6ª Jornada de Recuperación Mejorada de Petróleo - EOR
6 y 7 de noviembre - Mar del Plata

INSTITUTO ARGENTINO DEL PETROLEO Y DEL GAS

7° CONGRESO IAPG Producción y Desarrollo de Reservas

Thermal Stability Evaluation of EOR Polymers: Best Practices & Guidelines

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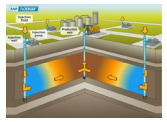
(SNF)

SNF

Introduction



Polymer flooding

- Proven technology worldwide
- Onshore and offshore

Current challenges

- Moving from PIT/pilot to full field
- Deployment in deeper reservoirs → temperature rising
- Looking @ offshore reservoirs → spacing & residence time ↗

Polymer stability in reservoir conditions = major concern

- Variations of protocols from lab to lab
- Bad protocols can lead to biased pessimistic results

Share 10+ years of lab experience and worldwide common practices

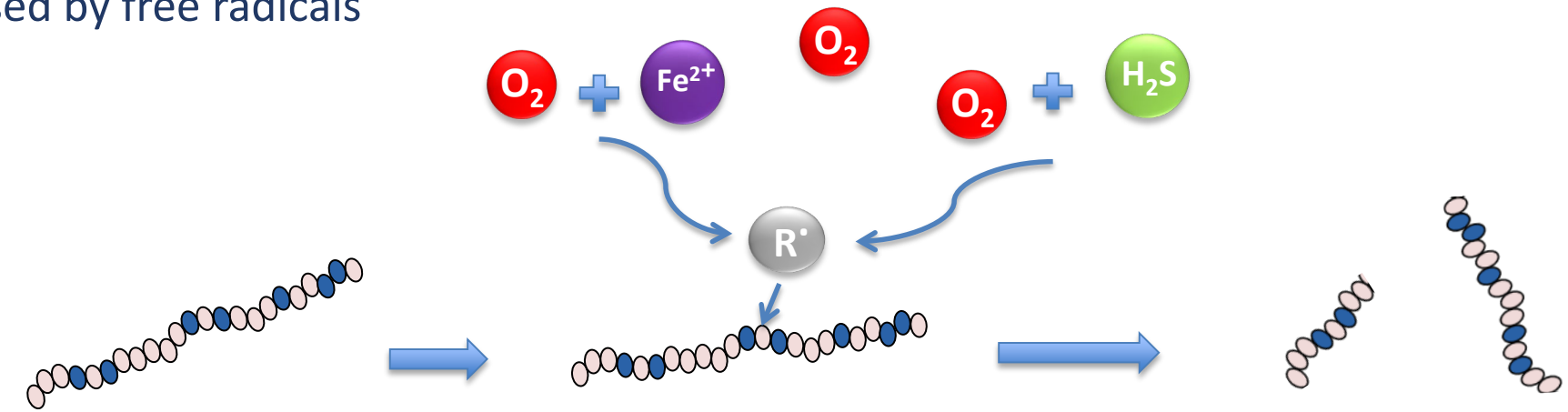
Layout

- Chemical degradation
- Thermal degradation
- Lab practices for thermal stability experiments

Chemical degradation

WHAT IS IT?

- Caused by free radicals



Red/Ox reactions

Viscosity +

R· Free radical

Viscosity -

F3P polymers : Protected Polymer Package

Use of protective cocktails to minimize chemical degradation of polymers

Isopropanol / Thiourea / Water (ITW) – injected in Oman : huge amount of chemicals (300 ppm) cost + toxicity + flammability

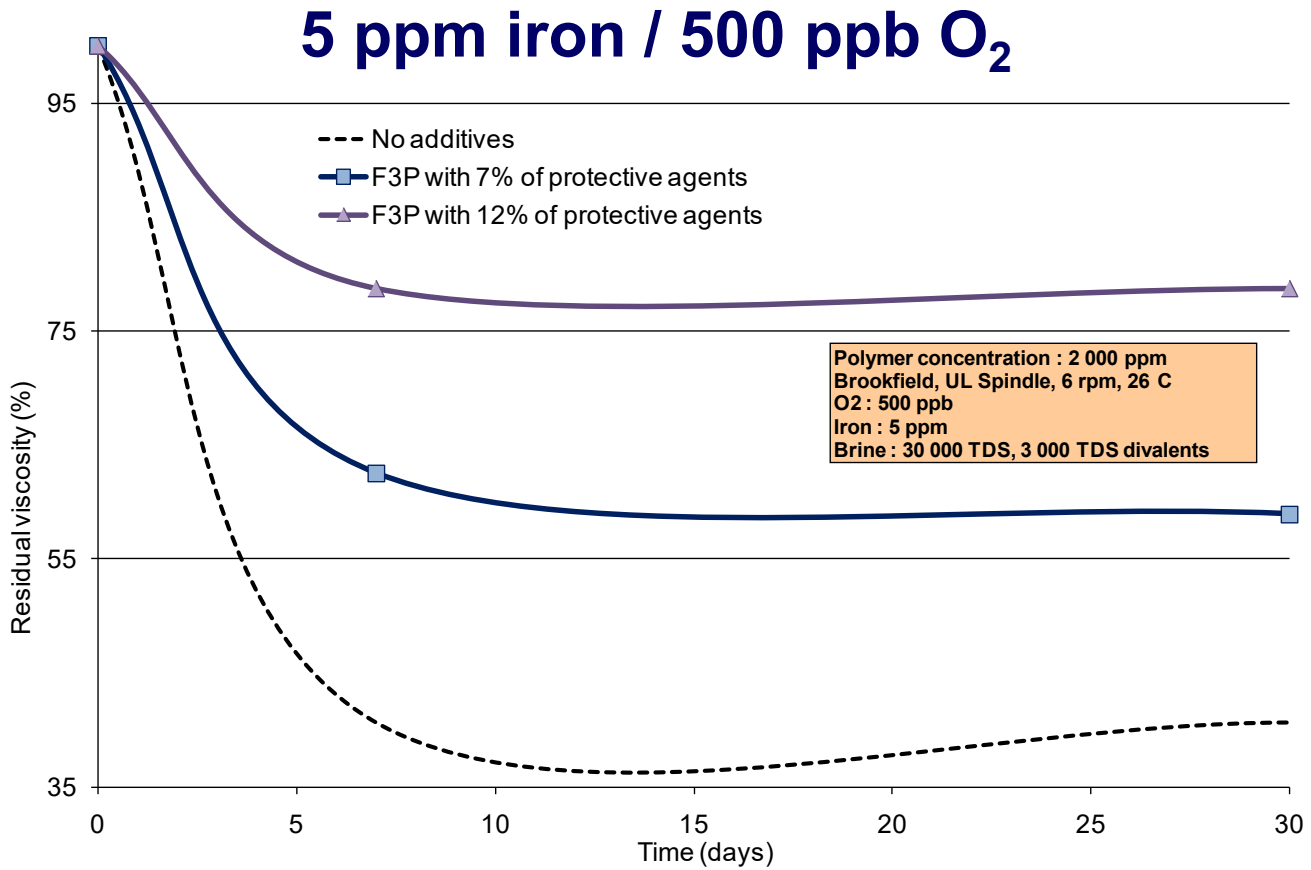
Friendly additives can be added in polymer formulation

- Protective package added at the manufacturing stage
- Package tailored to field conditions
  - Iron content
  - H2S content
  - O2 content

SPE 129756 Patent WO 2010/133258



Impact of iron on stability



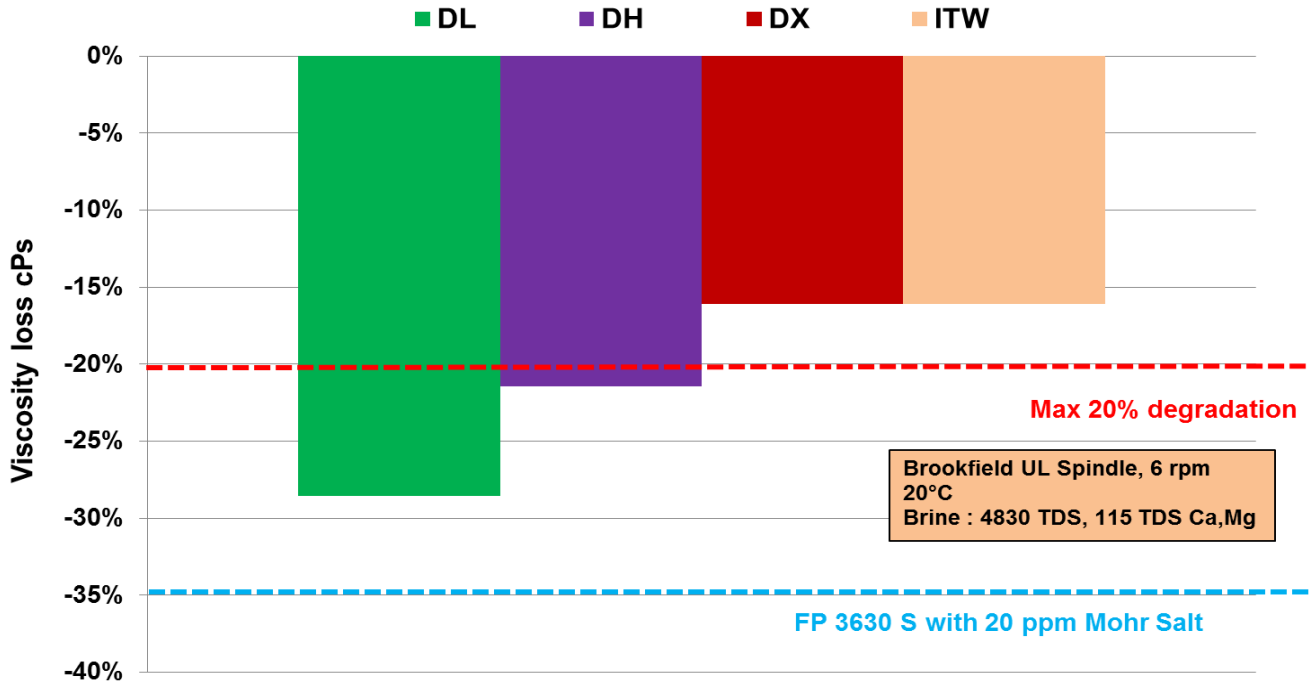
Integration of protective additives in the polymer formulation (F3P) significantly decreases polymer viscosity loss due to contaminant

Fast Stability tests : Stability to Fe2+/O2

Experiment = 20 minutes at air atmosphere : addition of 20 ppm of Mohr salt in a solution of polymer

FP 3630S (1000 ppm)

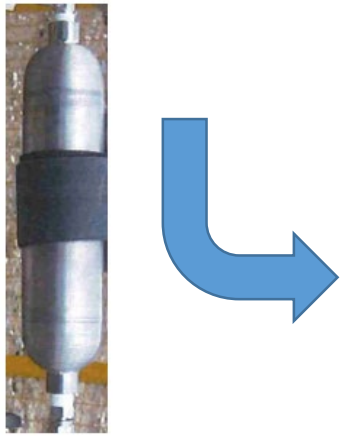
ITW = 10% thiourea+ 20% isopropanol

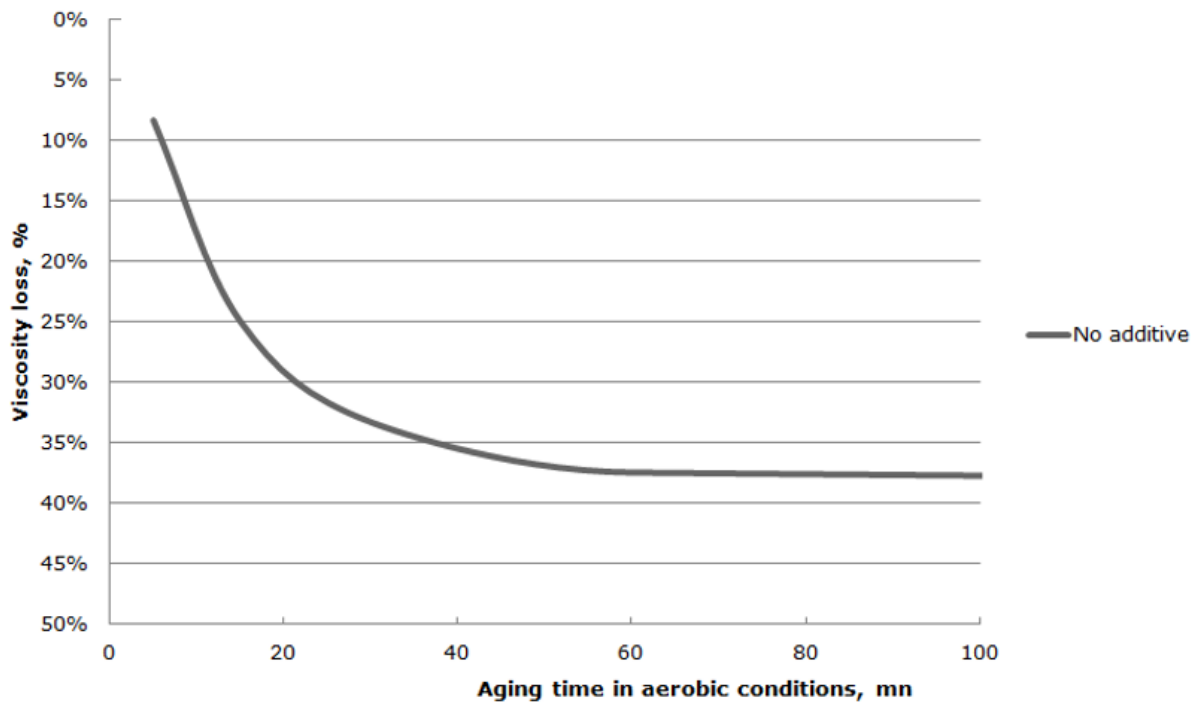


Non protected polymers → degradation = 35%
Fine-tuned protective package DX and ITW → less than 20% of degradation

Sampling on site : oxidative degradation

- **50 ppm of H2S in injection water, no oxygen**
- **Sampling container filled to avoid any shear degradation and oxygen ingress**
- **Back to the lab : exposure to air atmosphere**

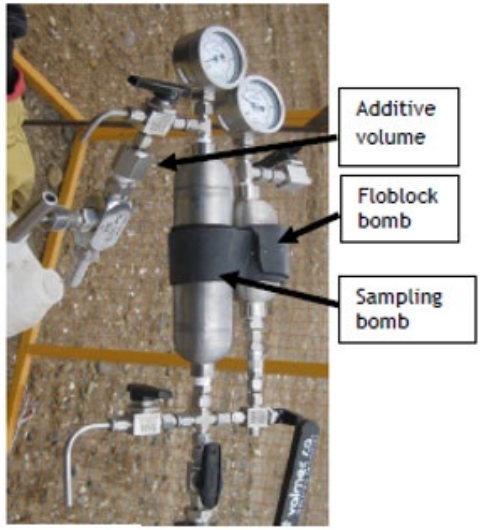




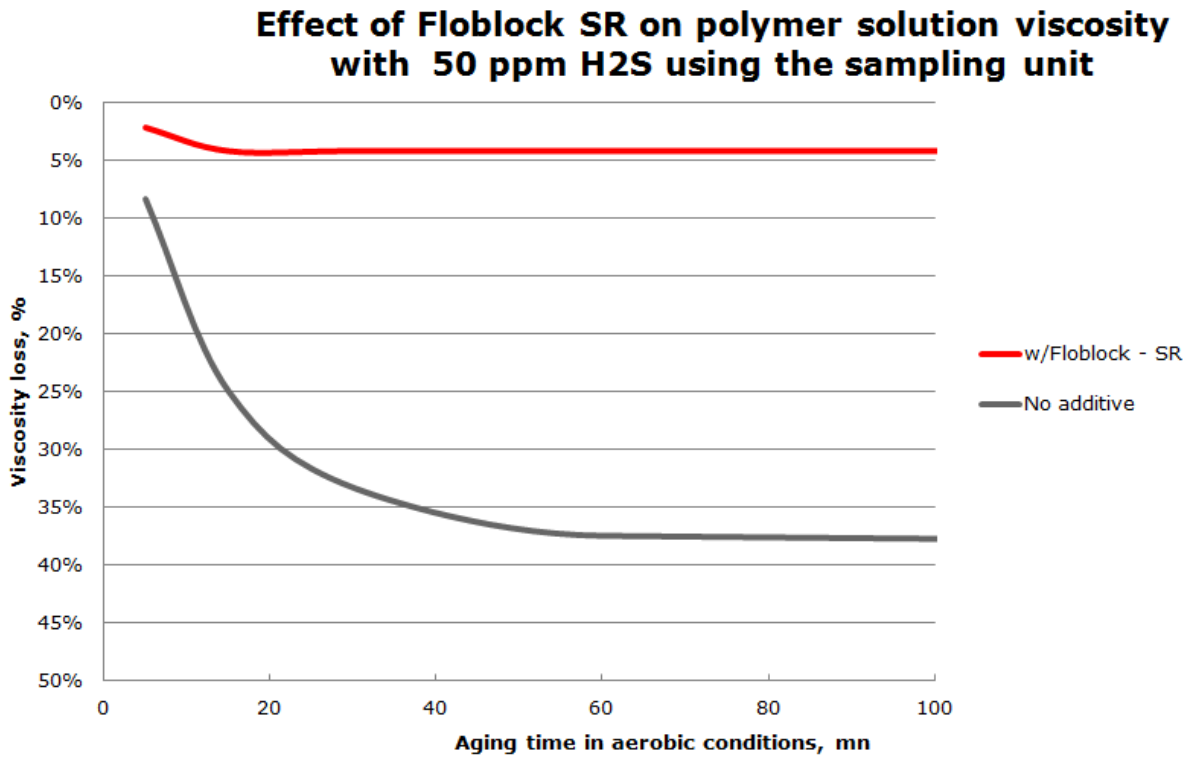
Sampling on site to avoid oxidative degradation

Addition of protective additives during sampling

Sampling unit in field conditions



Exposure to air



SPE 164121

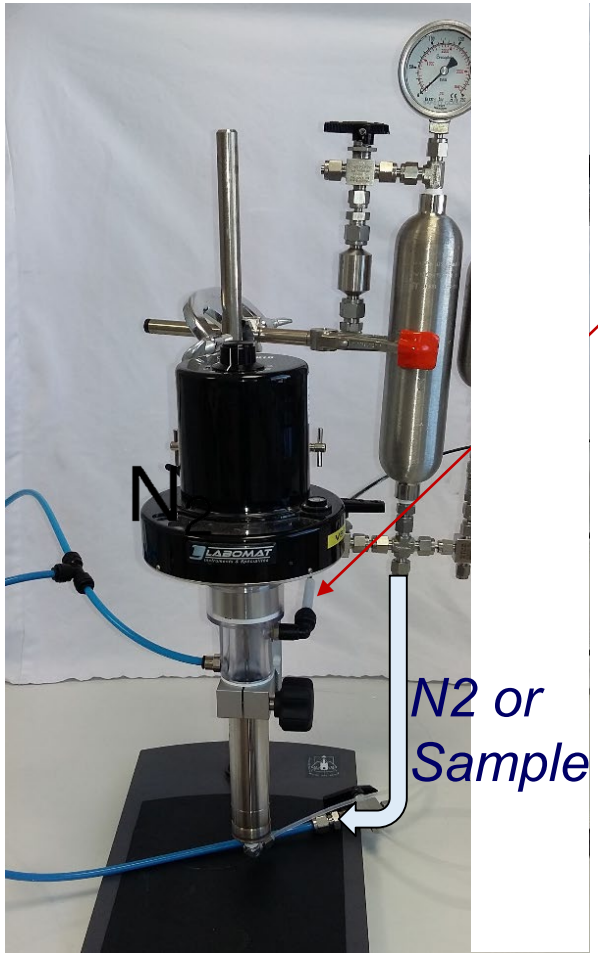
Effective Propagation of HPAM Solutions through the Tambaredjo Reservoir during a Polymer Flood

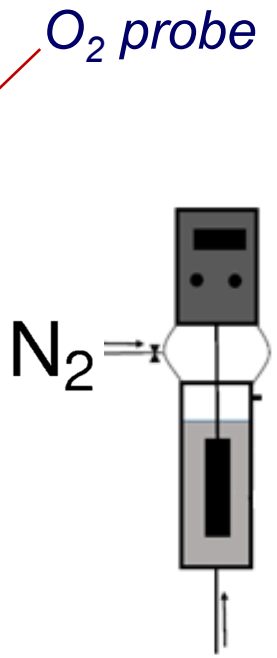
R.N. Manichand, SPE, K.P. Moe Soe Let, SPE, Staatsolie Suriname, J. Kiefer, SPE, L.Gil, SPE, B.Quillien, SPE, SNF SAS, and R.S. Seright, SPE, New Mexico Tech

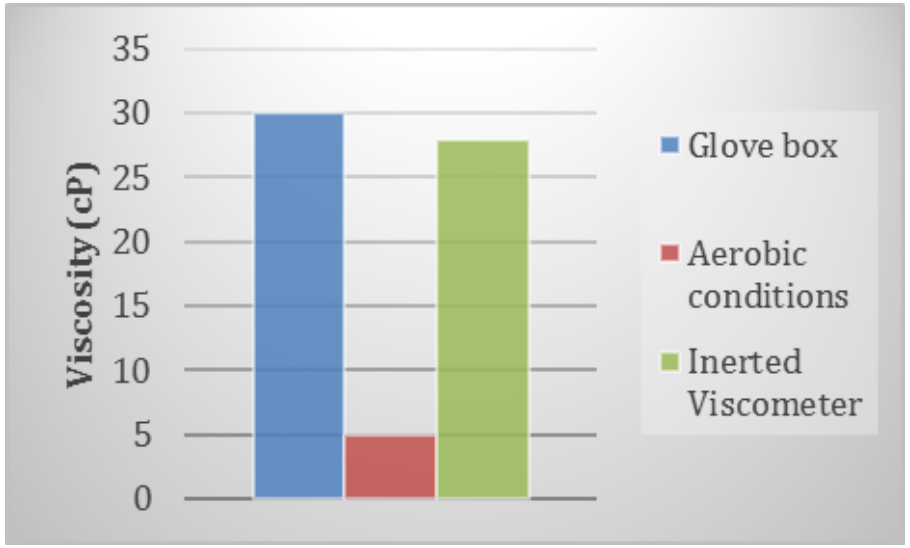
This paper was prepared for presentation at the SPE International Symposium on Oilfield Chemistry held in The Woodlands, Texas, USA, 8–10 April 2013.

Sampling to avoid oxidative degradation : O2F

Specific design to transfer the sample from the sampling container to the Brookfield cup under nitrogen







Mitigation of oxidative degradation

Chemical degradation

- Chemical degradation occurs in presence of contaminants and especially **oxygen, iron, H2S**
- Reaction between these contaminants => formation of free radicals => degradation of polymers

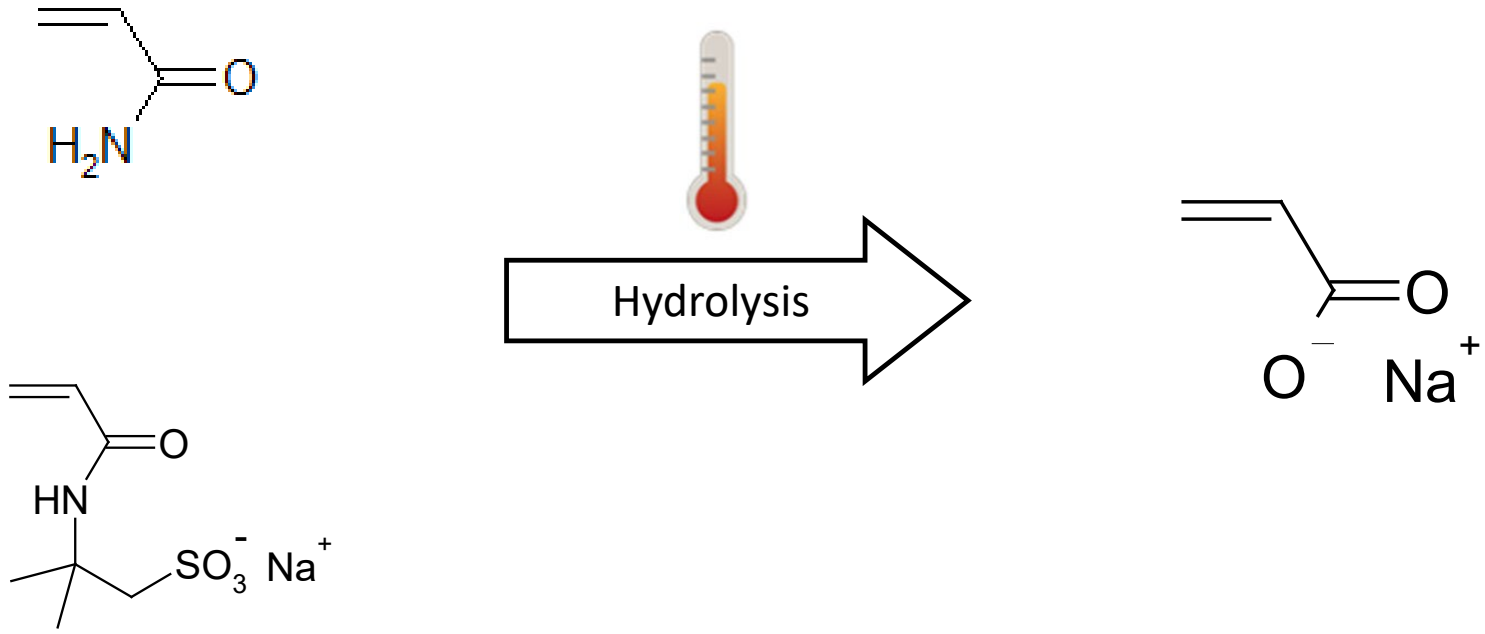
- Reducing polymer degradation encompasses:

  - Adapting injection strategy and auxiliary chemicals → **NO OXYGEN = NO PROBLEM**
  - Adapting chemistry and including protective additives → **F3P**
  - Sampling on site can lead to mis-leading results → **use of appropriate sampling and measuring tools**

Thermal degradation of polymers

Thermal degradation of polymers

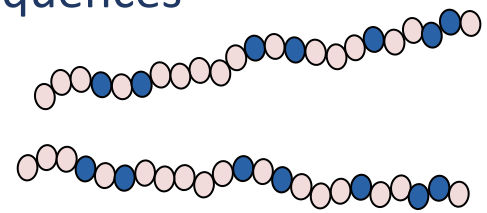
- **Mechanism**



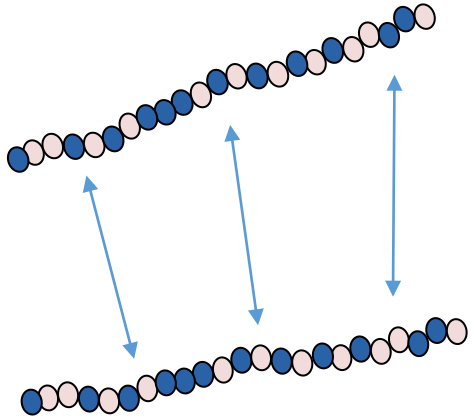
Introduction

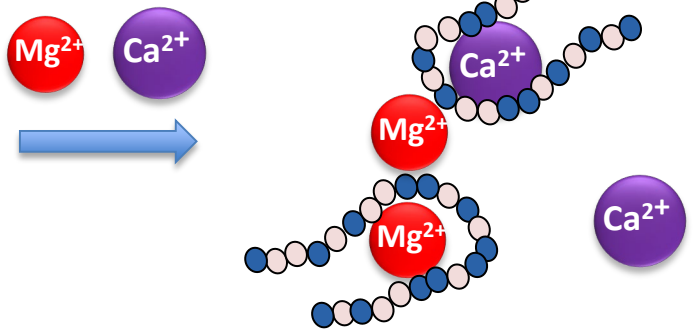
Thermal Degradation

- Consequences



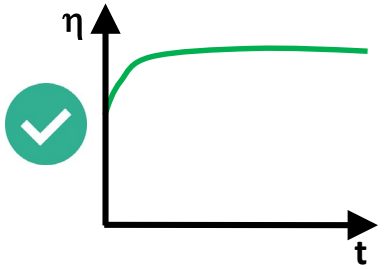
Hydrolysis



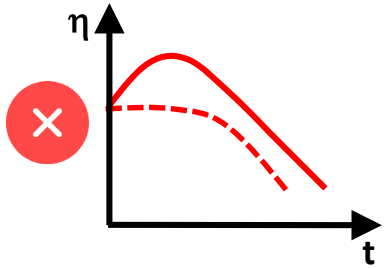


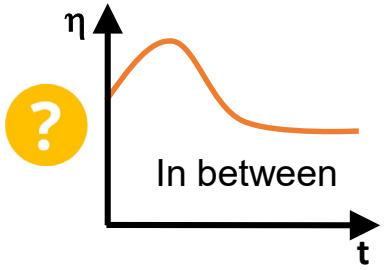
- Negative charge

no/low divalents



with divalents





How to Mitigate Degradation?

On the field

- Choose the right polymer
- N_2 blanketing
- O_2 scavenger
- Reservoir = strong reducer

In the lab

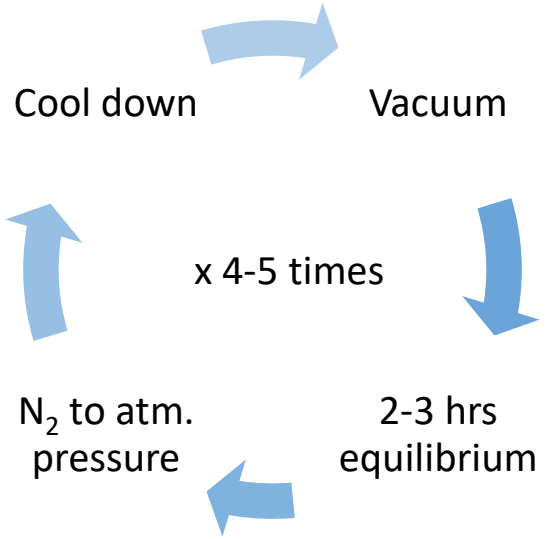
- Specific protocols are required

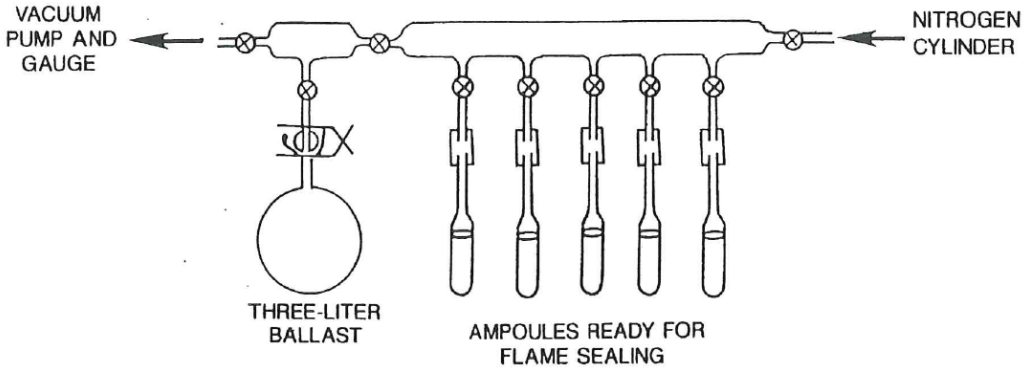
lab evaluation artefacts can kill projects

API Recommended Practice

Preparation of vacuum sealed glass ampoules

- Several cycles procedure rarely fully applied



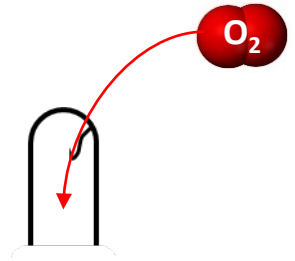


- $[O_2]$ ↘↘ ≈ 100 ppb
- Risks and limitations

time consuming

cuts

burns



cracks (O_2 ingress)

(Levitt *et al.*, 2008, SPE 113845)

Prefered Glove Box Method

Advantages

- Ultra low dissolved [O_2] (≈ 5-15 ppb)
- Time saving
- Only one cell/condition for the whole study

NMR characterization

In-glovebox viscosity measurment

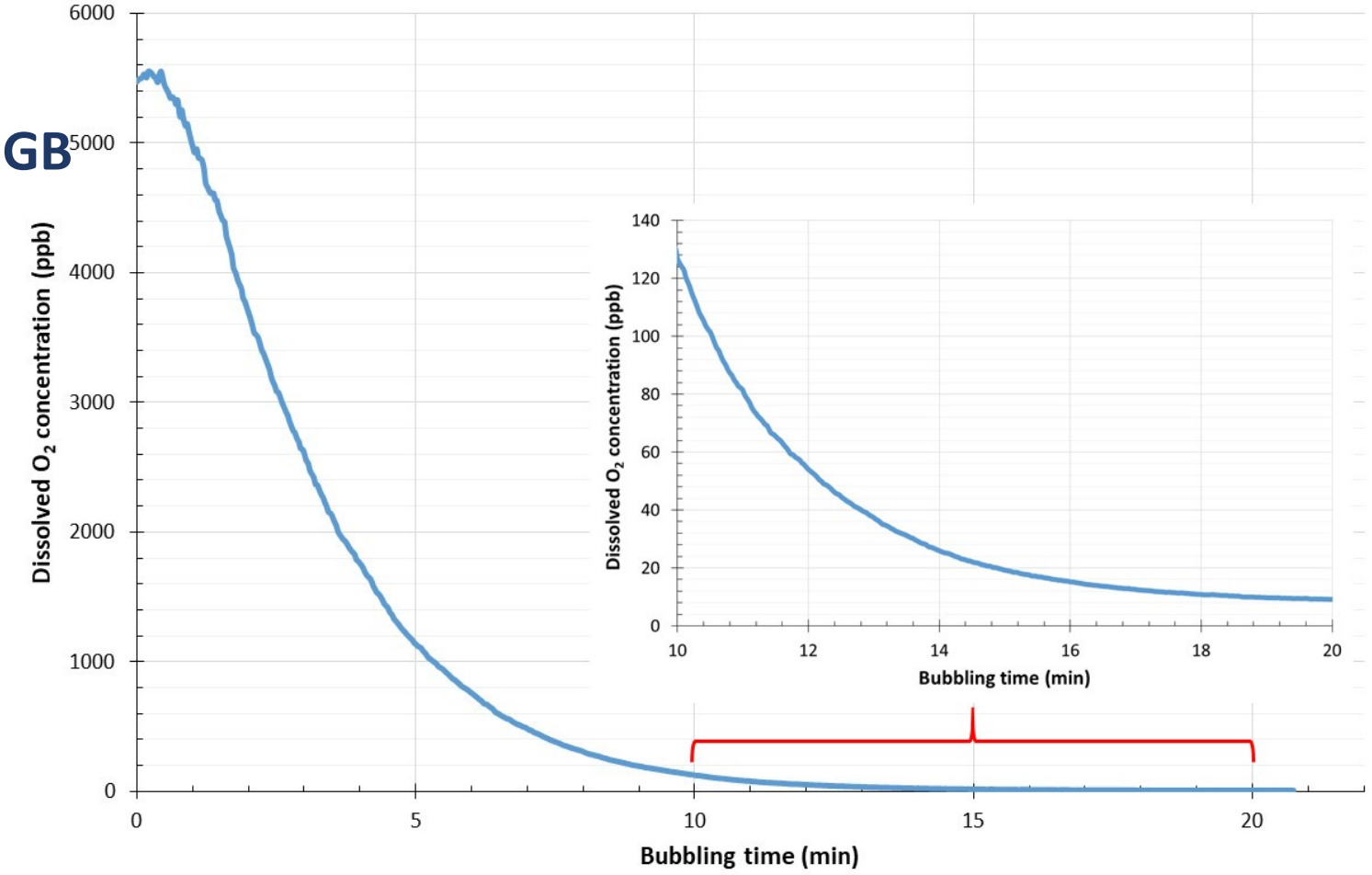
(Sandengen *et al.*, 2017, Journal of Pet. Sci. Eng. 158 (2017) 680-692)

Polymer Preparation

Option 1 = polymer preparation in GB

- Brine deoxygenation
- Dissolution & dilution of the polymer solution

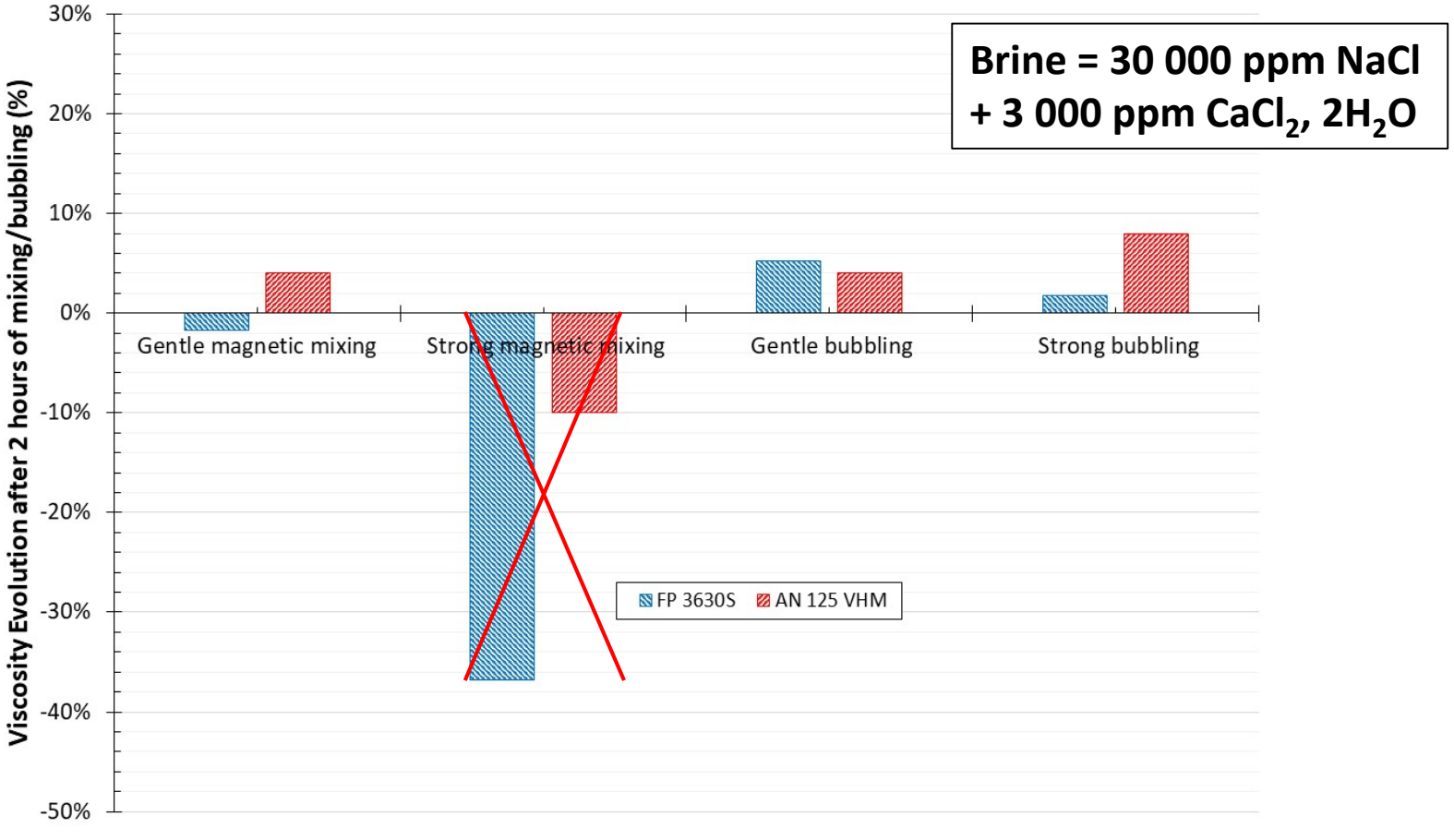
1L brine sample
=
20 min bubbling time

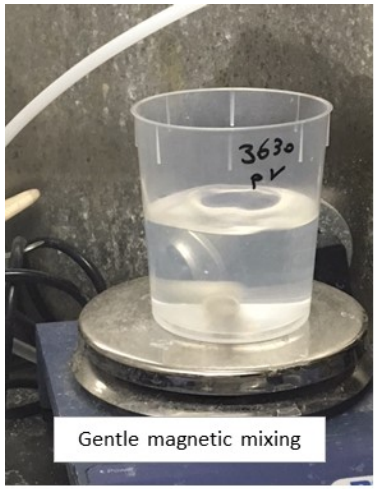


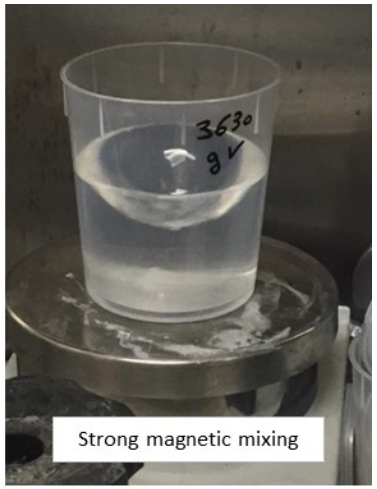
Polymer Preparation

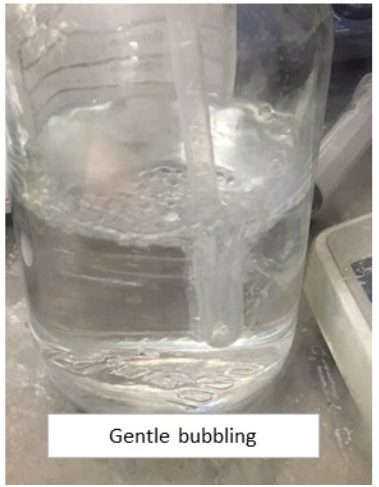
Option 2 = polymer preparation outside GB followed by deoxygenation in GB

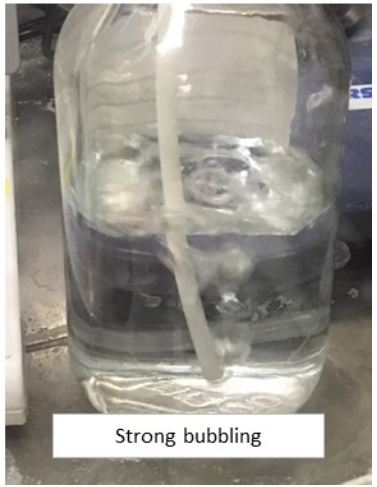
- Impact of deoxygenation method











Impact of Container Type

Ampoules / Bottles commonly found in the EOR labs



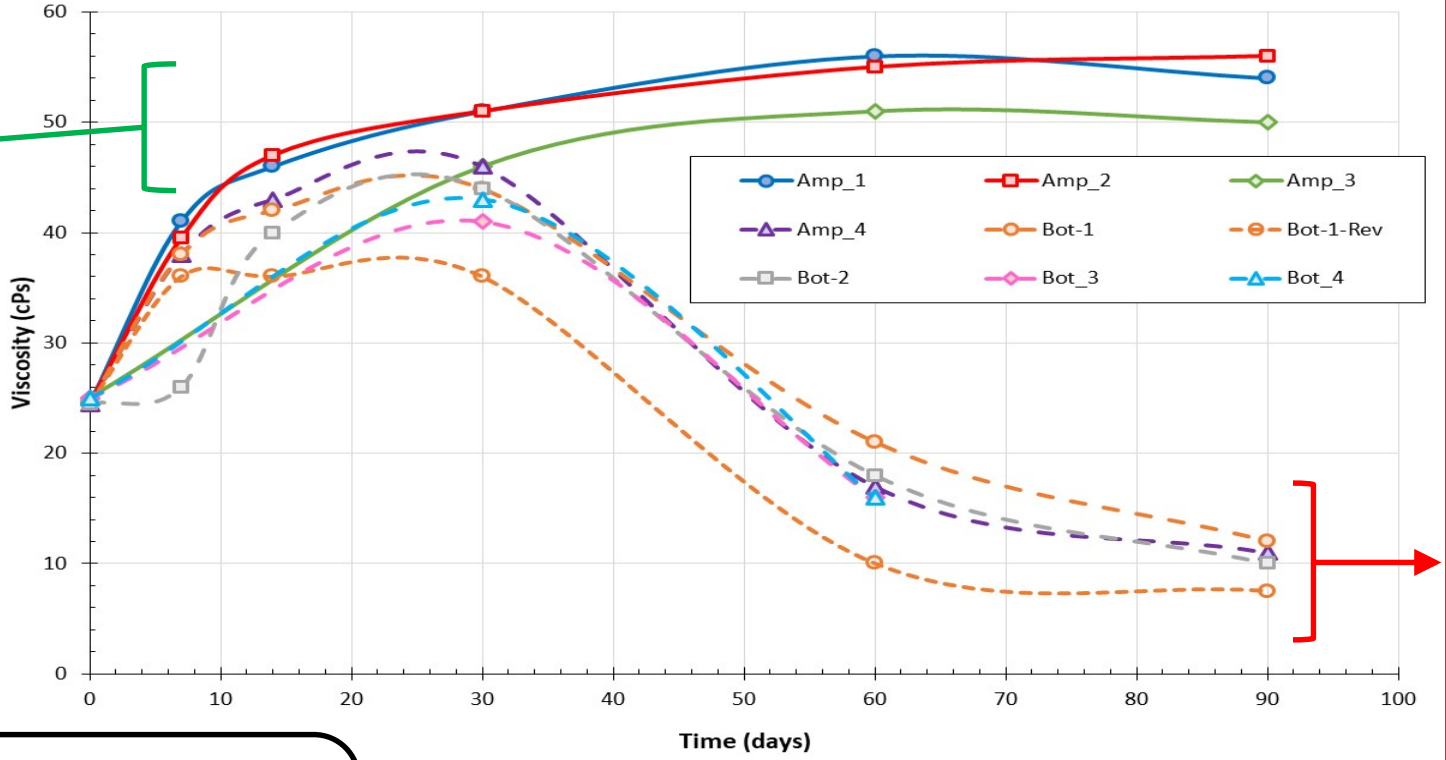


Impact of Container Type

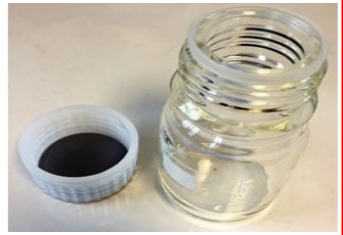
AN 105 VHM in 30 000 ppm NaCl (78°C)

Amp_1

Amp_2



Amp_4



Bot_1

Bot_2, 3 & 4

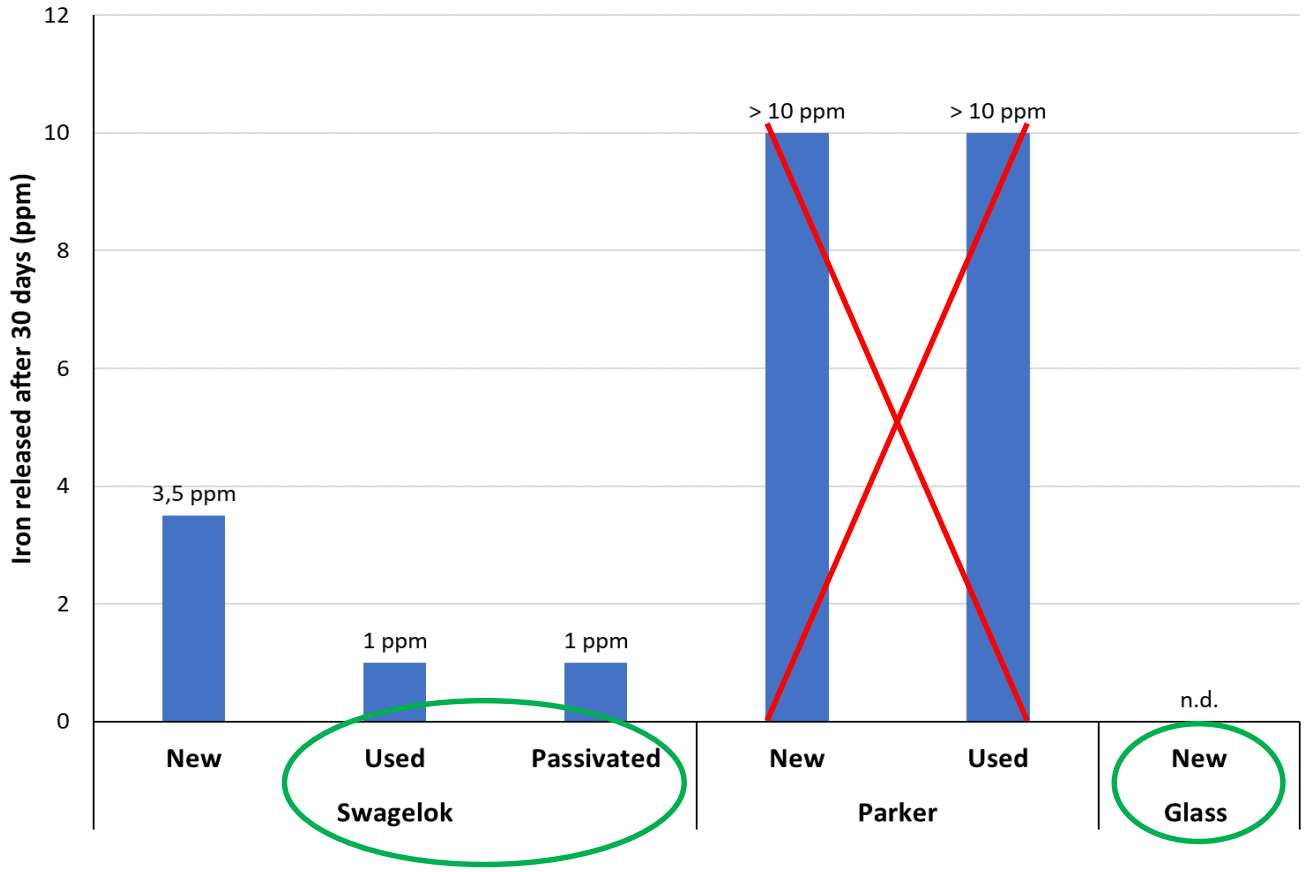
Learnings

- Ensure sealing
- Avoid contact with seals or o-rings

Leak suspected + contamination with radicals

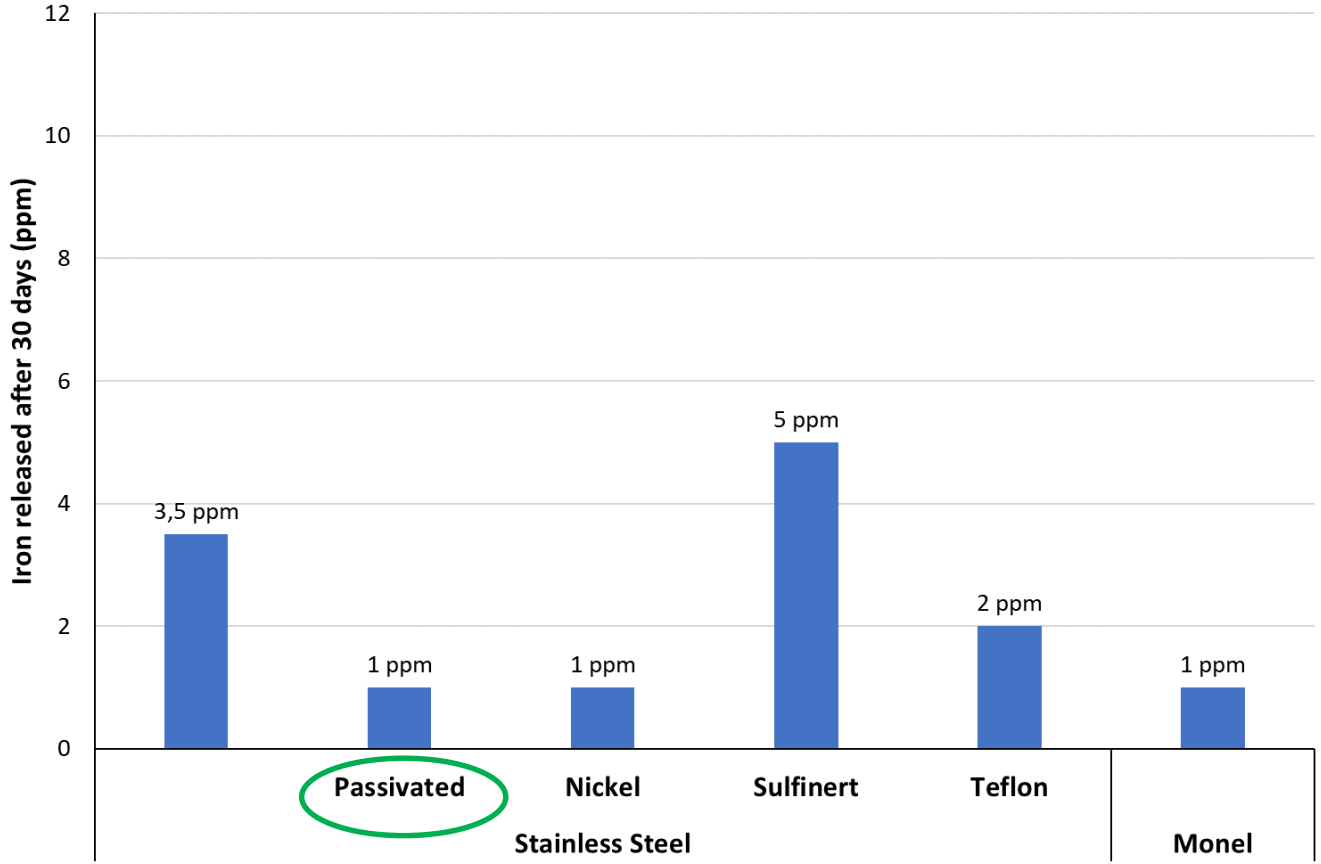
Ampoules Provider Matters

AN 105 VHM in 50 000 ppm NaCl (105°C)



Does Surface Treament or Alloy Make It Better?

AN 105 VHM in 50 000 ppm NaCl (105°C)



Conclusions

Glove box = reliable, efficient ultra O2 conc. (≈ 5-15 ppb)

Polymer solution can be prepared either in/outside the glove box

- Be careful with stirring the polymer solution for deoxygenation
- Nitrogen bubbling is preferred

Choice of the container is key

- Main commercial ampoules/bottles are subject to leak during cooling/heating
  - Pessimistic stability results
- Homemade glass ampoule was developed with specific glass to glass sealing

THANK YOU

Questions

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