Michel Bonis made a presentation (Appendix 6), where he outlined the need for alternative solutions to traditional biocides due to future restrictions aiming at reducing the environmental impact of biocides.

Michel insisted that any new approach with regards to biocides would require simultaneously some efforts to develop appropriate monitoring methods.

WP13 will organize a halfday workshop jointly with Working Party 10 “Microbial Corrosion” during Eurocorr 2012 in Istanbul. The title of the workshop will be “New age of MIC Control?”.

Following this workshop, a more extensive work programme will be drawn if necessary.

7. AOB & Close of Meeting

No other business was brought by the attendees.

Before closing the meeting, Thierry Chevrot thanked again all members of Working Party 13 and former Chairman S. Olsen for having given him the opportunity to chair the group for the last 3 years, which has been a very interesting and rewarding experience.

Thierry Chevrot also wished good luck to Michel Bonis for his chairmanship of the group which no doubt will be successful.

Appendix 1

Laboratory testing of materials to qualify clear brine fluids for use in wells

Laboratory testing of materials to qualify clear brine fluids for use in wells

1 Introduction

To avoid corrosion related problems when using clear brine fluids, the use of materials compatibility and corrosion prequalification testing is important. These guidelines give information on the types and extent of expected corrosion mechanisms and advice on the requirements for materials compatibility and corrosion testing needed before considering a brine with no or limited field experience.
In this document, clear brines include completion, packer, workover and well suspension fluids. Clear drilling fluids are not included in the scope of this document.

2 Guidelines

All brines without previous adequate relevant testing or adequate relevant field experience should be tested. Any change in salt content, additives and/or substitution of chemicals may require additional testing. If chemical concentrations are modified then the need and requirement for any additional testing is subject to end user evaluation/approval. The brine make-up shall be defined in a written specification that identifies all components, compositional limits and controlled properties.

The testing may be divided into two stages, with different responsible parties for each stage;

1. Pre-qualification tests; to be undertaken by the Brine Vendor
2. Qualification Tests; to be undertaken by the Brine Vendor together with end user collaboration.

Both test stages will, in most cases, require a test pressure above atmospheric pressure. Autoclave testing should therefore be expected.

The pre-qualification tests will use a simple test set-up, aimed to identify chemicals which either;

- decompose under the simulated operating conditions, or
- cause corrosion and/or environment stress cracking (ESC) of materials commonly used downhole, ref Table 1.

Important parameters in the pre-qualification test will be temperature, pressure and brine chemicals/constituents, including pH.

The qualification testing should normally be undertaken after successful pre-qualification tests. The qualification testing will more accurately reproduce the expected operating conditions for specific applications and will assess the intended downhole materials. More detailed test methods will be used to more accurately evaluate both general and localised (pitting/crevice) corrosion, and ESC (including hydrogen embrittlement) of metallic materials.

All test specimen preparation and loading shall be in accordance with the following Standards (Ref Section 2.7~~3.3~~):

- Weight loss specimens: ASTM G1
- U-bend specimens: ASTM G30
- Tensile test specimens: ISO 8692-1
- SCC testing in accordance with ISO 15156 part 1-3.

2.1 Pre-qualification tests

This testing should be completed by the vendor prior to the brine being offered to the end user. The testing can be used to establish a recommended maximum temperature for the brine to avoid decomposition into products which may crack materials or accelerate corrosion. The testing should also ensure compatibility with commonly used metallic oilfield materials at this maximum temperature.

The testing should comprise thermal stability testing and materials testing, separately or together. Test requirements are shown in Table 1.

Common Test Parameters	**Requirement, All Tests**
Temperature	Test temperature should be higher than, or equal, to the intend~~t~~ed application temperature (to be stated by end user) See also Section 2.3
Brine and chemical additives	Industrial grades (i.e. similar to those to be used in the final product) shall be used. The full chemical package in accordance with the written specification shall be used in the test[1]
Test environments	Environment 1: No acid gas contamination and no forcible oxygen removal condition Environment 2: Gas contamination condition, the actual partial pressures of CO_2 and other gases anticipated in service should be used[2]
Exposure time (min)	90 days (minimum)
Material types[3]	• Low alloy steel (LAS) tubing/casing grade (110 ksi strength grade preferred) • 13Cr steel (e.g. L80) • 13Cr/5Ni/2Mo Super martensitic stainless steel (SMSS) (110ksi strength grade preferred) • 25%Cr Super duplex stainless steel (SDSS steel) (125ksi strength grade preferred) • Super-austenitic stainless steel (e.g. 28%Cr 125ksi strength grade preferred), • Ni alloy (125 ksi strength grade 718 preferred)
Material Sample Types	• Weight-loss/pitting corrosion coupons • Tensile Tests before and after exposure[4] • U-bend SCC for CRAs [5]
Reporting	• General corrosion rate • Localised corrosion (rate and type) • Environment sensitive cracking (ESC)[5] • Change in ductility (elongation and/or area reduction). • Chemical degradation, change in autoclave pressure and pH should be identified [6]

Table 1: Test Parameters and Requirements, pre-qualification test

Notes:

1. Corrosion inhibitors, oxygen scavengers and all other chemicals that are likely to be present in an actual field application should be included in the tests. The brine make-up should be defined in a written specification identifying all components. Note that tap water chemistry may vary significantly.
2. H_2S may influence test result and should be considered when expected in operation. The solution should be purged for at least 1 hour or until equilibrium is reached using the test gas mixtures and prior to pressurising the autoclave/starting the test.
3. Decomposition may be catalysed by certain materials, especially Ni-alloys. This should be considered when selecting autoclave and other test equipment materials. All types to be included for generic testing. For specific

applications materials not to be used may be omitted or additional alloys substituted by agreement with the end user. Care should be taken when mixing different materials in the same autoclave. Galvanic corrosion and other interactive effects should be considered,.

4. Tensile Test (at 10^{-5} s^{-1} strain rate) to be undertaken on tested and untested samples to evaluate ductility loss. Minimum 2 repeat tests recommended.
5. U-bend selected for consistency and simplicity. Other tests may be used if agreed by the end user, but these are not encouraged. Evaluation of test results should include specimen sectioning once at centre line for round-bar specimens; minimum t~~T~~wice ~~(3 times?)~~ (1/3 and 2/3 through width) for strip specimens AND/OR through any 'suspect' areas identified from the previous visual examination.
6. This would typically include chemical analysis before and after test and, if necessary, identification of possible reaction mechanisms and end products. It is recommended to continuously monitor and record temperature and pressure for the duration of the test. pH measurements should be made in a standardised atmosphere.

2.2 Qualification Test

This test should be undertaken by the vendor only after agreeing the testing conditions/programme with the end user. The purpose of the test is to qualify the brine for specific applications, as defined by the environment/materials combination (or a range of applications, environments and materials).

Typical test requirements are shown in Table 2.

Possible galvanic effects should be considered. ISO 15156-3 may be used for guidance on Galvanic Hydrogen Stress Cracking (GHSC) testing.

Common Test Parameters	**Requirement, All Tests**
Temperature	Design/Maximum Temperature (see also Section 2.3)
Brine and chemical additives	Industrial grades (i.e. similar to those to be used in the final product) shall be used The full chemical package in accordance with the written specification shall be used in the test[1]
Test environments	Environment 1: No acid gas contamination and no forcible oxygen removal condition Environment 2: Gas contamination condition; the actual partial pressures of corrosive gases anticipated in service (typically CO_2 and H_2S) should be used[2]
Exposure time	90 days[3]
Material types	Application dependent[4]
Material Sample Types	Weight-loss/pitting corrosion coupons Tensile Tests after exposure[5] SCC Tests[6] Crevice corrosion coupons (metal-to metal) Hydrogen samples[7]
Reporting	• General corrosion. • Localised corrosion (rate and type) • Environment sensitive cracking (ESC)[8] • Change in ductility (elongation and/or area reduction) • Hydrogen content before and after testing[7] • Chemical degradation, change in autoclave pressure and pH should be identified [6]

Table 2: Typical test Parameters Requirements, Qualification Test

Notes:

1. Corrosion inhibitors, oxygen scavengers and all other chemicals that are likely to be present in an actual field application should be included in the tests. The brine make-up should be defined in a written specification identifying all components. Note that tap water chemistry may vary significantly.
2. CO_2 and H_2S mixture shall be bubbled through the solution for at least 1 hour or until equilibrium is reached prior to pressurising the autoclave/starting the test.
3. Shorter exposure times can be justified based on pre-qualification test data or shorter field exposure periods.
4. All materials in contact with brine in service should be tested.
5. Tensile Test (at 10^{-5} s^{-1} strain rate to be undertaken on tested and untested samples to evaluate ductility loss. Minimum of 2 repeats recommended.
6. One or more test method of either 4PB (100% AYS), C-ring (100% AYS) or Constant Load (90% AYS). DCB testing may be used for low alloy steels if agreed with end user. Only the test methods suitable for the candidate materials being evaluated should be selected, ref ISO 15156 part 2 and 3.
7. Optional test; to be decided with end user. Hydrogen to be measured after cleaning by combustion method. Samples to be stored cryogenically immediately after removal of autoclave until combustion. The following should be approved by the end user before testing:
    - Specimen size and cleaning procedure
    - Technical and calibration procedures

   Hydrogen measurements should be evaluated together with tensile samples (ref note 4). Acceptable hydrogen levels will vary with alloy and acceptable levels should be established together with the end user.
8. Test specimen to be sectioned once at centre line for round-bar specimens; minimum Twice (1/3 and 2/3 through width) for strip specimens AND/OR through any ‘suspect’ areas identified from the previous visual examination.
9. This would typically include chemical analysis before and after test and, if necessary, identification of possible reaction mechanisms and end products. It is recommended to continuously monitor and record temperature and pressure for the duration of the test. pH measurements should be made in a standardised atmosphere.

2.3 Other considerations

In some cases the maximum temperature may not represent the worst case for some cracking mechanisms. Table 3 gives guidance to other temperature ranges which may be considered when testing brines for specific field applications.

Material type	Failure mode	Worst case temperature
Low Alloy Steels, 13Cr/S13Cr	SSC, SCC	Ambient for SSC Maximum design for SCC [1]
Duplex	SSC/SCC (mixed mode) SSC	80-100 ^{o}C Max. design
Alloy 718	HSC SCC	Ambient for HSC[1] Maximum design for SCC [1]

1. May become enriched by H at high temperature and brittle when temperature reduces.

Table 3: Worst case test temperatures

Additional information

2.4 Definitions and abbreviations

Abbreviations

4PB	Four point bent beam
DSS	Duplex Stainless Steel
ESC	Environmental Stress Cracking
GHSC	Galvanic Hydrogen Stress Cracking
GL	Guideline
HE	Hydrogen Embrittlement
HSC	Hydrogen Stress Cracking
LAS	Low Alloy Steel
N/A	Not Applicable
P	Pressure
SCC	Stress Corrosion Cracking (occurs at high T)
SDSS	Super Duplex Stainless Steel
SMSS	Super Martensitic Stainless Steel
SSC	Sulphide Stress Cracking (occurs at low/ambient T)
T	Temperature

2.5 Definitions

<u>Brine (or Clear brine fluid)</u>
- covers a range of solids free solutions that are used for the following applications:

- *Completion and Workover Fluids* - can be defined as any fluid that is pumped downhole to conduct operations after the initial drilling of the well. These fluids are employed to balance formation pressures, circulate / transport solids and protect the formation during well killing, perforation, fishing and gravel packing operations.
- *Packer Fluids* – are the fluids present in the annular volume between the tubing and the casing above the production packer. The completion fluid may remain in the annular space following the packer setting operation thus becoming the packer fluid. Alternatively, the completion fluid may be circulated out of the annular space to be replaced by dedicated fluid. Packer fluids typically remain in the annulus for extended periods during which time they may become contaminated with produced fluids or lift gas.
- *Well Suspension Fluids* - A fluid that is left in a completed or uncompleted well for a longer period of time, to maintain well control and integrity prior to bringing the well onto production.
- *Drilling Fluids* – are fluids used during the drilling of a well. These fluids are typically circulated down the drill string and up the annulus to cool the bit, transport cuttings and stabilise the well bore. Formate brines may be employed as drilling fluids for specialised applications. The selection of clear brine drilling fluids is considered out with the scope of this document.

2.6 Changes from previous version

N/A

2.7 References

ASTM G1	Standard Practice for Preparing, Cleaning and Evaluating Corrosion Test Specimens
ASTM G 30	Standard Practice for Making and Using U-Bend Stress-Corrosion Test Specimens
ISO 6892-1	Metallic materials - Tensile testing at ambient temperature
NACE MR0175/ ISO 15156	Petroleum, petrochemical and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production
NACE TM0177	Standard Test Method. Laboratory testing of metals for resistance to specific forms of environmental cracking in H2S environments.

Appendix 2

CEFRACOR - Corrosion in O&G industries Committee (CIPG) - Subgroup WG 5

Corrosion in O&G industries Committee (CIPG)

Subgroup WG 5

Environmentally Assisted Cracking

CEFRACOR
CENTRE FRANÇAIS DE L'ANTICORROSION

- <u>Septembre 2006</u>: Creation of the committee, impulsed by Marcel ROCHE (Total)

- Definition of 9 working groups

- More than 150 people interested in the activities of the committee

- More than 50 active participants

- Current President is Jean KITTEL (IFP-EN)

Main activities:

- To share information on the topic (both upstream and downstream)
- To discuss on test procedures (Unaxial Tensile, HIC, DCB, FPB, Corr-Fatigue)
- To visit corrosion laboratories
- To dicuss technical papers, standards relevance
- To present scientific works
- To organize one-day seminars
- ...

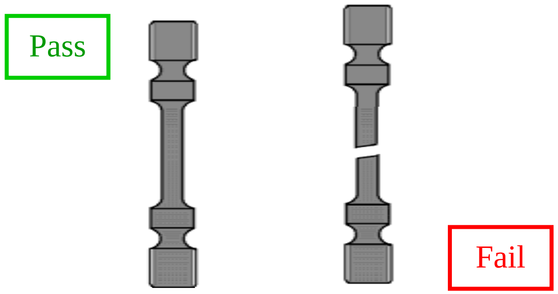
Main activities:

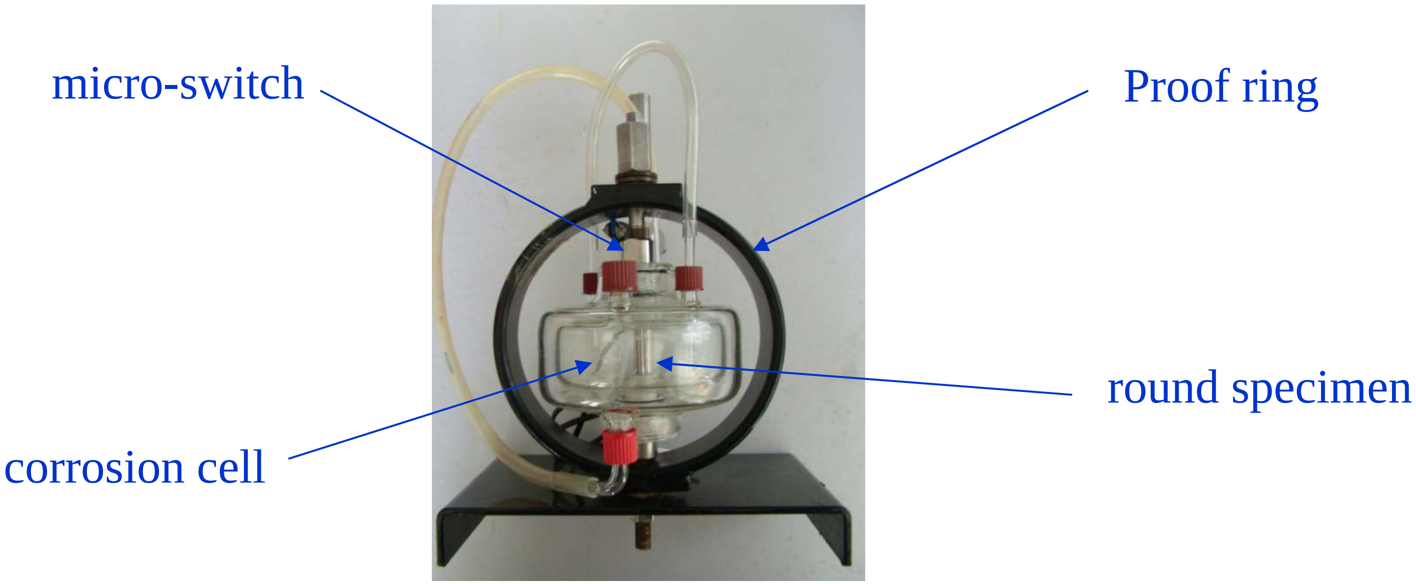
- Focus on the NACE TM0177 Uniaxial Tensile (Method A)

NACE TM0177 Method A: Basics

Uniaxial Tensile test

- *NACE TM0177-05 Method A*
- *Standardized test in the OCTG industry*
- *Critical test seen as a reference*





Test is stopped after 720 hours (1 month) if no failure has occurred… otherwise, TTF is checked

WP 5: NACE TM0177 Method A: Back to the history

Method A = Unaxial Tensile test

Results of Interlaboratory Sulfide Stress Cracking Using the NACE T-1F-9 Proposed Test Method*

(Materials Performance Sept. 1977)

J. B. GREER
Exxon Production Research Company, Houston, Texas

Eighteen companies participated in interlaboratory sulfide stress cracking tests using the NACE T-1F-9 Proposed Test Method as a core program. The results of testing are presented along with suggested modifications for T-1F-9 consideration.

2. The sulfide stress corrosion cracking data are logarithmically related to time, *i.e.*, $\sigma = \sigma_0 - \beta_{\log} t$, where σ is stress, σ_0 and β are material constants, and t is time.

3. Variations in NaCl content are not an important parameter for low alloy steels, however, it is necessary to exclude oxygen by continuous H_2S bubbling during the experiment.

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WP 5: Is Uniaxial Tensile the right methodology?

2.2.7 EC test results can show statistical variability. Replicate testing may be needed to obtain a representative value characterizing resistance to EC.

from NACE TM0177-2005

Variability induced: by the SSC mechanism vs. the test procedure?

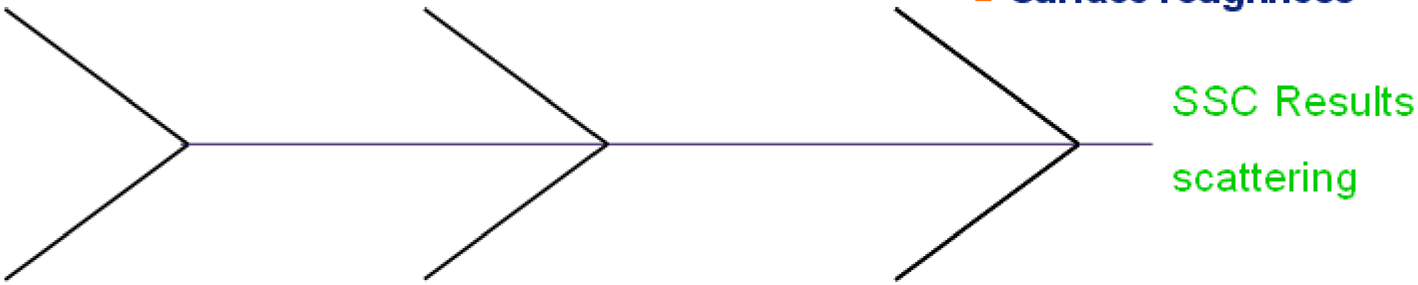
WP 5: Influent parameters that may affect the SSC test result

During samples' preparation

Before sampling
- Inclusions
- Cracks

Sampling
- Cutting: tool
- Site: around circumference, thickness
- Storage, handling

Machining
- Tool, parameters
- Residual stresses
- Polishing
- Design
- Surface roughness



Handling
- Storage
- Gloves
- Cleanliness

Equipment
- Proof rings
  - Calibrated
  - Uniform/ reproducible loading
- Threads
- Ball thrust bearing
- Airtightness
- Corrosive solution

Test implementation
- Gas composition
- Quality of water, NaCl, *etc.*
- Temperature maintained

Post test
- Stripping down
- Storage
- Chemical post treatment

During samples' tests

WP 5: Important parameters to be checked (1/3)

Sampling/machining of the specimen

- At the origin of TM0177, machining tools were « rapid steels » and the Std. still requires « in machining operations, the final two passes should remove no more than a total of 0.05 mm (0.002 in.) of material »
  - According to machining experts, this requirement does not fit with the use of new machining tools (« carbide or ceramic tools »). Need to be updated?
- Manual mechanical polishing (long./transverse) vs. automated polishing
  - Influence of non reproducible polishing (residual stresses, heterogeneities)
- Electrolytic polishing vs. mechanical polishing
  - Stainless steels/Carbon steels: To be clearly distinguished
  - Influence of compressive/tensile stresses
- Roughness (R_z + R_a instead of only R_a) – frequency of the checking – 0.81 µm in NACE Std. instead of 0.2 µm in EFC 16 (subsize vs. Std. size)

WP 5: Important parameters to be checked

Solution preparation

- CO2 / H2S vs. N2 / H2S comparison? pH "drift, shift"
  - Influence of the start pH (FeS layer, H uptake kinetic, etc.)
- N2 or CO2 degassing? -> better efficiency with CO_2
  - Influence of the residual oxygen content (some labs carry out testing in « glove boxes »)
  - Influence of the gas quality, permeability of the system/pipes
- 20 mn degassing (see TM0177) leads to ca. 200 ppb of residual O_2?
  - Maximum and minimum O_2 concentrations values to be checked vs. testing apparatus?
  - NACE does not specify maximum O_2 concentration depending on gas quality (O_2 residual content)
- Units/concentration: wt. % vs. g/L

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WP 5: Important parameters to be checked

Test launching

- Stress measurement: « Bending issue »
    - API WG 1055 « Bending stress error » or torsion effect
    - Some NACE papers on the topic
- Stress measurement: « torsionnal effect » when loading the tensile specimen with proof-ring
- Constant load vs. Proof-ring vs. Spring loaded
    - Some NACE papers on the topic
- Used of proof-ring
    - Calibration of the proof-ring (frequency, method, *etc.*)

Focus on NACE TM0177 Method A: To be cont'd…

- **Need to share this work with EFC members and to discuss any REX on the Std./guidelines**
- **Publish a short paper on the topic summarizing the important parameters to be controled**
- **Organize « one-day seminar » on HE (Nov. 17th, 2011)**
- **Open for collaboration and exchanges**
  - Share database on API grades, *etc.*

- ***Any people/companies interested in discussing the topic within EFC WP13?***
- **For more informations:**

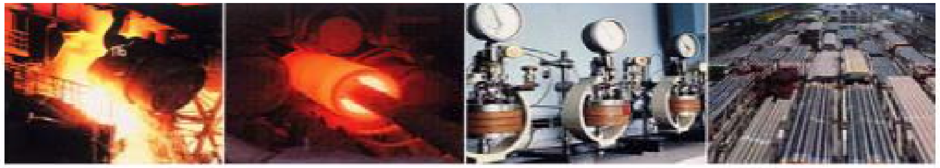
jean.kittel@ifpenergiesnouvelles.fr (Chairman of CIPG)

herve.marchebois@total.com (WG leader)

One day seminar on Nov. 17th

CEFRACOR

APPEL À COMMUNICATIONS
CALL FOR PAPERS



Première journée
«Fissuration assistée par l'environnement
en milieux pétrolier et gazier»

1st Event on
“Environmentally Assisted Cracking
in Oil & Gas Production”

17 novembre 2011 – Lyon (France)

INSA Lyon
Campus de la Doua
31, avenue Jean Capelle
69100 VILLEURBANNE

Objectives

- **The CEFRACOR Working Party on Corrosion in Oil and Gas is now organizing at INSA de Lyon a seminar on the *"Environmentally Assisted Cracking in Oil & Gas Production"***
  - To propose an adapted scene for discussion progresses accomplished on all areas of environmental assisted cracking.
  - The themes cover the state of the art and recent advances in mechanisms, methods of testing and characterization, standardization, development of materials, lessons learned, but also on issues that remain to be discussed.
  - This is also an opportunity for exchange and sharing among different actors from academia and industry on key themes

- **Scientific committee**

  Hervé MARCHEBOIS (Chairman - Total), Marion FREGONESE (INSA de Lyon, laboratoire MATEIS), Jean KITTEL (IFP Énergies nouvelles), Vincent LIGIER (TECHNIP), Christophe MENDIBIDE (ASCOMETAL), Marcel ROCHE (former Total – Consultant)

Agenda of the day

Material selection and Return of experiments

Key note lecture «ISO 15156/NACEMR0175 Standard», T. Cassagne (Total)

«Hydrogen embrittlement in H_2S environment: REX», C. Duret-Thual (Institut de la Corrosion)

«Management of H_2S cracking in refinery», M. Lobaton (Petroplus)

«Failure analysis of H_2S cracking in refinery», C. MAJOREL (Total)

«Stress Corrosion Cracking on an amonia storage tank: REX», V. Amrhein (YARA France)

«Material selection of CRAs in formation and condensed water», S. Le Manchet (ARCELORMITTAL-Industeel)

Open discussion on related topics

Mechanisms and testing

Key note lecture «Cracking mechanisms in H_2S: A review», J-L. CROLET (Consultant)

«Use of acoustic emission to monitor SSC», C. Plenneveaux (Total)

«Trapping and stresses in the microstructure of low alloy steels regarding Hydrogen Embrittlement », C. Bosch (ENSMSE engineering school)

« Role of the acetates on SSC of martensitic stainless steels », C. Augustin (V&M)

« Effect of residual stresses due to machining on SSC», C. Mendibide (Ascometal CREAS)

Appendix 3

4 point bend testing

WP13 – Working group on 4pb

Update on status

EuroCorr Stockholm 2011

Status

- Comments received through 2010
- Concept
  - TM0177 will be the detailed test method (WG085f)
    - Specific details on specimens
    - Specific details on testing
    - No acceptance criteria
  - Supporting knowledge on issues and best practice will be incorporated into EFC16 and EFC17
    - Capture the feedback and reasoning plus important issues which have led the test method derivation
    - Acceptance criteria

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TM0177 4pb - Parent

- Material considerations based upon product form (in line ISO15156 which requires this):
  - Parent materials of homogeneous form
    - Plate, pipe etc – Prismatic specimens ASTM G39, straining per formulae in EFC16 & 17 below elastic limit (otherwise strain gauge)
      - Parent full thickness or maximum possible
        - Minimum 4mm?
  - Non-uniform material – armour wires, pilger pipe, expanded tube. Retain surface condition, loading jigs to accommodate material/product, strain gauged

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Engineering

TM0177 4pb - Weldments

- Weldments
  - Test weld in transverse orientation, root in tension (as appropriate to product)
  - Full thickness or maximum possible
    - 8mm minimum or full thickness
    - Full thickness for clad, remove iron contamination (metallurgically bonded or dilution layer in weld overlay)
  - Test with root intact
  - Strain gauge specimens

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Test Method – Mechanical Properties

- DISCUSSION POINT -1
- Options:
  - ➢ Derive yield strength from UT specimen
    - ➢ ISO15156 present requirement, as used also for C-rings
  - ➢ Derive yield strength from flexural specimen
    - ➢ Note this will be conservative (increase of 15-25% strain)
- DISCUSSION POINT -2
- Derivation of properties at elevated temperature?
  - ISO15156-3 requires use of elevated temperature properties be applied to the specimen
  - UT relatively common, flexural less so?
  - Can consensus be achieved?

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Test Method – Loading for elevated temperature

- DISCUSSION POINT -3
  - 4pb initial load, either:
    - Could be based upon RT properties and load to this (conservative), or,
    - Load specimen to the elevated temperature properties at RT
  - Require experience and data from WP13 members on comparative results if this can be provided?

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Additional Points on Testing

- Strain gauge location
  - Proximity to HAZ, retention of as-welded oxidized surface, removal of adhesive…
- Rounded edges to minimise edge effects
- Account for cold creep in constant deflection loading
  - Incremental loading whilst monitoring, discuss typical time people utilise
  - Calibration of creep at test temperature?

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Assessment

- EFC16 gives evaluation method
  - Add the guidance on “crack-like pits” generated by stress-assisted corrosion (TWI Paper)
- EFC17 needs this adding
  - Consider presence of pits, acceptable dimensions?
  - Discussion should dimensions be noted:
    - <100um diameter on surface and <25um deep is acceptable if sectioned and no cracking from base
    - In other cases the dimensions to be recorded
    - Concern is pits can initiate cracking

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Appendix 4

Corrosion in Dense Phase CO2 Transport and Storage

Corrosion in Dense Phase CO_2 Transport Pipelines

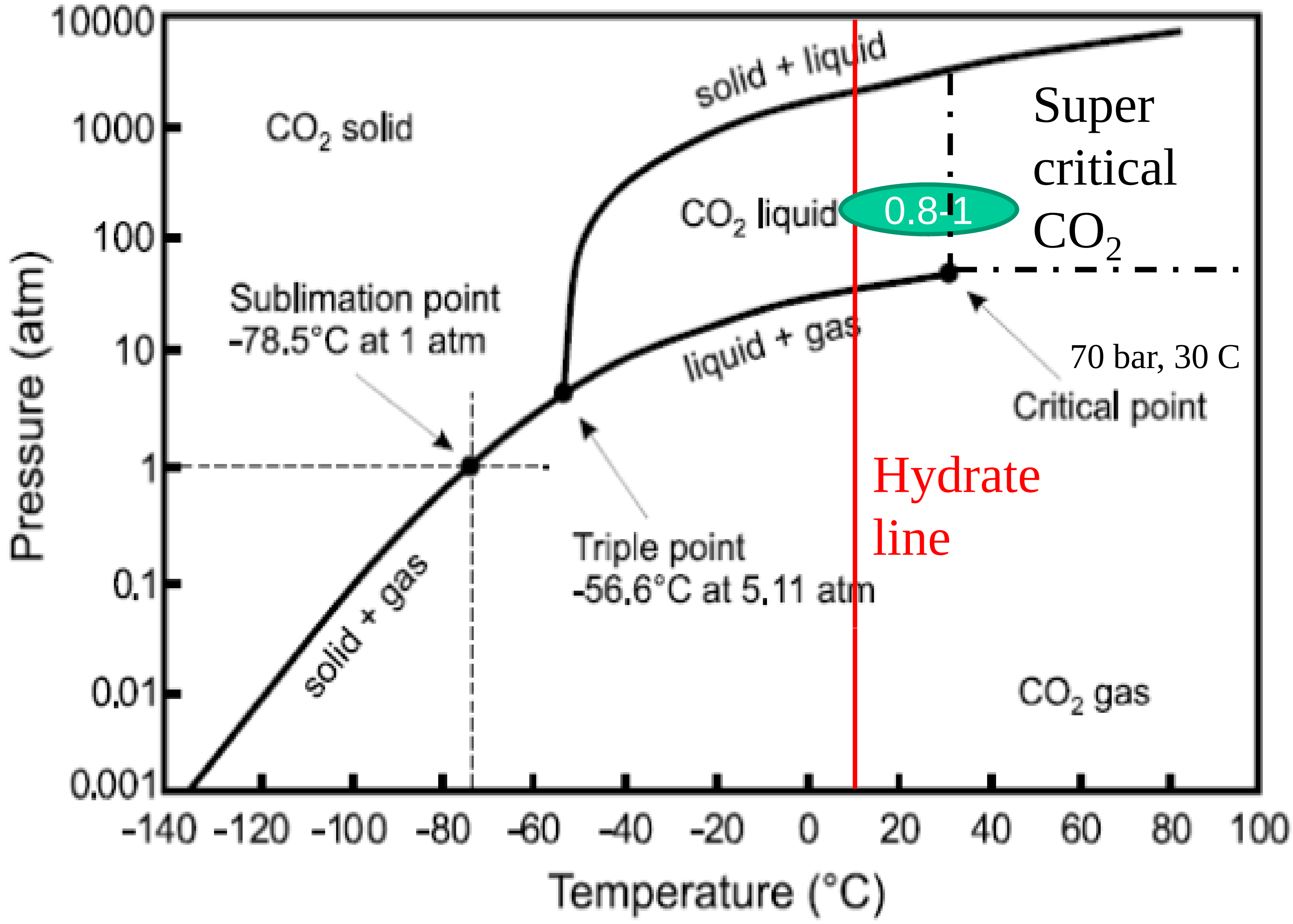
Arne Dugstad

Institute for Energy Technology
Kjeller, Norway
www.ife.no
arne.dugstad@ife.no

WP13, Thursday September 8^{th}

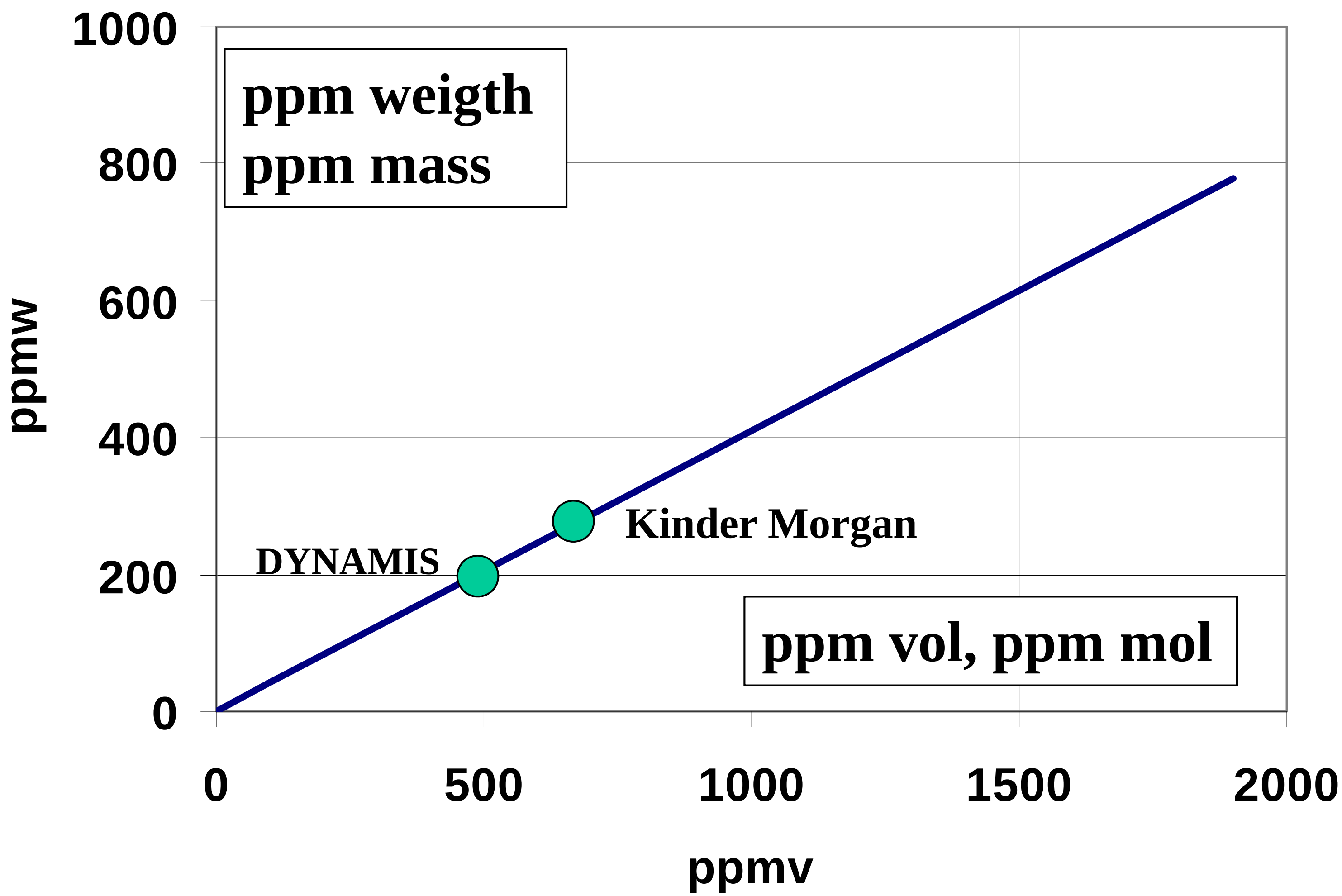
Issues to be addressed

- Motivation for studying corrosion in CO_2 transport pipelines
- State of the Art
- When can we get corrosion
- What is IFE doing
- Experimental results
  - Corrosion, water < 500 ppmw
  - Corrosion in a separate water phase (water ingress)
  - Depressurization and the effect on the corrosivity



10000
1000
100
10
1
0.1
0.01
0.001
Pressure (atm)
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
Temperature (°C)
CO2 solid
solid + liquid
CO2 liquid
0.8-1
Super
critical
CO2
Sublimation point
-78.5°C at 1 atm
liquid + gas
70 bar, 30 C
Critical point
Hydrate
line
solid + gas
Triple point
-56.6°C at 5.11 atm
CO2 gas

ppmv vs. ppmw



1000
800
600
400
200
0
ppmw
0
500
1000
1500
2000
ppmv
ppm weigth
ppm mass
ppm vol, ppm mol
DYNAMIS
Kinder Morgan

Significant reduction i CO_2 emission

Transport and injection of large amounts of CO_2 (2-3x)

Huge amount of pipes

<u>Emission 2010: 30 Gt CO_2</u>

$$\left.\begin{array}{l}\text{12" pipelines \textasciitilde 3400} \\ \text{36" pipelines \textasciitilde 280}\end{array}\right\} \textbf{12 GT, 1.5 m/s}$$

Need to define the safe operation window
before the process plants are designed and built!

Dense phase CO_2 transport, State of the Art

- CO_2 injection for EOR > 30 years (USA)
- More than 100 installations, more than 5000 km pipeline
- C-steel: Good experience with <u>clean and dry CO_2</u>
- Reported corrosion when water accumulates
- CRA: ”Wet” CO_2, Sleipner, short distance
- Thousands of papers/corrosion studies for pCO_2 < 20 bar
- Few studies for pCO_2 > 50 bar
- Less than 10 publications presenting data with flue gas impurities
- Not much focus on corrosion in the CCS community (GHGT 10)

``The pipeline $CO_2$ transportation process is well understood as $CO_2$ pipelines have been used since 1970s, transporting large volumes of $CO_2$ to oil fields for <u>enhanced oil recovery, EOR</u>``

Will corrosion be a problem?

Good experiences with CO_2 transport in USA!

Is CCS different?

Concentrations of impurities in dried CO_2

	SO_2	NO	H_2S	CO	N_2 /Ar/O_2
COAL FIRED PLANTS					
Post- combustion capture	<100	<100	0	0	100
Pre-combustion capture(IGCC)	0	0	100-6 000	300-4 000	300-6 000
Oxy-fuel	5 000	100	0	0	37 000
GAS FIRED PLANTS					
Post-combustion capture	<100	<100	0	0	100
Pre-combustion capture	0	0	<100	400	13 000
Oxy-fuel	<100	<100	0	0	41 000

Source: Intergovernmental Panel on Climate Change (IPCC)

Many different tables with large differences in concentration ranges are issued

DYNAMIS CO_2 quality recommendation

Component	Concentration	Limitation
H_2O	**500 ppm**	Technical: below solubility limit of H_2O in CO_2. No significant cross effect of H_2O and H_2S, cross effect of H_2O and CH_4 is significant but within limits for water solubility.
H_2S	**200 ppm**	Health & safety considerations
CO	**2000 ppm**	Health & safety considerations
O_2[2]	Aquifer < 4 vol%, **EOR 100 – 1000 ppm**	Technical: range for EOR, because lack of practical experiments on effects of O_2 underground.
CH_4[2]	Aquifer < 4 vol%, EOR < 2 vol%	As proposed in ENCAP project
N_2[2]	< 4 vol % (all non condensable gasses)	As proposed in ENCAP project
Ar[2]	< 4 vol % (all non condensable gasses)	As proposed in ENCAP project
H_2[2]	< 4 vol % (all non condensable gasses)	Further reduction of H_2 is recommended because of its energy content
SO_x	**100 ppm**	Health & safety considerations
NO_x	**100 ppm**	Health & safety considerations
CO_2	>95.5%	Balanced with other compounds in CO_2

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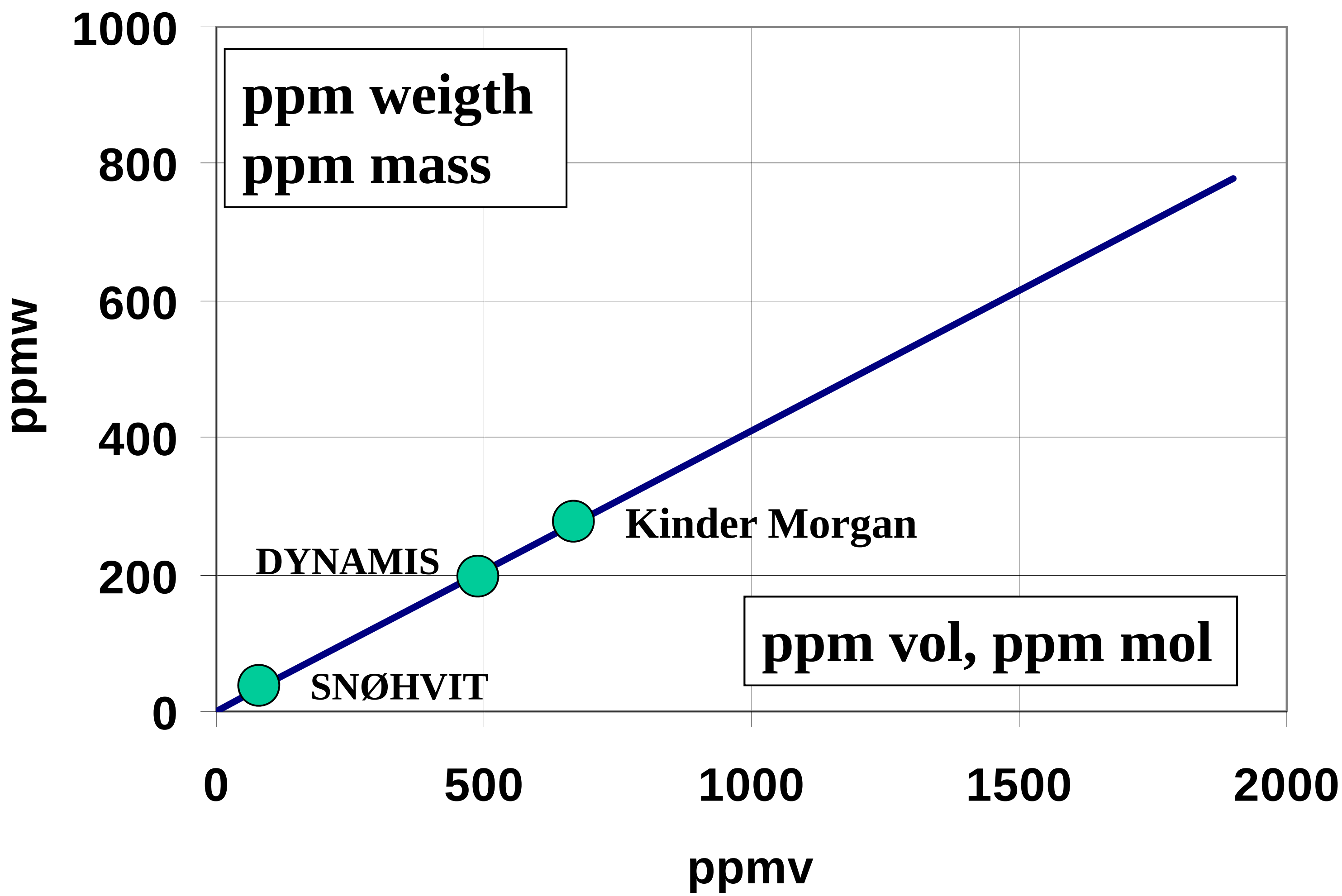
CH_4[2]	Aquifer < 4 vol%, EOR < 2 vol%	
N_2[2]	< 4 vol % (all non condensable gasses)	
Ar[2]	< 4 vol % (all non condensable gasses)	
H_2[2]	< 4 vol % (all non condensable gasses)	Further reduction of H_2 is recommended because of its energy content
SO_x	**100 ppm**	Health & safety considerations
NO_x	**100 ppm**	Health & safety considerations
CO_2	>95.5%	Balanced with other compounds in CO_2

20”, 2 m/s

100 ppm

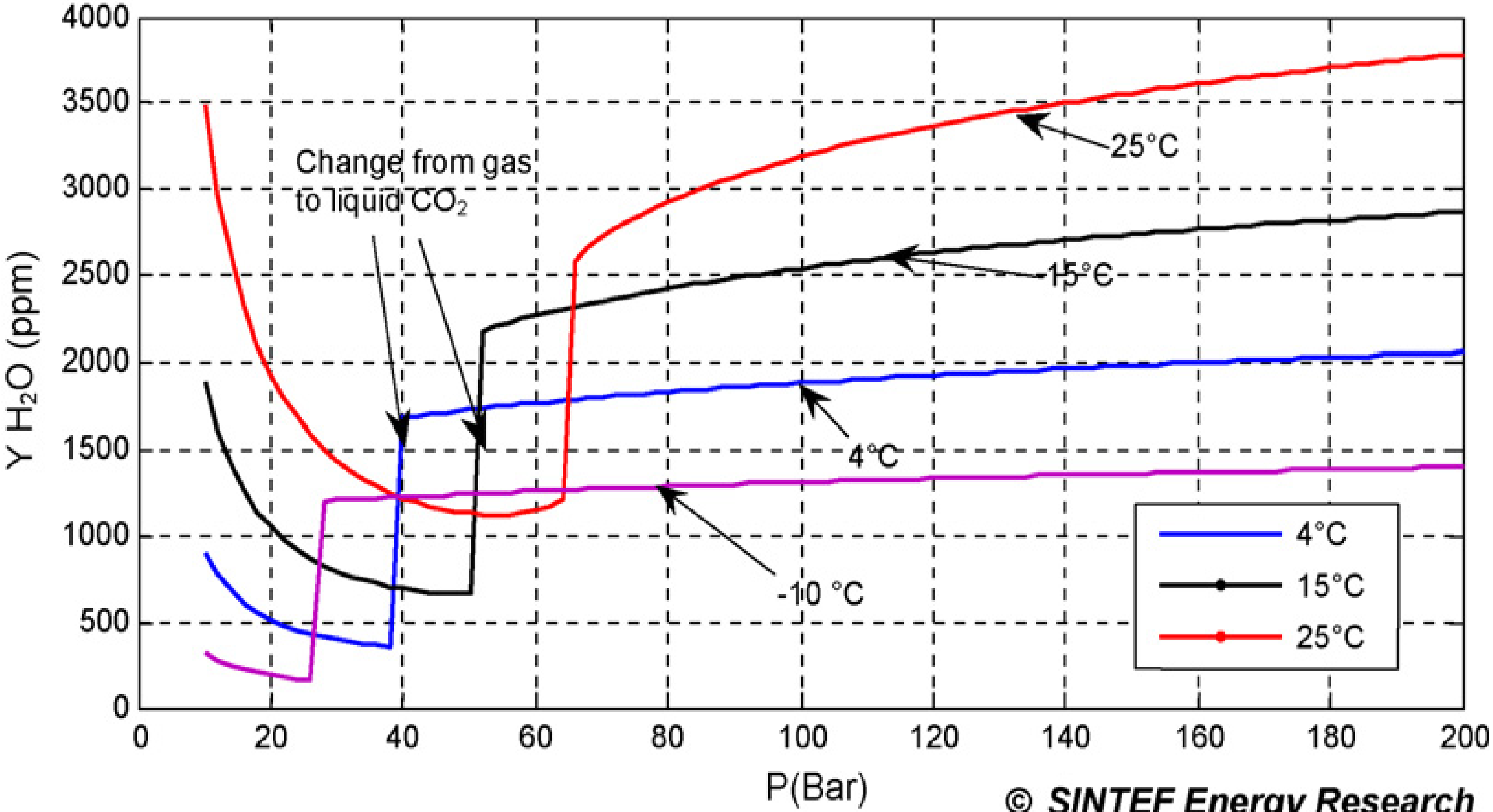
1-2 ktons/year

ppmv vs. ppmw



ppm weigth
ppm mass
ppm vol, ppm mol
Kinder Morgan
DYNAMIS
SNØHVIT
ppmw
ppmv
1000
800
600
400
200
0
0
500
1000
1500
2000

Water solubility (pure CO_2)



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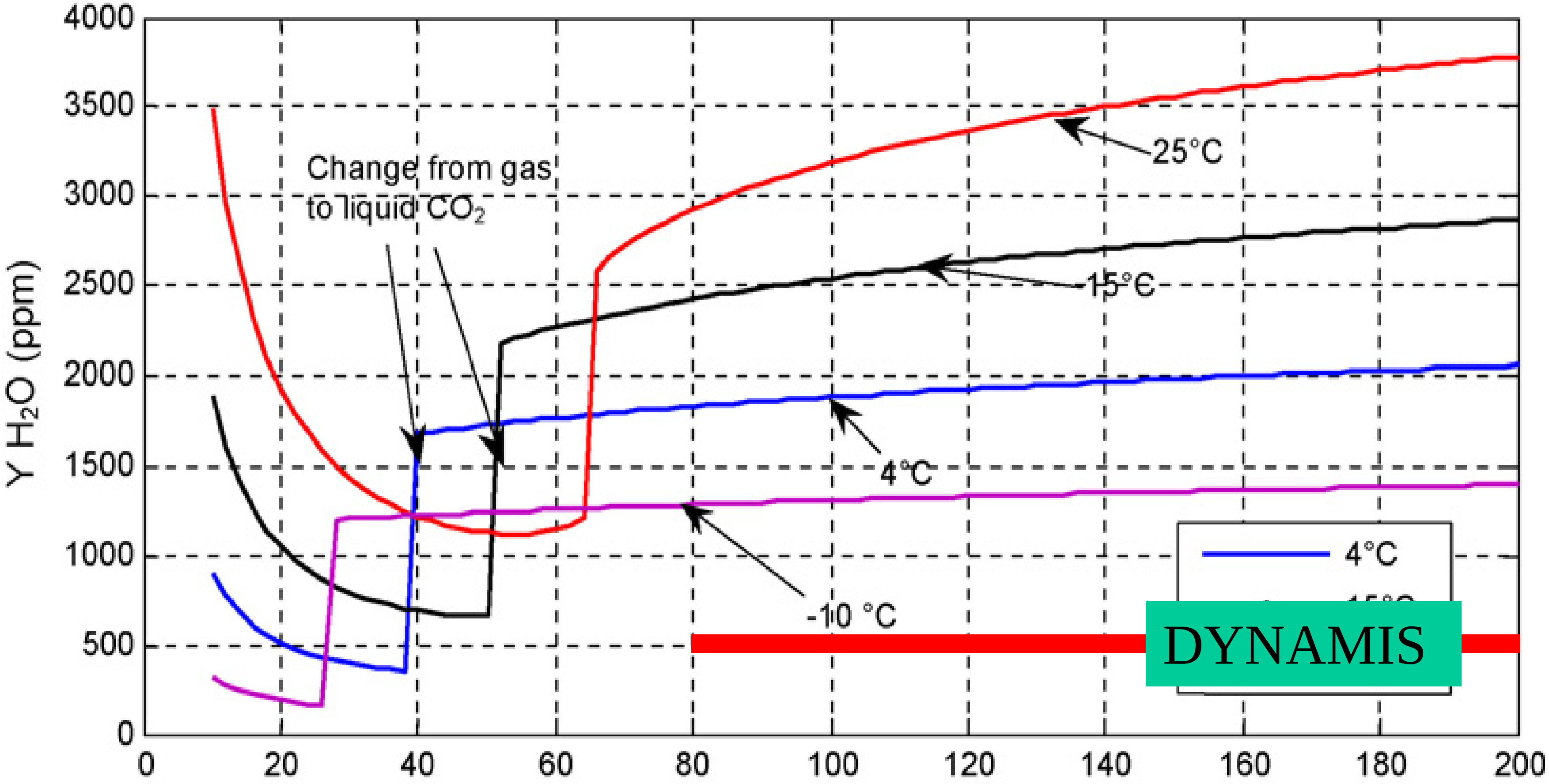
Water solubility (pure CO_2)



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Corrosion scenarios in dense phase CO_2 systems?

- Impurities and low water content (50-650 ppmv H2O)
  - O_2
  - H_2S, S
  - CH_4, N_2, Ar ++
  - SO_x and NOx, CO
  - MEG, TEG, amines, salt

Affects water solubility, the corrosion mechanisms and the phase properties +++

- Free water phase
  - Insufficient drying, water may condense/precipitate from the CO_2 phase
  - Accidental/unforeseen water ingress

Network and different sources

- Shut down, depressurization and accumulation
- Re-using existing infrastructure, deposits (UDC)

Rotterdam CCS

Development of an 'open access' transport infrastructure, offshore storage

Plant type & size	Capture type & size	Target capture operational date
Ultra Supercritical Pulverised Coal Power Station with Biomass Co-Firing, 1080 MW	Post-combustion capture, 1.43 Mt CO_2/yr	2015
Ultra Supercritical Pulverised Coal Power Station with Biomass Co-Firing, 800 MW		
Integrated Gasification Combined Cycle (IGCC) with potential biomass co-firing and hydrogen offtake, 900 MW	Pre-combustion capture, 5.07 Mt CO_2/yr	2015
IGCC, 450 MW	Pre-combustion capture, 2.5 Mt CO_2/yr	2015
IGCC, 350 MW	Pre-combustion capture, 2.0 Mt CO_2/yr	2015
Hydrogen plant	Pre-combustion capture, 0.5 Mt CO_2/yr	2015
Hydrogen plant	Pre-combustion capture, 0.5 Mt CO_2/yr	2015
Furnaces in crude distillation unit	Post-combustion capture, 0.9 Mt CO_2/yr	
Waste heat incinerator	Post-combustion capture, 0.15 Mt CO_2/yr	

http://www.rotterdamclimateinitiative.nl/en/about_rotterdam_climate_initiative/rotterdam_climate_initiative/publications

Corrosion scenarios in dense phase CO_2 systems?

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Affects water solubility, the corrosion mechanisms and the phase properties +++

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What do we know and what do we need to know?

- Pure dry dense phase CO_2 with small amount of H_2S – **No problem**
- What is the effect of impurities on the water limit for no/acceptable corrosion?
  - When do we get a water containing phase?
  - MEG/TEG, salt, amines, hygroscopic salt deposit,
- Consequences of accidental water ingress – injection point (brine)
- When do we form corrosive phases during and after depressurisation?
  - How much H_2SO_4, HNO_3, O_2, H_2S, S? will partition to the water phase?
  - What is the corrosion in the mixed system?
- Bulk phase reactions:
  - $H_2S + O_2$ S (reactivity, solubility?)
  - $SO_2 + O_2 + H_2O$ H_2SO_3, H_2SO_4 (reactivity, solubility?)
  - $NO_2 + H_2O$ HNO_3 (reactivity, solubility?)

20”, 1.5 m/s
100 ppm
1000 tons/year

What is IFE doing?

- Worked with CO_2 corrosion > 30 years
- New high pressure testing facilities for dense phase CO2 work
- Corrosion in dense phase CO_2 at IFE
  - **Statoil 1997-2001 (experimental work, MEG, CI, pH stabiliser)**
  - **CCP 2000-2003 (experimental work, no impurities)**
  - Gassco 2008- (experimental work impurities)
  - SIS (in house IFE project), 2011-2013
  - CO2-pipetrans 1&2 (DnV), 2007- 2012
  - KDC (IFE JIP), dense phase CO_2 and impurities

«Old work», separate aqueous phase

- M. Seiersten "Material selection for separation, transportation and disposal of CO_2" CORROSION/2001, Paper no. 01042.
- Sven Morten Hesjevik, Stein Olsen, Marion Seiersten: Corrosion at High CO_2 Pressure. CORROSION/2003, Paper No. 03345,
- K. O Kongshaug, M. Seiersten, "Baseline Experiments for the Modelling of Corrosion at High CO_2 Pressure", CORROSION/2004, Paper No. 4630, NACE International, Houston, 2004.
- M.Seiersten, K.O. Kongshaug: "Materials Selection for Capture, Compression, Transport and Injection of CO_2", pp 937 in "Carbon Dioxide Capture for Storage in Deep Geologic Formations - Results from the CO_2 Capture Project, Capture and Separation of Carbon Dioxide from Combustion Sources", Vol. 2, Ch. 16, Edited by David C. Thomas, Elsevier, 2005.

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  - **SIS (in house IFE project), 2011-2013**
  - CO2-pipetrans 1&2 (DnV), 2007- 2012
  - KDC (IFE JIP), dense phase CO_2 and impurities

Impurities and low water content

- A. Dugstad, B. Morland, S. Clausen, “Corrosion of Transport Pipelines for CO2 – effect of water ingress”, GHGT 10, Amsterdam, 19-23.09.2010.
- A. Dugstad, M. Halseid, B. Morland, S. Clausen “Dense phase CO2 transport – when is corrosion a threat?”, NACE International 2011 Northern Area Western Conference, Regina, February 7-8, 2011
- A. Dugstad, B. Morland, S. Clausen “Transport of dense phase CO2 in C-steel pipelines –when is corrosion an issue?”, CORROSION/2011, Paper No. 19202

What is IFE doing?

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  - **CO2-pipetrans 1&2 (DnV), 2007- 2012**
  - KDC (IFE JIP), dense phase CO_2 and impurities

CO2PIPETRANS Phase 2

- **Objective**: Close significant knowledge gaps and update the Recommended Practice
- **Scope of Work:**
  - WP 1 – Dense phase CO_2 release modeling validation data
  - WP 2 – Full scale crack arrest testing
  - WP 3 – Corrosion
  - WP 4 – Material compatibility (elastomers/polymers)
  - WP 5 – Examine effects of contaminants on the phase diagram
  - WP 6 – Hydrate formation/ Water solubility
  - WP 7 – Public Communication and Interaction
  - WP 8 – Update of Recommended Practice

- CO2PIPETRANS phase 2 is an *enabling* project to support implementation and promote public and regulatory acceptance of CCS
- **Fast track** project with 2 years schedule

What is IFE doing?

- Worked with CO_2 corrosion > 30 years
- New high pressure testing facilities for dense phase CO2 work
- Corrosion in dense phase CO_2 at IFE
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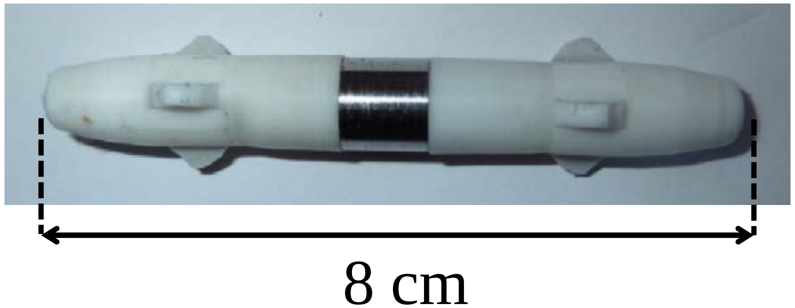
  - SIS (in house IFE project), 2011-2013
  - CO2-pipetrans 1&2 (DnV), 2007- 2012
  - **KDC (IFE JIP), dense phase CO_2 and impurities**

KDC (Kjeller Dense Phase CO2 Project)

- JIP
- Period: 2011(spring) – 2013 (2014)
- Main objective: Determine the operation window for safe transport of dense phase CO_2 with impurities in carbon steel pipelines and generate a basis (data base and understanding) for prediction, mitigation and management of corrosion in CO_2 transport pipelines.

IFE corrosion studies in the dense phase CO_2

Sliding specimen rack



Autoclaves (ID 20-30 mm, length 2 m)
Pressure 200-700 bar
Temperature range (0-50 °C),
Corrosive phase ($<10^{-3}$)

GC, moisture analyzer with silicon sensor, mass loss

Loop experiments

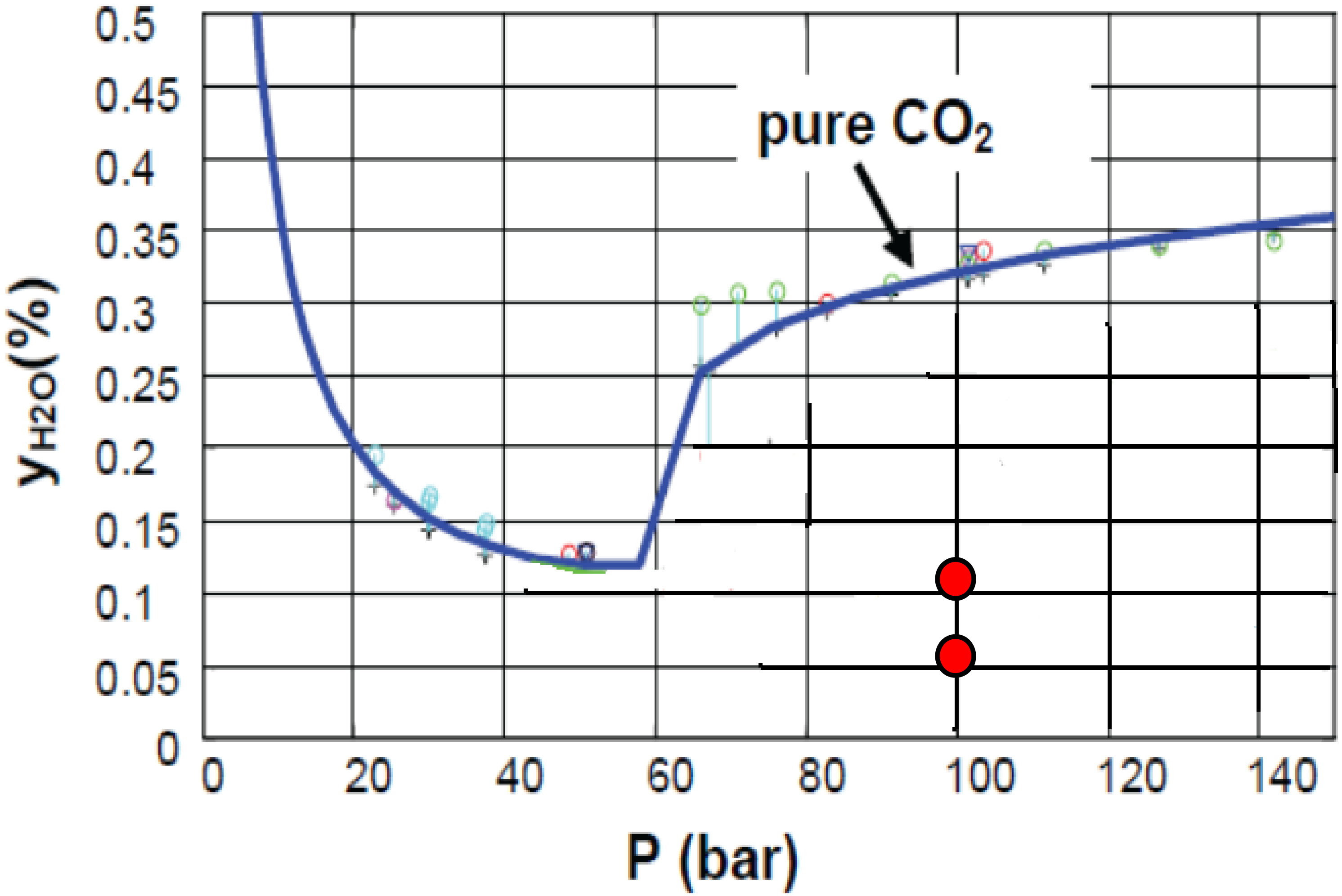
Alloy C 276
Pressure: 200 bar
Flow:0.1-3 m/s
Iron counts
Electrochemistry

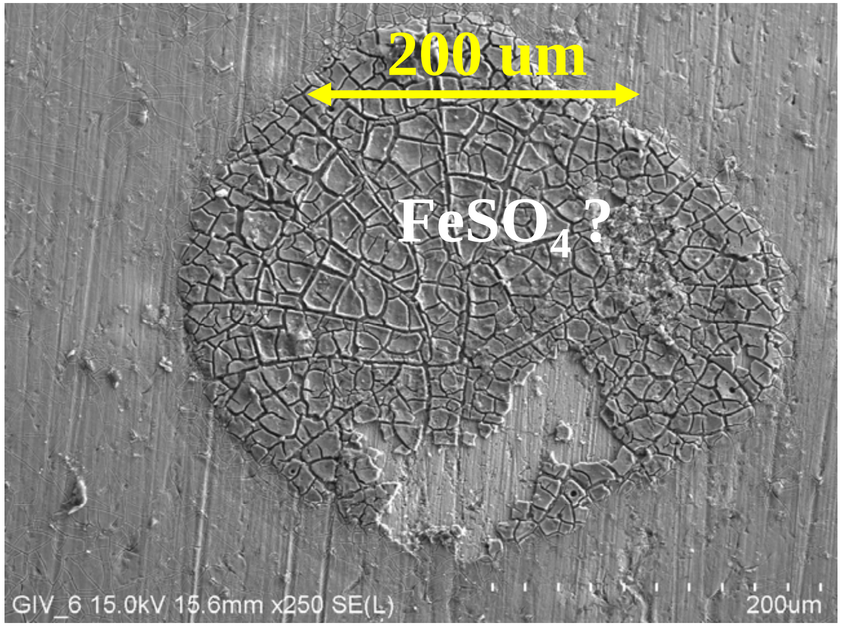
Ti-autoclave
30 litres
180 bar

Ti-autoclave
30 litres
180 bar

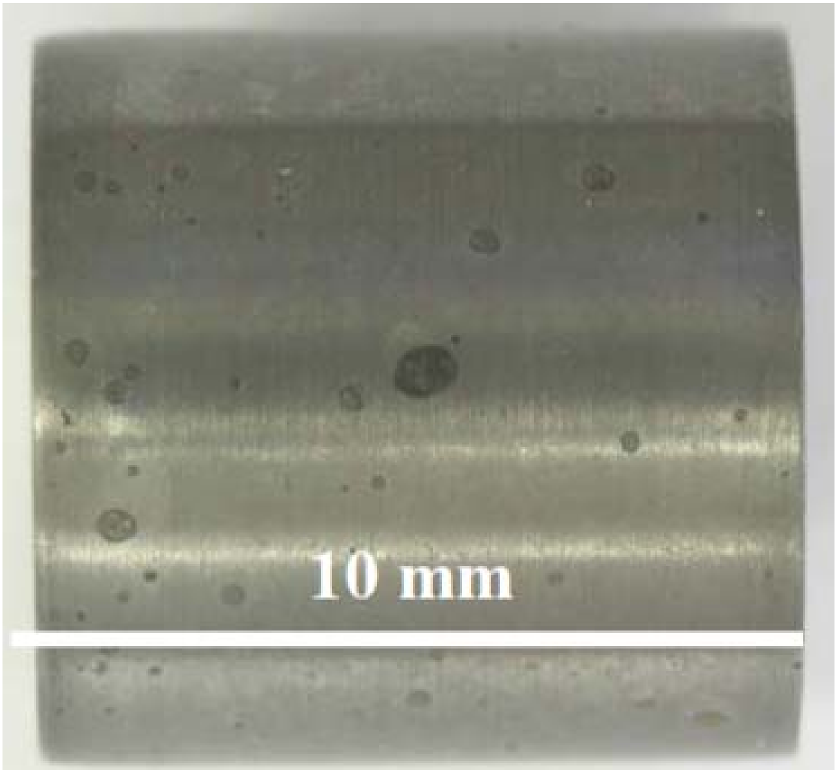

1A1/X/550/07
GB/0001

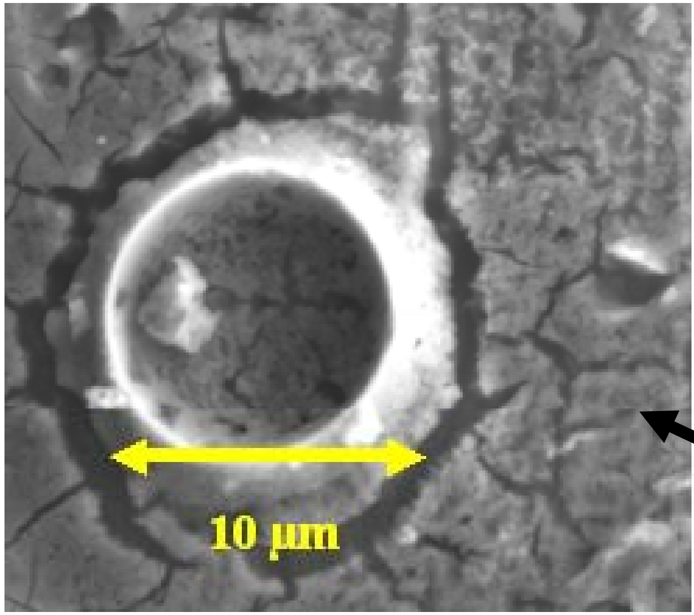
500 ppmw (1220 ppmv) H_2O in dense phase CO_2, 25 C





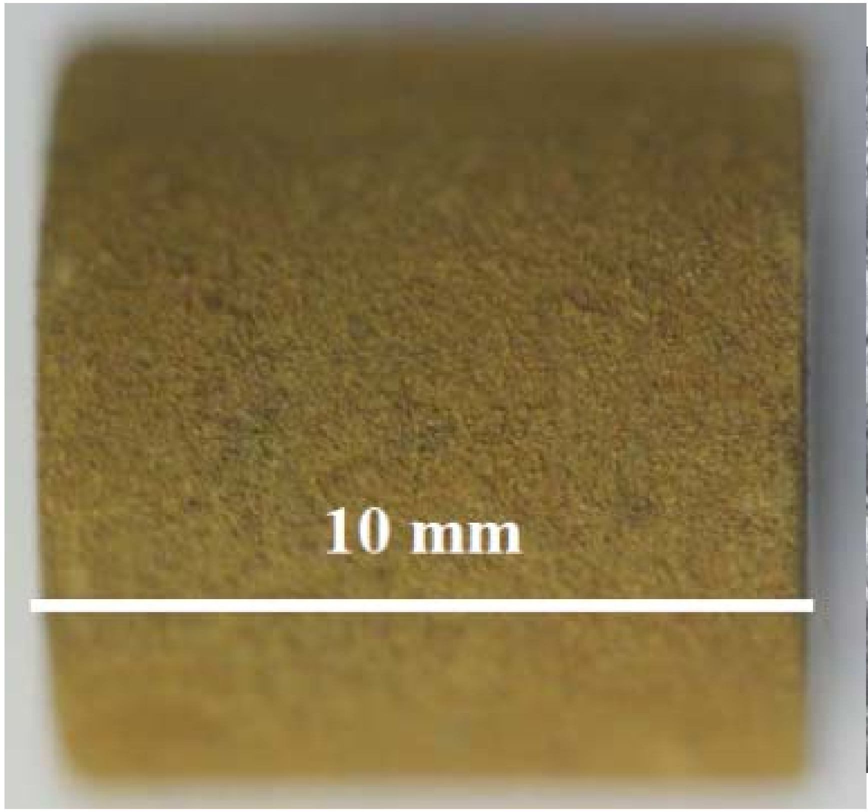
500 ppmw SO_2 and H_2O

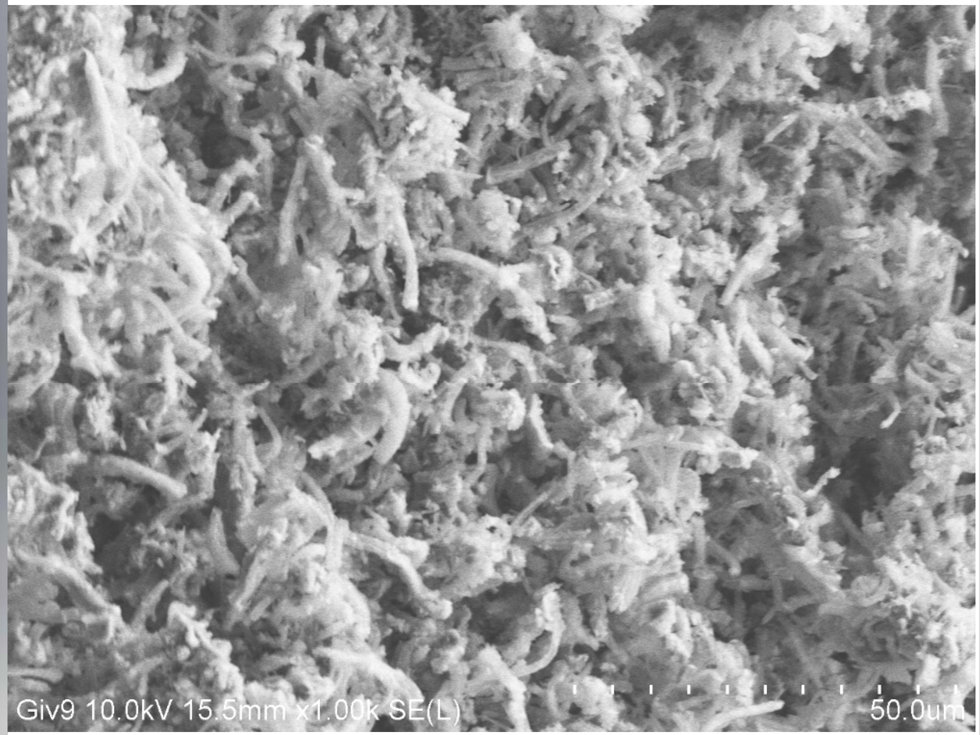




200 ppmw H_2O

500 ppmw NO_2 and H_2O

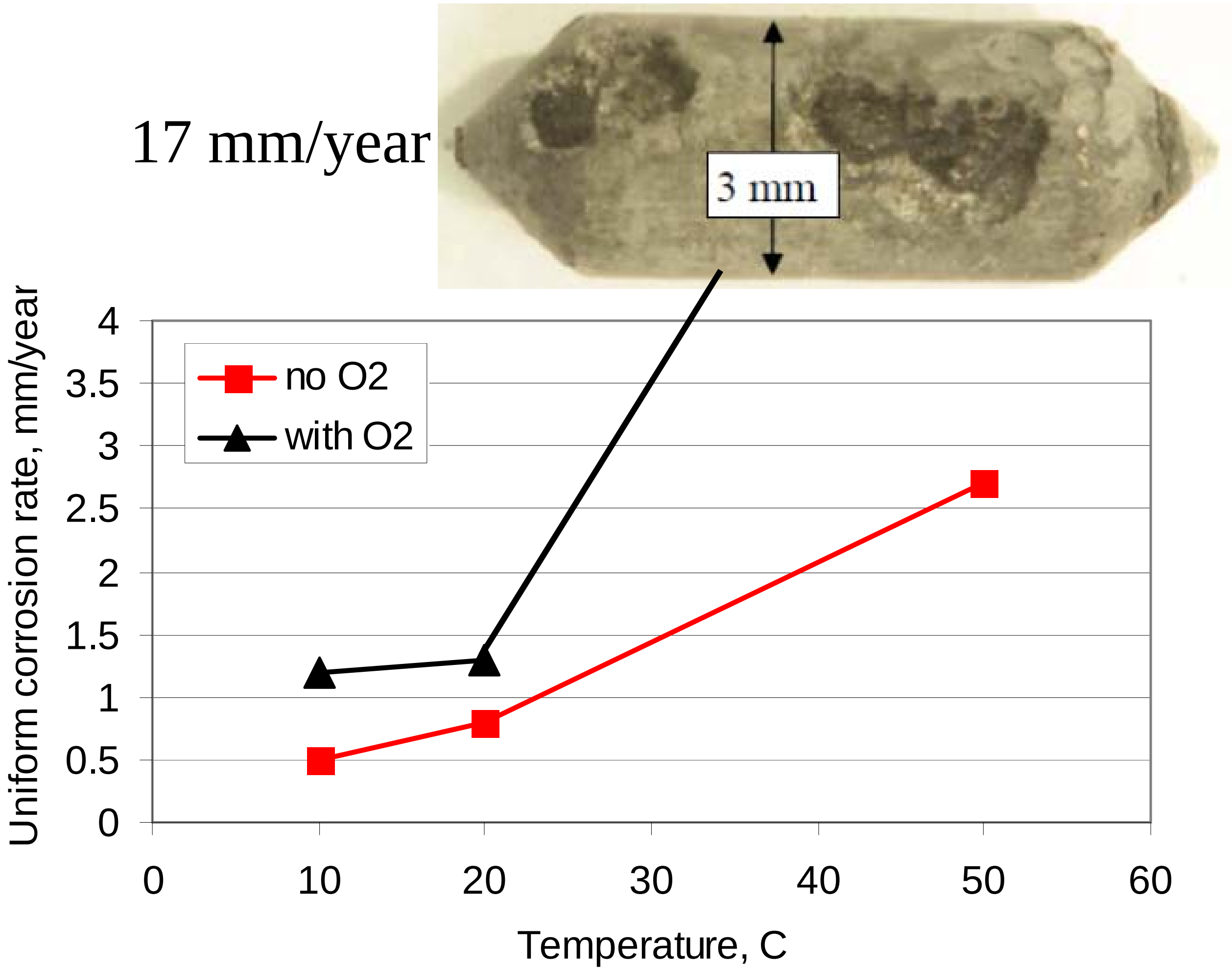




50 um

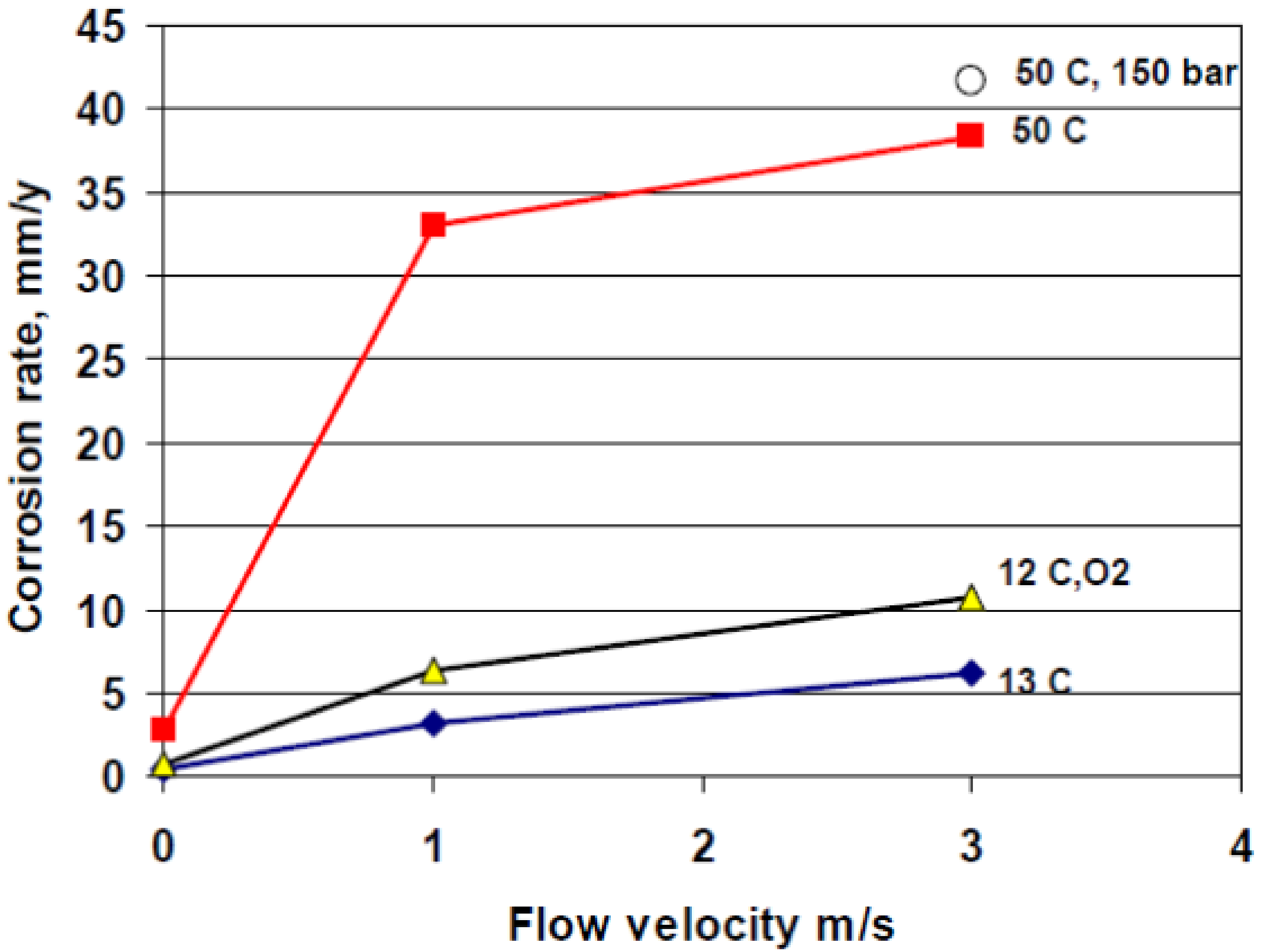
Corrosion rate 1.6 mm/y

Free water phase (50 vol%), stagnant conditions

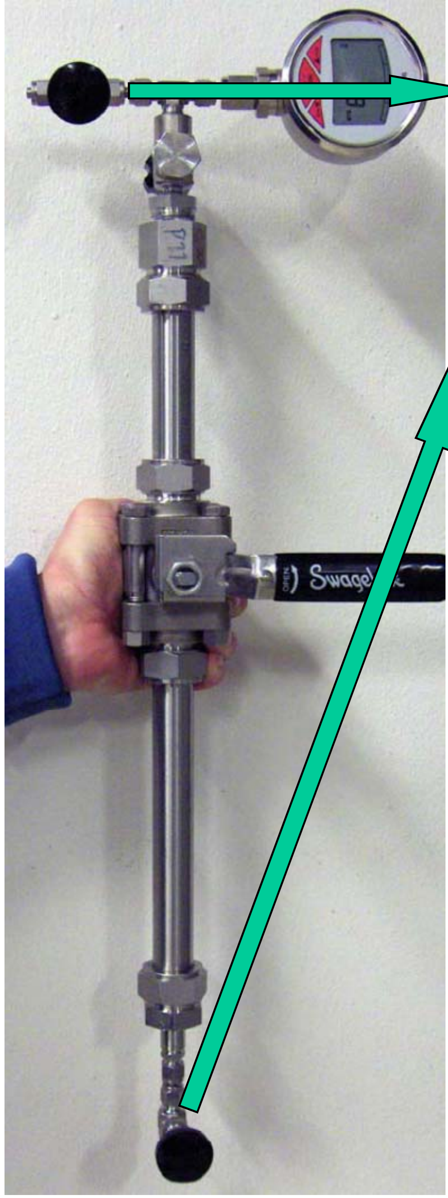


- Start pH 3-3.2
- High cm^2/cm^3 ratio
- Fe^{2+} 90-900 ppm
- pH shift
- Film formation
- Duration 2-3 weeks

Free water, flowing conditions, 10 MPa



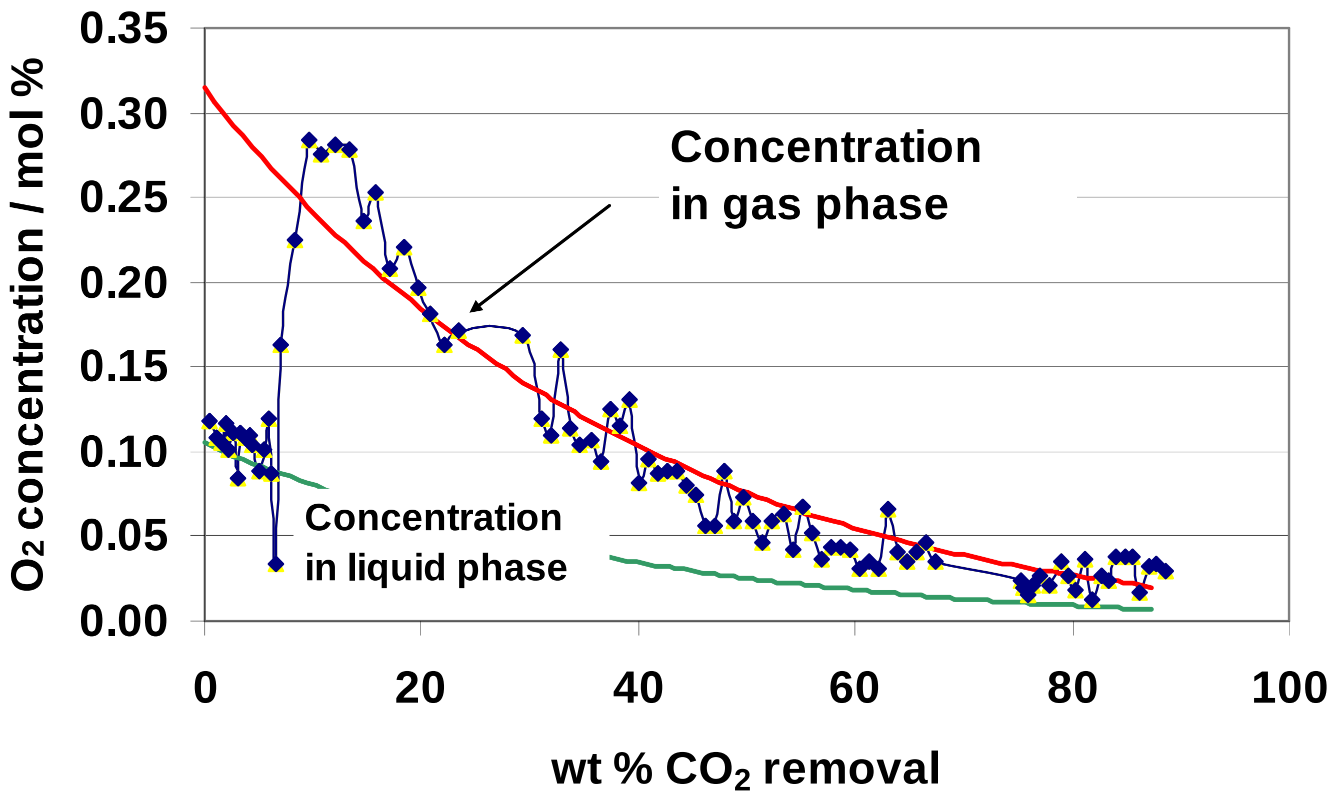
Partitioning



GC: NO_2, SO_2
Dew meter

Partitioning coefficients (gas/liquid)

O_2	H_2S	SO_2	H_2O
2.5-3	0.6-0.8	0.04-0.06	0.2-0.3



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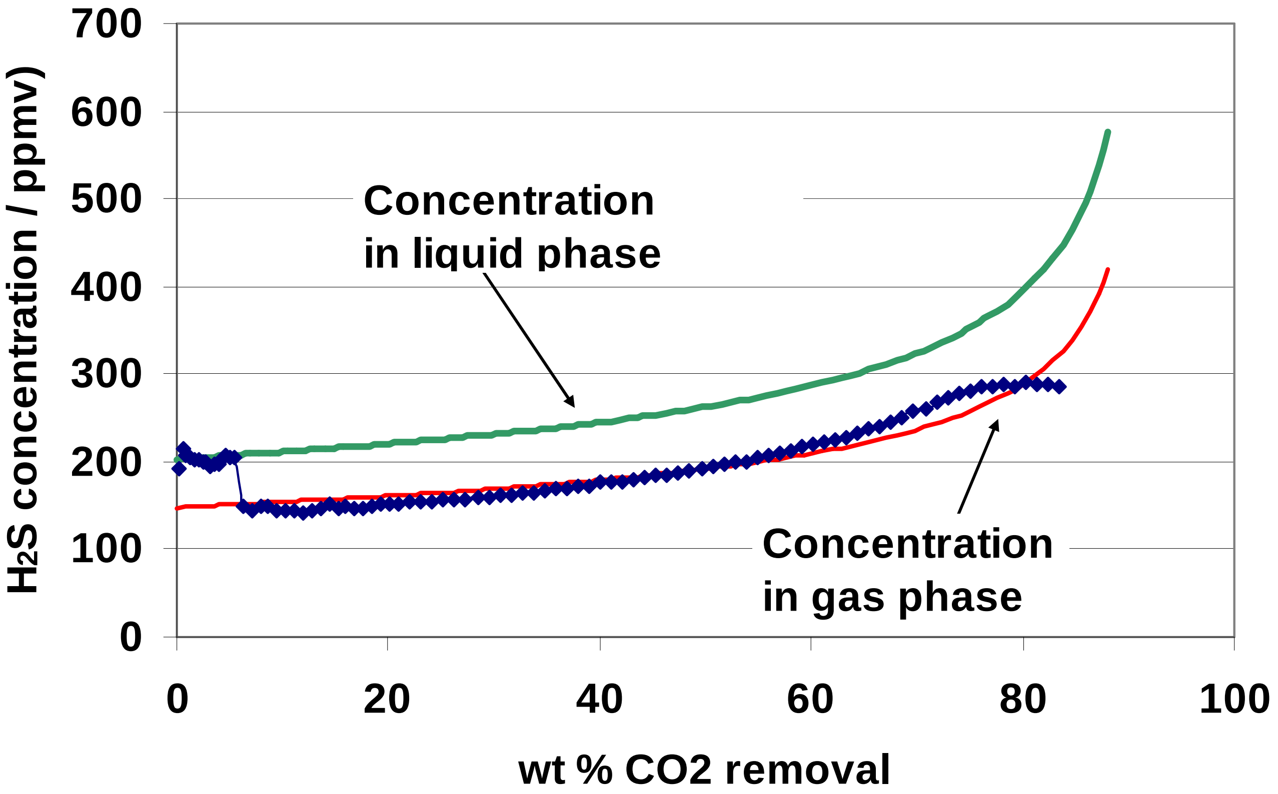
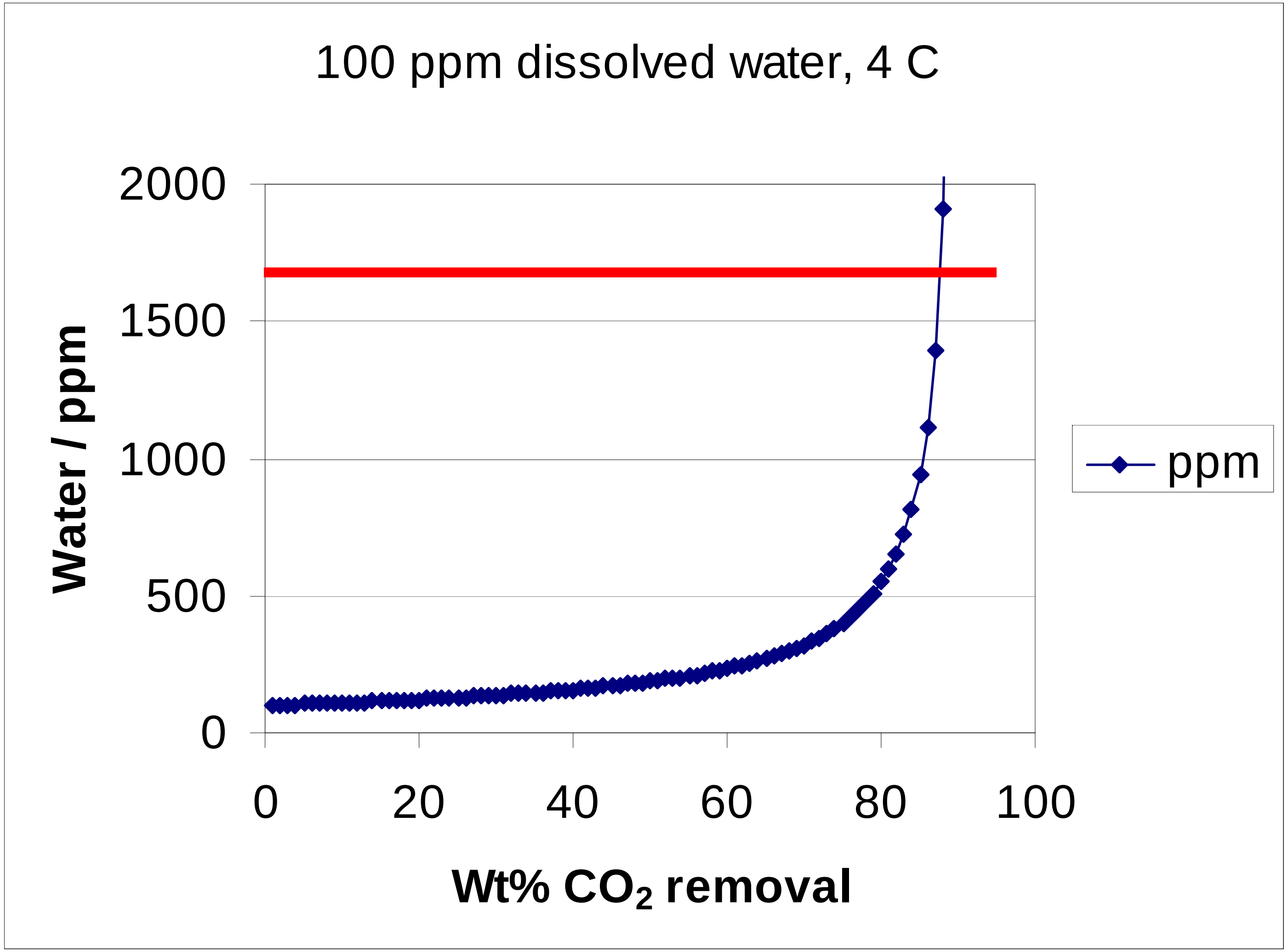
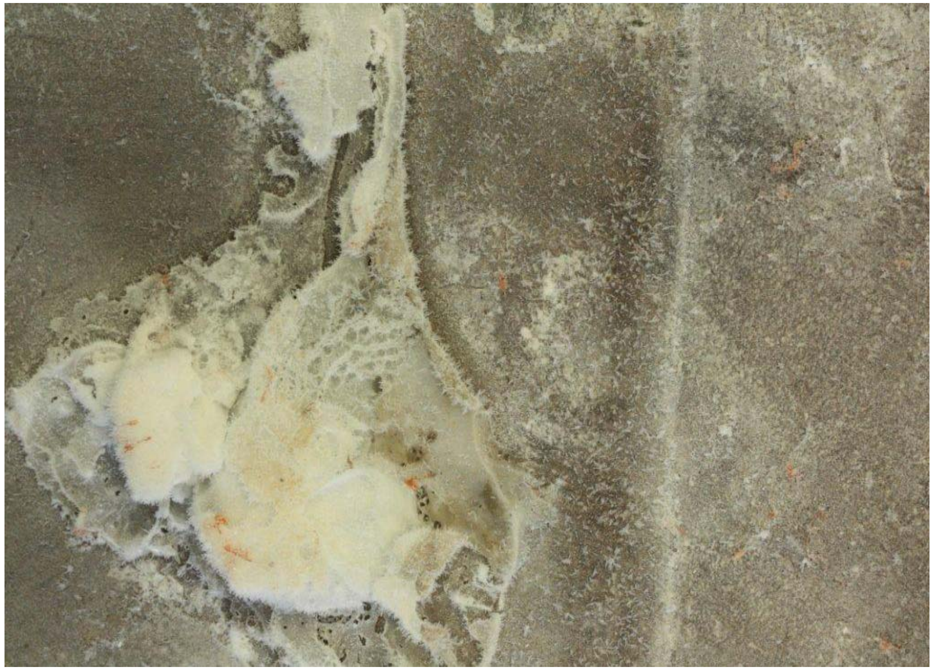


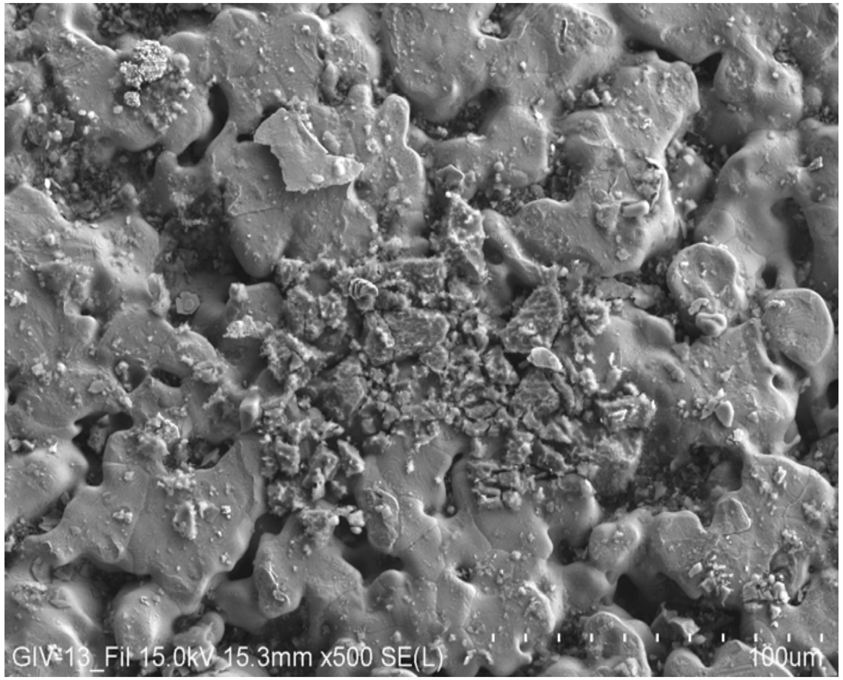
Water accumulation in the liquid CO_2 phase

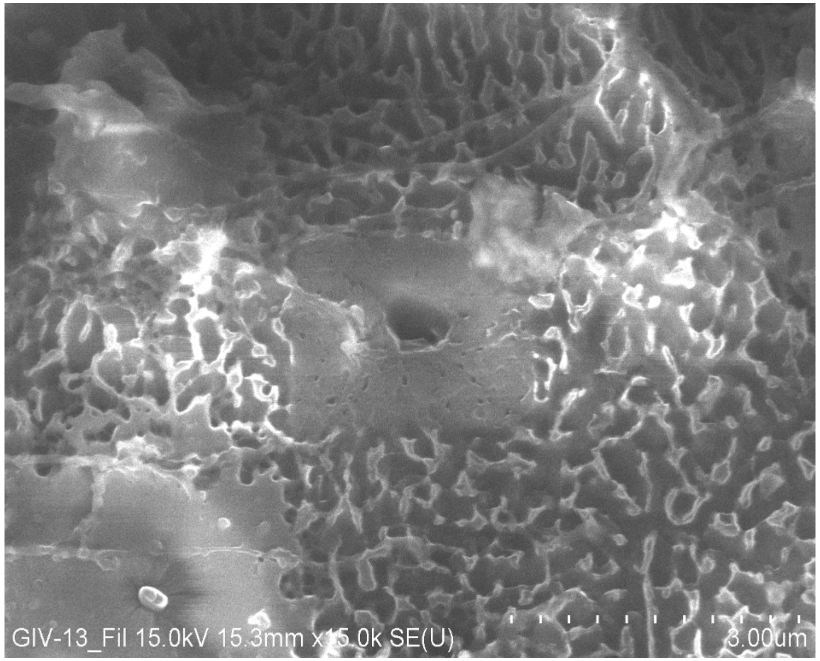


Depressurisation, 50 C, 150 bar, 1000 ppm water

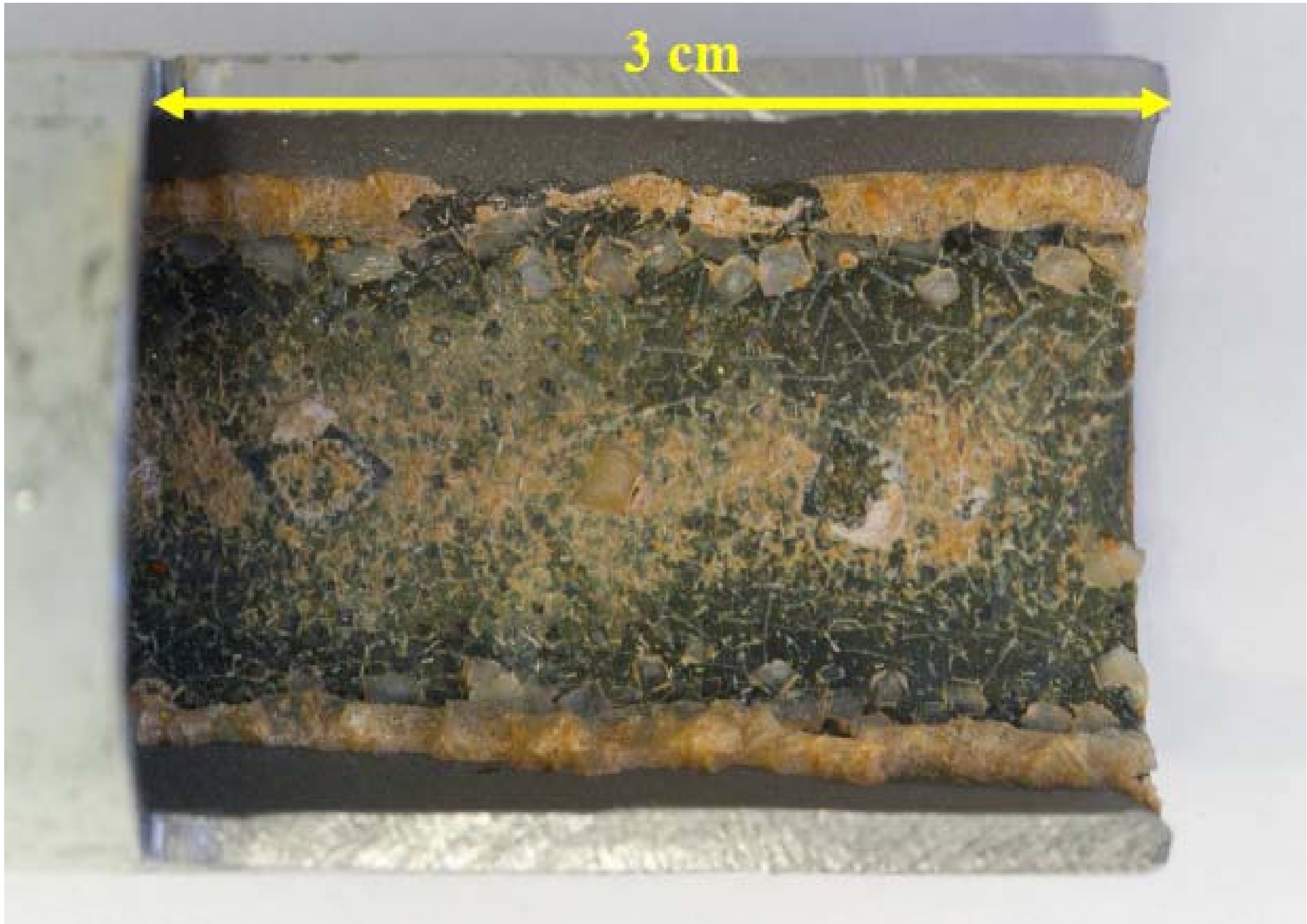


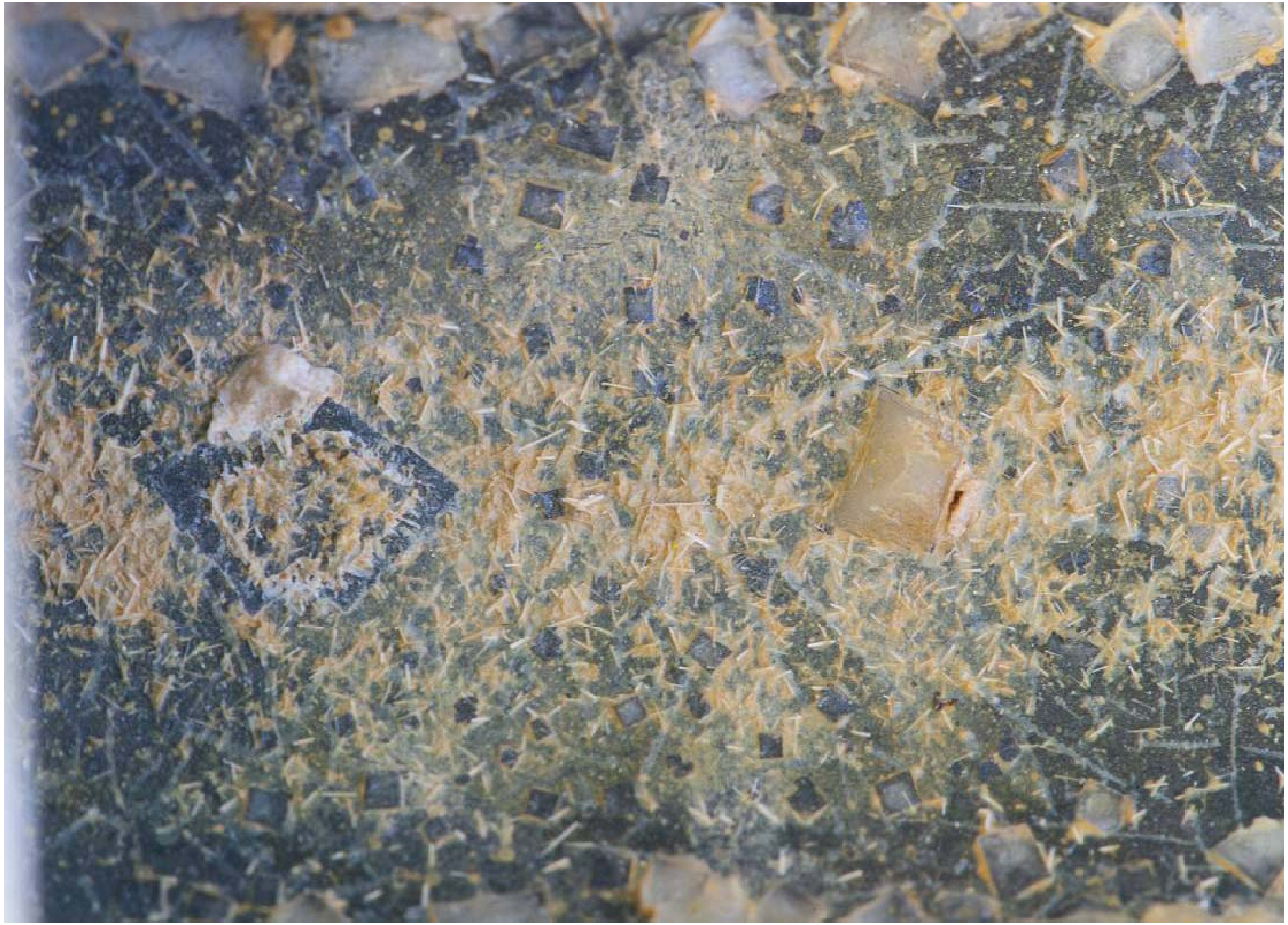
Elemental sulphur on a 0.5 um metal sinter





Salt precipitation, 50 C





Present situation

- Not much focus on corrosion in CCS community
- Less than 10 publication actually reporting corrosion data in dense phase CO_2 with flue gas impurities
- Very little is known about the effect of impurities and particularly about mixed contaminants
- The lack of data makes it difficult to predict corrosion rates and define a safe operation window for transport of dense phase CO_2 originating from different sources with different contaminants
- The acceptable composition of the CCS stream should be agreed upon before the process plants are designed and built!
- Corrosion should be given more attention

Appendix 5

Oil Soluble Inhibitors - Developing an Acceptable Testing Methodology

Oil Soluble Inhibitors
Developing an Acceptable Testing Methodology

Steve Turgoose
Graeme Dicken
WP13 Meeting – Stockholm
8th September 2011

- During the joint NACE/EFC meeting at Corrosion 2011, Houston it was agreed that there were no universally accepted testing protocols for oil soluble inhibitors. A working team has been set up to develop a Guideline for Testing Oil Soluble Corrosion Inhibitors.
- The team members are:
- Andrew MacDonald – Clariant
- Alyn Jenkins – MISWACO
- Mohsen Achour – Conoco
- Yolanda De-Abreu – Nalco
- Graeme Dicken – Intertek CAPCIS (leader)

Questionnaire

- A questionnaire has been circulated seeking some initial input into the thinking and viewpoints relating to the selection of oil soluble products for service and their selection process.

- When would an oil soluble inhibitor be recommended, are there consistent approaches to this question?

- What are the factors that lead to an oil soluble CI recommendation?
  - Oil cut? what level?
  - Flow rate/velocity? What criteria?
  - Other factors, potential for water dropout? Topography? Deadlegs? Operations related preferences?

- What test methods are most commonly used to evaluate OSI?
- As with water soluble inhibitors we need to demonstrate that the inhibitor will be effective versus:
  - General corrosion
  - Localised Corrosion
  - Injection interruption or post batch performance (persistency).
  - High wall shear stress
  - Partitioning?

- Who drives the selection, e.g. are there operator guidelines in place, is the selection based on an individual's preference or experience or is the selection left to the vendor or other third party?
- What are the preferred delivery methods of oil soluble inhibitors and what factors would influence the delivery method?

Test Methods

- Success in field versus test method deployed
- Are the techniques as successful as those that have been used for water soluble products

- When would an oil soluble inhibitor be recommended, are there consistent approaches to this question?
- When continuous inhibition is not applied
- When periodic batch inhibition is sufficient (wet gas, dry gas and low water cut oil lines)

- What are the factors that lead to an oil soluble CI recommendation?
  - Oil cut? what level?
    - low water cut is favourable
    - <5% water cut if flow regime turbulent/mixed – not for stratified flow
  - Flow rate/velocity? What criteria?
    - Low flow is probably favourable so that film is not sheared off
  - Other factors, potential for water dropout? Topography? Deadlegs? Operations related preferences?

- What are the factors that lead to an oil soluble CI recommendation?
  - Other factors, potential for water dropout? Topography? Deadlegs? Operations related preferences?
    - Space limitations for skids for continuous injection
    - Temperature – oil soluble inhibitors tend to be more stable at high T
    - For batch treatment oils soluble products are always recommended

- What test methods are most commonly used to evaluate OSI?

  As with water soluble inhibitors we need to demonstrate that the inhibitor will be effective versus:

  – General corrosion
  – Localised Corrosion
  – Injection interruption or post batch performance (persistency).
  – High wall shear stress
  – Partitioning?

- Who drives the selection, e.g. are there operator guidelines in place, is the selection based on an individual's preference or experience or is the selection left to the vendor or other third party?
    - Normally up to chemical supplier
- What are the preferred delivery methods of oil soluble inhibitors and what factors would influence the delivery method?
    - Responses based on batch treatment

Intertek

Test Methods

capcis™
making a material difference

- Success in field versus test method deployed
- Are the techniques as successful as those that have been used for water soluble products

Appendix 6

Alternative Solutions to Biocides for MIC and Souring Control

Alternative solutions to biocides for MIC and souring control?

Eurocorr 2011, Stockholm, WP 13 Business Party Meeting

Alternative solutions to biocides?

- Currently used biocides are more and more looked as undesirable chemicals.
- We have to anticipate serious restrictions in the use of such biocides, and not solely in the European area.
- Changes should better be initiated by users than only waiting from Regulators or from Suppliers.
- Changes must not compromize our ability to control MIC and reservoir souring.

TOTAL

Our own approach within Total

- **MIC control moves back as a priority within our R&D program in corrosion.**
- **No more focused on how to mitigate it efficiently as during the 90's**
- **Mostly focused on minimizing the environmental impact of its mitigation through:**
  - Optimized mitigation solutions, only when needed,
  - Quick monitoring solutions,
  - Alternate and focused solutions rather than large scope solutions
- **A long term approach, still at the exploratory stage:**
  - What promizing solutions, from medium term to blue sky?
  - What JIPs/ Collaborations to fund?
  - What efforts to dedicate to each topic?

We see an interest to a joined effort at the EFC level

TOTAL

Why / What at the EFC level?

Objectives?

- Formally highlighting and adressing the problem of MIC/ Souring control with increasing restrictions to the use of most biocides,
- **Proposing lines of action to minimize the environmental impact of biocides**, through realistic progressive steps:
  - Reducing/ optimizing treatments,
  - Re-injection,
  - Alternate solutions.

What ? (tentative)

- A joined Workshop with WP 10 (New age of MIC control?), focused on:
  - Present status of MIC and souring issues. Present status on the use of biocides in the oil and gas production industry,
  - Overview of possible alternate or new solutions (monitoring and mitigation)
  - The way forward: Necessary R&D efforts.
- An EFC Green Book, e.g. as "Looking for new solutions to MIC control"

TOTAL

Possible solutions (non exhaustive)

- **Physical treatments**
  - Pigging
  - Bactericidal coatings
  - …
- **Chemical treatments**
  - Synergies of different products, Surfactants
  - Bacteriostatic treatments at low dosage,
- **Biological treatments**
  - Bio-competition, phages, EPS,
  - Quorum sensing
  - …?

A quick and accurate monitoring is a pre-requisite to the application of new mitigation solutions

TOTAL

Any comment?

Any interest?

Any other committee already involved in similar activities, out of EFC?

TOTAL