Electrodialysis for cEOR

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Outline

- Introduction

What is EDR?

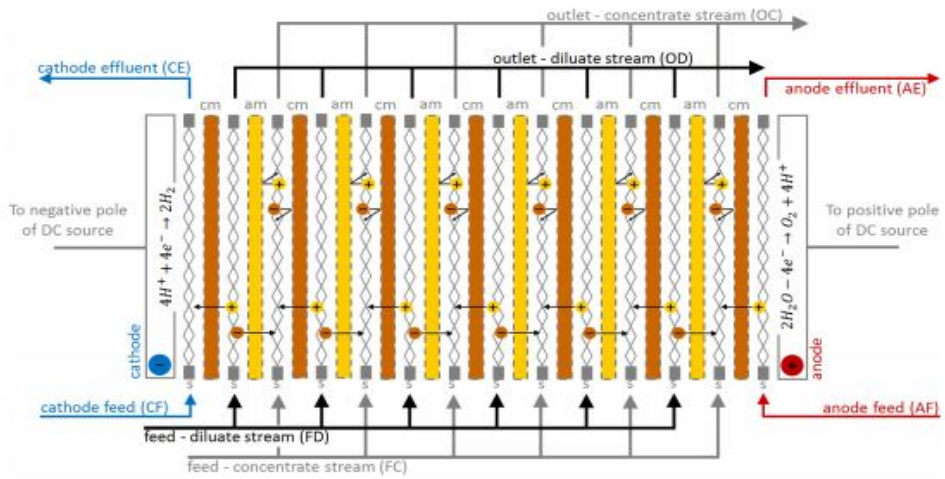
Desalination in cEOR?

EDR Challenges?

EDR in the context of Total O&G projects?

- Material & Methods
- Results at large scale (30 m^2)
- Conclusions and perspectives

Introduction : What is EDR?



Advantages

Water does not permeate through the membrane
→ Less fouling than RO

Current intensity directly related to desalination rate

Potential Drawbacks

Resistance to temperature < 45°C

Require high footprint at high salinity (>10 g/L)

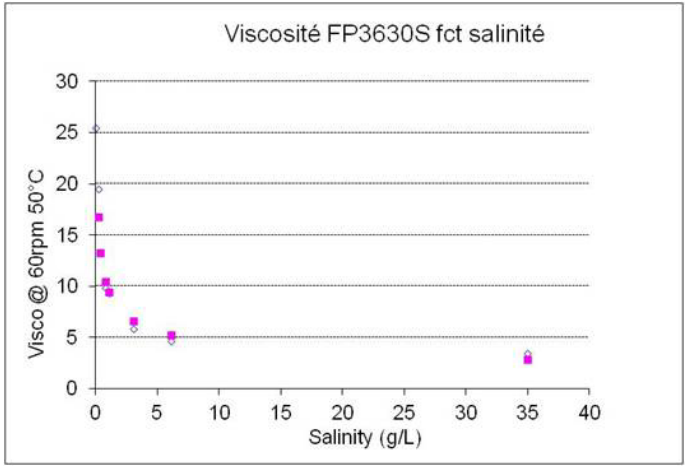
Not competitive for desalting at very low level

Non-ionic species are not treated

Introduction : Why EDR?

- In Chemical EOR, the lower the water salinity, the lower the polymer concentration required to reach a viscosity target

Water salinity	Polymer concentration to reach 10 cP at 55 C (measured at 7 s-1)	Polymer concentration reduction
Base case:6 g/L	1210 ppm	reference
Scenario 1: 1 g/L	545 ppm	-55%
Scenario 2: 0.4 g/l	363 ppm	-70%

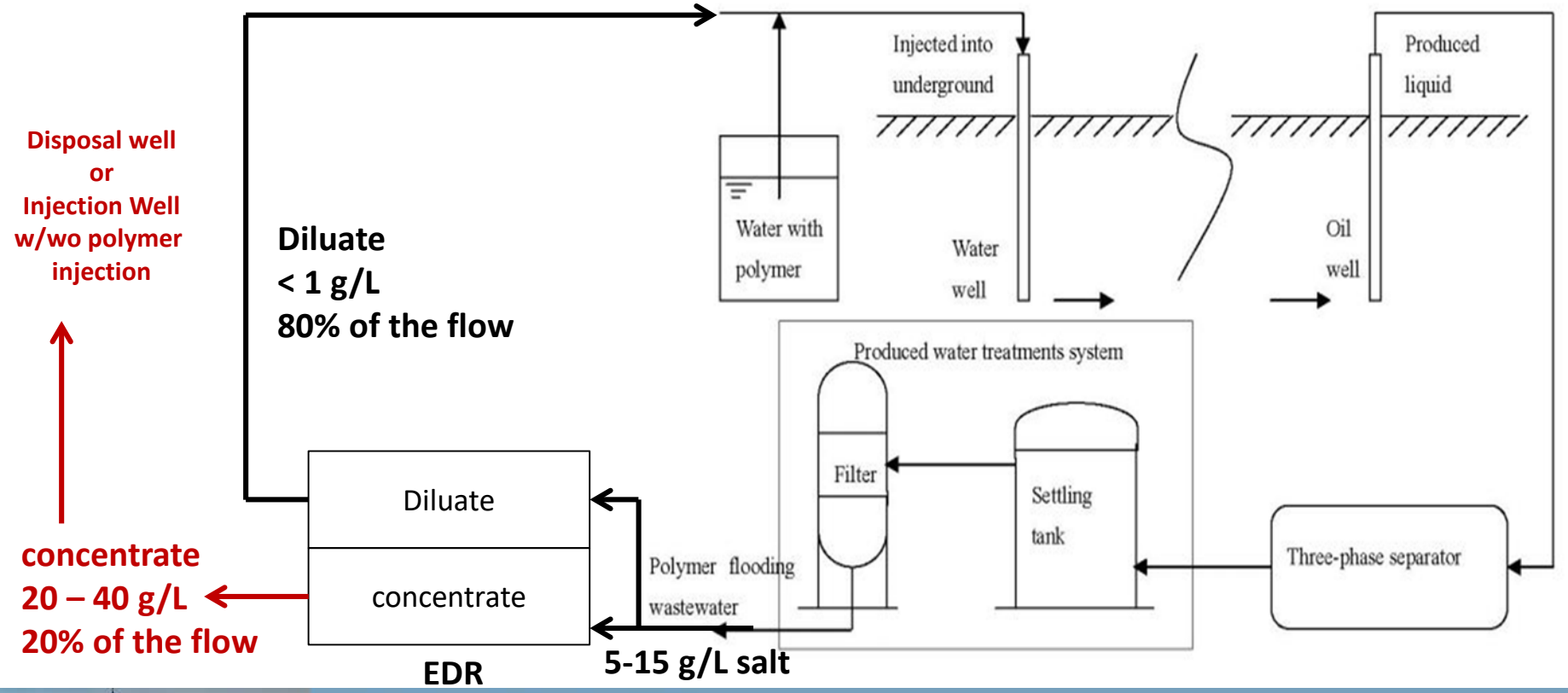


- Less polymer = less OPEX (powder handling, less loading and unloading of large quantities of polymers, fewer trucks, less polymer in the back produced water)
- EDR seems the best compromise for desalting viscosified PW.

  Reverse Osmosis gets fouled by long polymer chains.

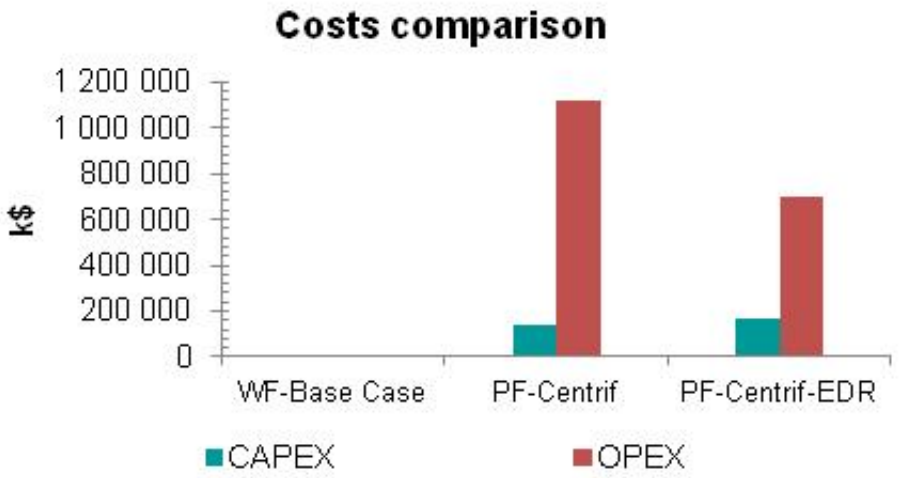
  Evaporators consume a lot of energy and could get fouled in presence of polymer at high temperature.

Introduction : EDR in the context of a Total project



Introduction : EDR in the context of a Total project

Economics



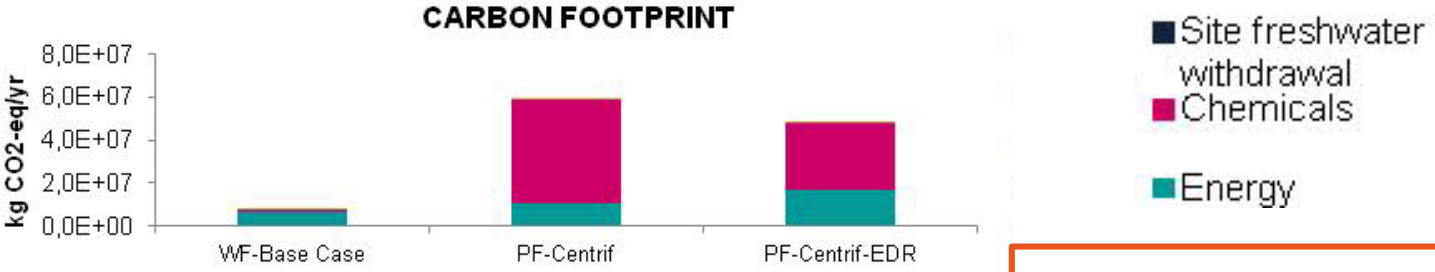
Wat – R – Use ® results

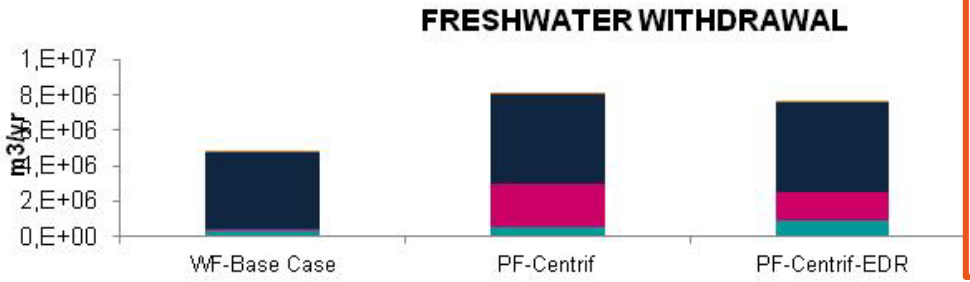
EDR needs oil polishing treatment (Walnut shell filter, centrifugation or membranes)

Slightly higher CAPEX (~50M€) but major saving in terms of OPEX (>400 M€) when using EDR

Introduction : EDR in the context of a Total project

Environment indicators





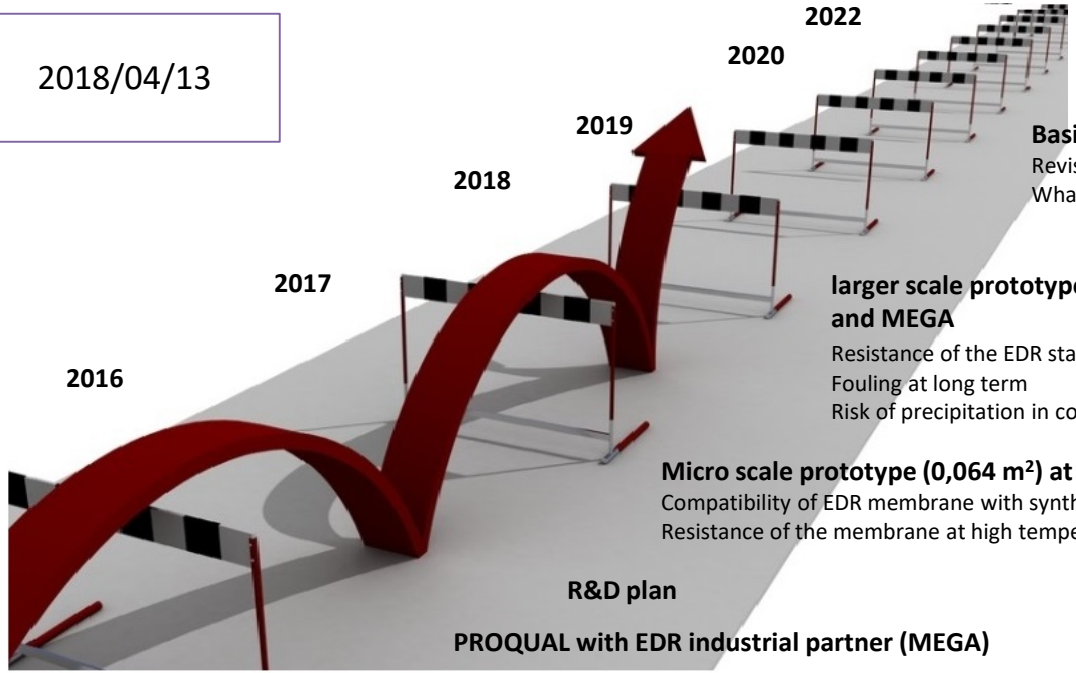
Wat – R – Use ® results

Carbon footprint: More than 20% carbon footprint saving using EDR. Even if EDR consumes more energy, it enables to save enough polymer to improve this indicator.

Freshwater withdrawal : EDR is also **beneficial** for the freshwater withdrawal, water scarcity and freshwater ecotoxicology indicators for the same reasons as carbon footprint.

Introduction : EDR derisking program

PATENT FILLED 2018/04/13



2022

test onsite on representative water

2020

Basic Engineering study
Revised data
What to do with concentrate?

2019

2018

larger scale prototype (13-30 m²) at PERL and MEGA
Resistance of the EDR stack to the temperature
Fouling at long term
Risk of precipitation in concentrate and diluate

2017

Micro scale prototype (0,064 m²) at PERL
Compatibility of EDR membrane with synthetic PW
Resistance of the membrane at high temperature (60°C)

2016

R&D plan

PROQUAL with EDR industrial partner (MEGA)

Preliminary tests with HPAM polymer

Preliminary technico-economic study

Concept

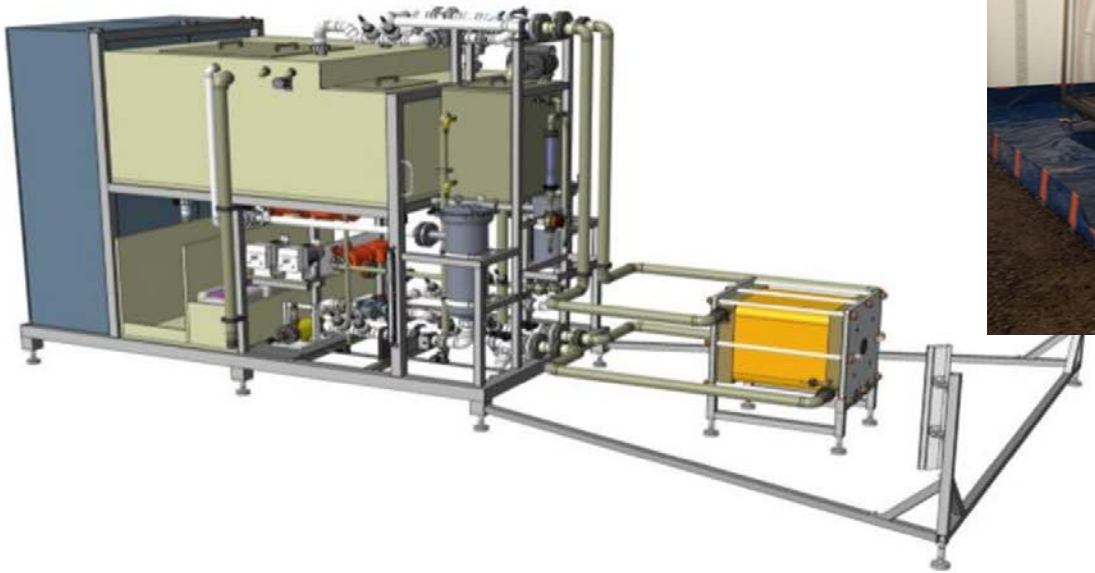
TRL 6

TRL 4

TRL 3

Material & Methods

Pilot installed at Total PERL lab (Lacq, France)



Material & Methods

- EDR Module : 30 m2 area

Characteristics of the stack	
Effective membrane Surface	29,2 m2
Active cell surface	0,767x0,382 m2
Number of cell pairs (Diluate/ concentrate)	100
Anion-exchange membrane	• Ralex AM-PES TR (X100) • Thickness : 0,65mm • Permselectivity >90% • Temperature resistance : up to 70°C • PH range : 0 -10
Cation-exchange membrane	• Ralex AM-PES TR (**X103**) • Thickness : 0,65mm • Permselectivity >90% • Temperature resistance : up to 70°C • PH range : 0 -10
Electrodes	Ti/Pt (X2)

Material & Methods

Synthetic water

Salt	Mass concentration (g/L)
Na_2SO_4	0.019
$NaHCO_3$	1.79
KCl	0.471
$CaCl_2,2H_2O$	0.545
$MgCl_2,6H_2O$	0.36
NaCl	2.956

Total salt concentration= 6.15 g/L.

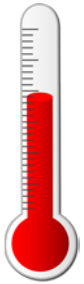
+anti-scalant product at 20 ppm

+HPAM polymer at 300ppm/ 600 ppm

+crude oil at 20 ppm

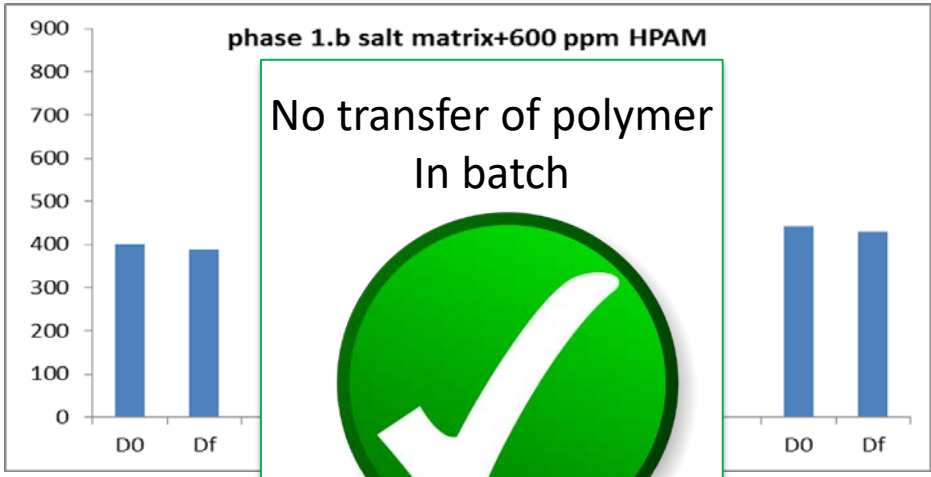
+corrosion inhibitor at 50 ppm

T°C = 60°C



Results : batch mode

Desalination
In batch



No transfer of polymer
In batch

D0 = diluate at t=0
DF = diluate at t= end

- ✓ Time to = 20 min for all b
- ✓ 23 g/L reached in concentrate at the end of batch 4.
- ✓ No ough the membranes

Results : continuous mode (one stage)

Flowrate : 8,9 m3/h (D and C)

1,6 m3/h Electrolyte

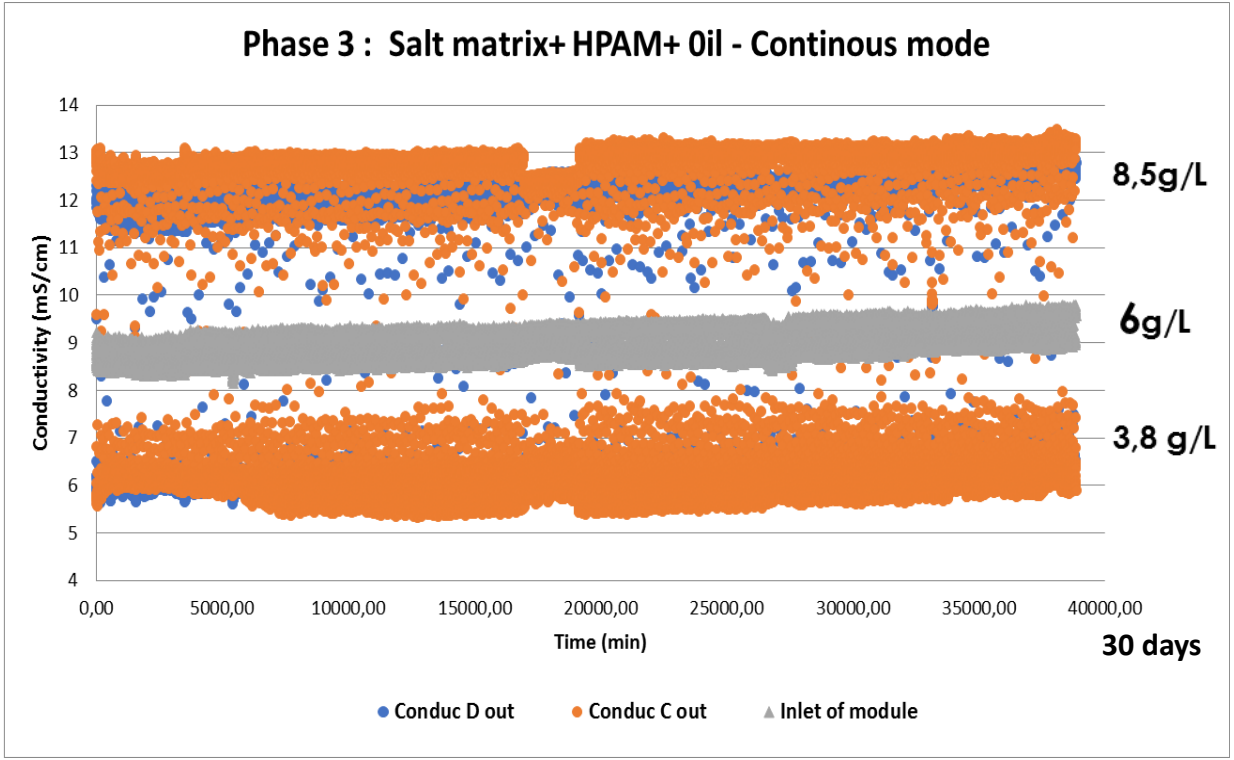
Continuous mode

T= 60°C

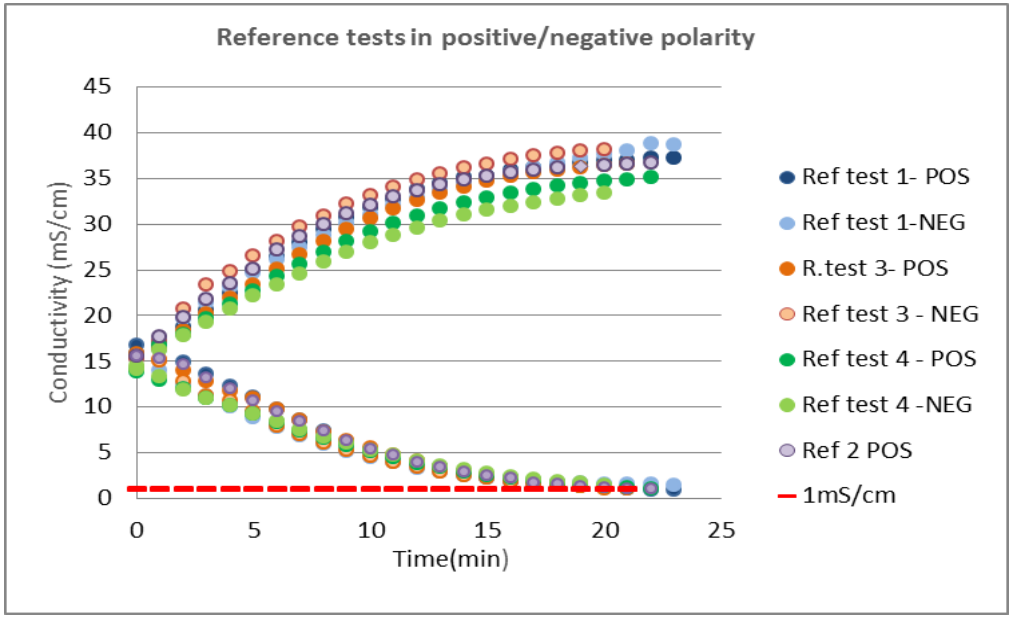
Polarity reversal time = 23min

Test duration = 4 weeks

37% constant desalination rate on one stage



Results : continuous mode (one stage)



- ✓ **Slight decrease of performance probably due to fouling of the membrane during the long term test with 600 ppm HPAM and tenth of ppm of crude oil.**
- ✓ **It is acceptable since it can be recovered easily via CIP cleaning**

Conclusions

- Industrial scale module (30 m2) works at 60°C with HPAM and crude oil
  - No/low membrane fouling at short term (<2-month test)
  - Desalination rate in continuous mode was constant at around 37% for one stage

- Still some issues with internal leakage at high temperature that are being fixed to enhance the reliability of the technology. Membrain (R&D subsidiary of MEGA) is working on the reliability of its stack at high temperature. The target is to have a fully reliable stack certified for high temperature (<70°C) for end of 2020.

- Economics are very attractive when dealing with HPAM polymer and relatively low salinity produced waters (5-10 g/L)

- Next step is to install a semi-industrial scale pilote (3 stages in serie) on a real viscosified produced water flow (continuous operation during at least 4 months)

Thank you for your attention