Upset time allowance for different humidity levels in the gas phase of CO_2 transportation pipeline

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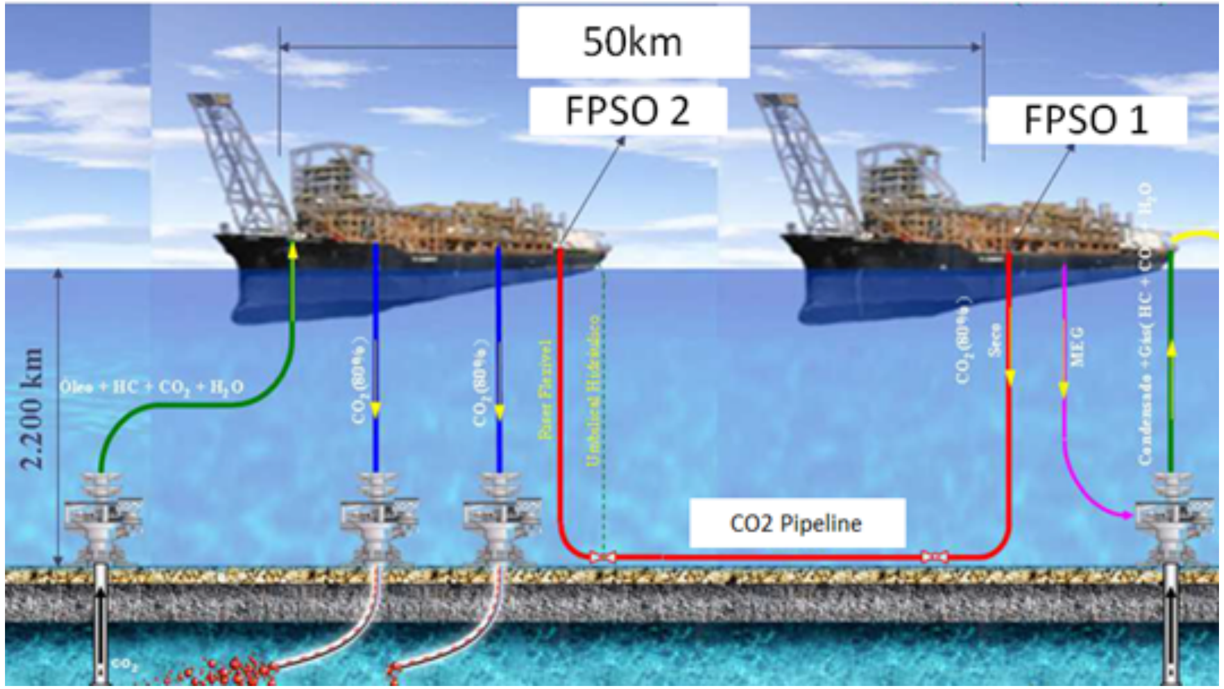
Introduction

- Some integrity requirements are necessary to be established for pipeline manufacturing:
  - Material selection: C-Mn; Low Alloy Steel (LAS) or Corrosion Resistant Alloys (CRA);
  - Corrosion Allowance (CA) (if C-Mn or LAS);
  - Type and availability of corrosion inhibitor (if C-Mn or LAS);
  - NACE requirements for sour service;
  - Corrosion fatigue curves (S-N and FCGR);
  - Corrosive environment in Toughness test.

Introduction



- Long distance pipelines have to be manufactured in C-Mn due to high costs associated to CRA material;
- When the pCO_2 is high enough corrosion might take place in aqueous media;
- Gas must be dehydrated and/or Corrosion Inhibitor (CI) used;
- Use of CI only, in very high pCO_2 conditions, demands:
    - High CI availability (challenging logistic to vessels away from the coast);
    - High CI efficiency (challenging to be achieve in high gas flow rate conditions);
    - High CA (challenging to pipeline manufacturing and laying).
- Dehydration is advantageous for CO_2 transportation pipeline, but upsets must be considered to establish pipeline CA.

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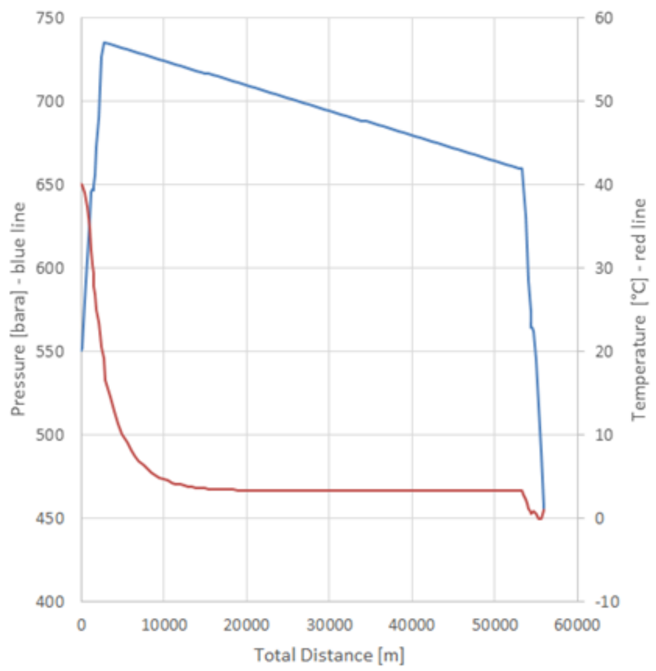
- Cooling cycles dehydration system take advantage of the anomalous behavior of high CO_2 gas stream (increase in humidity solubility when pressure increases);
- Designed to operate at 5° C and 50 bara;
- Gas might have different levels of humidity (depending on dehydration system upsets);
- Corrosion might take place in wet regions when gas reach dew point (Pipeline has temperature and pressure gradient when operating).

Objective: To present a high pCO_2 gas transportation pipeline application scenario of the maximum allowable time at different levels of humidity in the gas phase in function of CA.

Thermodynamic model

A thermodynamic model for high pCO_2 condition was built by PETROBRAS flow assurance team.

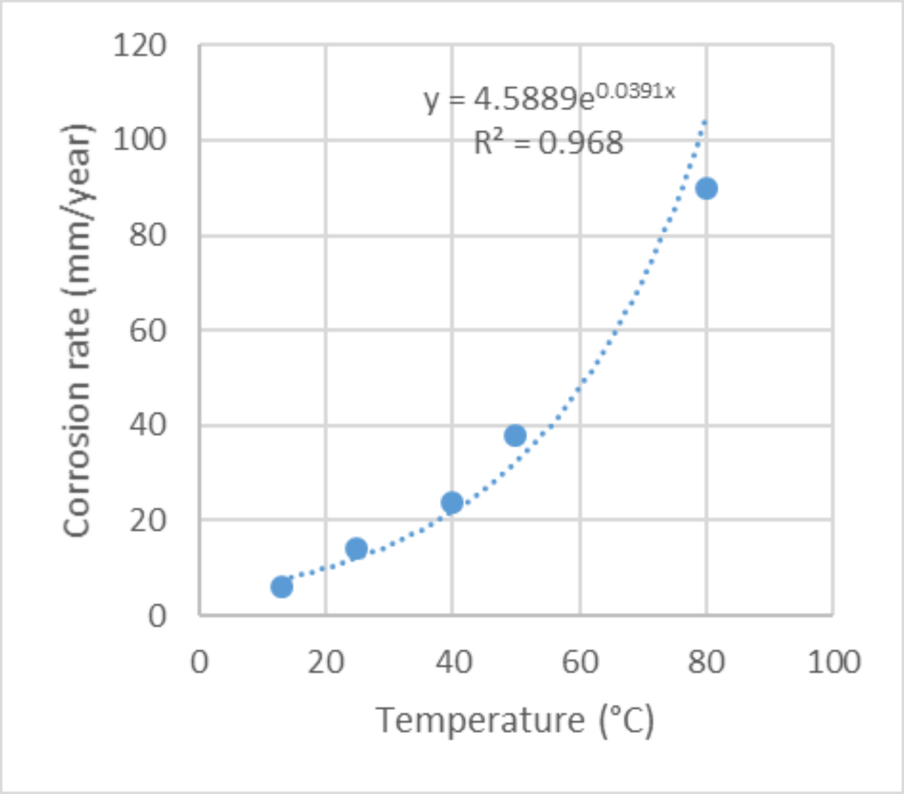
Condition	Pressure (*bara*)	Temperature (°C)	Humidity (*ppmv*) 60% CO_2	Humidity (*ppmv*) 80% CO_2
Normal operation	50	5	314.1 ± 31.4	354.3 ± 35.4
Upset 1	50	15	558.9 ± 55.9	614.7 ± 61.5
Upset 2	50	20	737.6 ± 73.8	803.9 ± 80.4

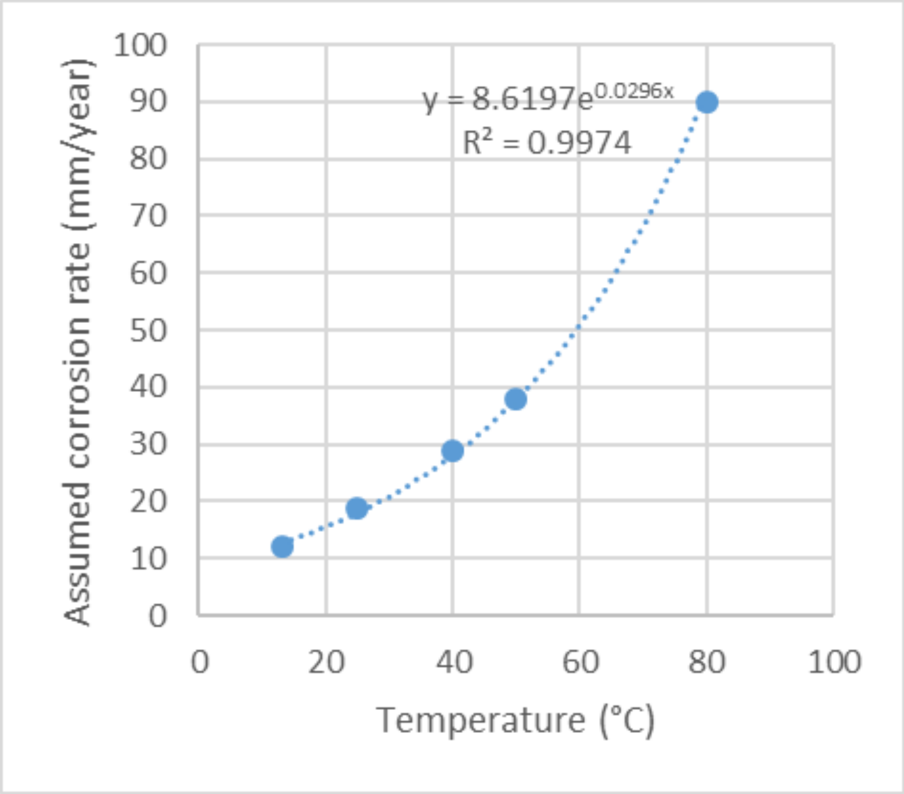


Section	Pressure (*bara*)	Temperature (°C)	Humidity (*ppmv*) - 60% CO_2	Humidity (*ppmv*) - 80% CO_2
Top of riser	551	40.1	2541.4 ± 127.1	3968.8 ± 198.4
Intermediate riser	601	42	2723.5 ± 136.2	4247.3 ± 212.4
Bottom of riser	639	42.8	2803.6 ± 140.2	4375.3 ± 218.8
Flowline KP0	708	23.8	1529.9 ± 76.5	2498.8 ± 124.9
Flowline KP45	638	3.2	718.2 ± 35.9	1229.8 ± 61.5
Bottom of riser (destination FPSO)	532	-0.5	613.1 ± 30.6	1058.0 ± 52.9
Top of riser (destination FPSO)	416	-4.6	508.2 ± 25.4	886.3 ± 44.3

Corrosion model

A corrosion rate model for high pCO_2 condition was built based on literature survey (corrosion rate tests in loop).





Adjustments due to low flow velocities and high time during some corrosion rate tests (loop); Equation extrapolated to temperatures lower than 13°C.

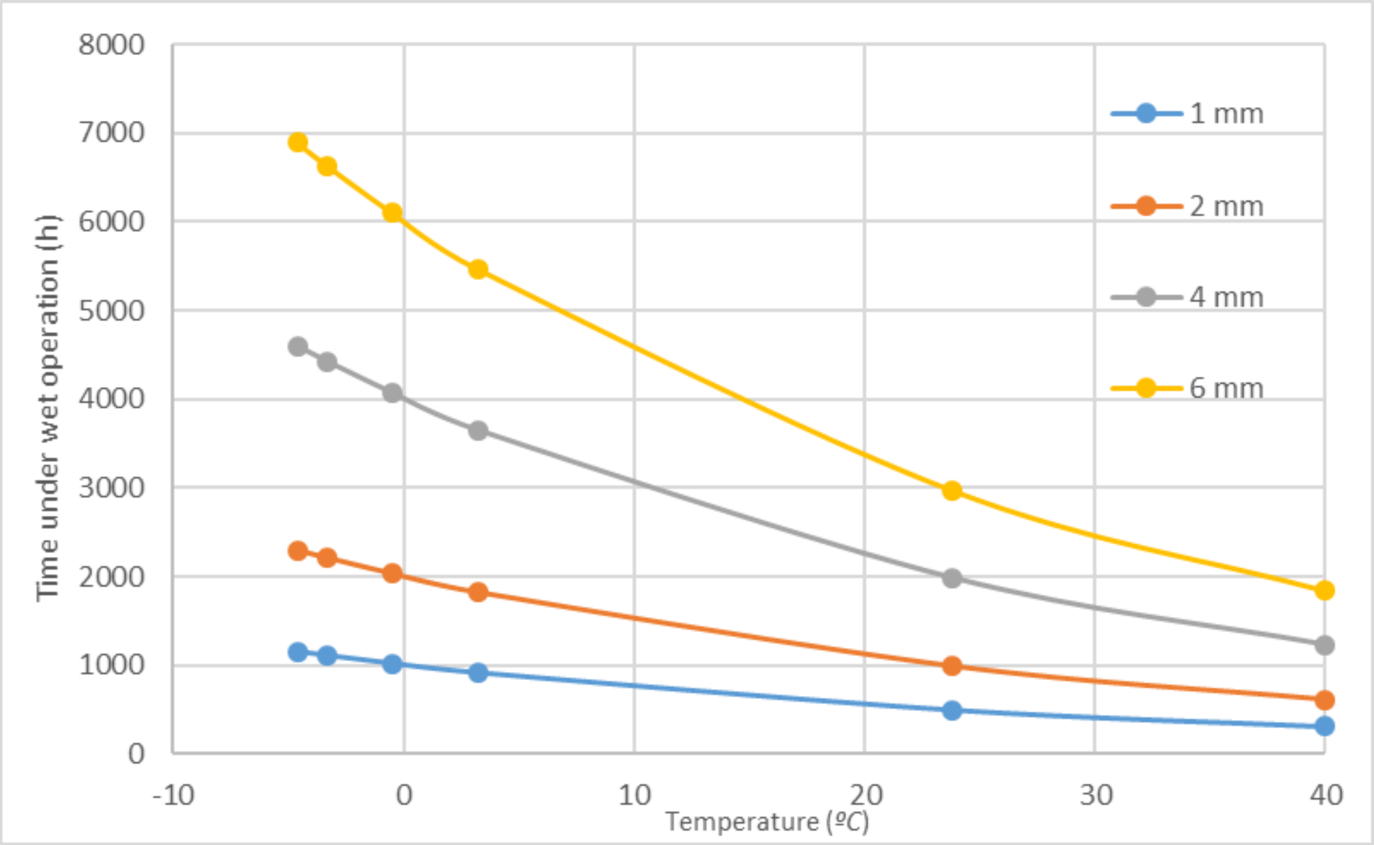
Results

Allowable time of wet pipeline operation as a function of:

- Temperature;
- CA.

The following issues must be considered:

- Time required of drying after upset is controlled;
- Drag of water droplets downstream the dehydration system;
- The region downstream of the first condensation is also wet.



Conclusions

This approach and the results obtained in this study shows an important tool for optimization of the process plant dehydration system and correct selection of materials and CA for the pipeline;

In the application scenario C-Mn steel pipeline could be a suitable material and Alloy 625 claded pipeline might be required in some regions of: i) high fatigue criticality, such as top of the riser and TDP, and ii) very cold regions (destination vessel riser).

The authors dedicate this presentation to Jonatas Ribeiro (in memoriam) who encouraged us and collaborated with the execution of this work.

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Thank you for your attention!

Questions?

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