Trondheim CCS Conference

CO_2 Capture, Transport and Storage

VESSEL DEPRESSURIZATION OF CO2-RICH FLUIDS FROM EXPERIMENTS TO SIMULATIONS

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TOTAL

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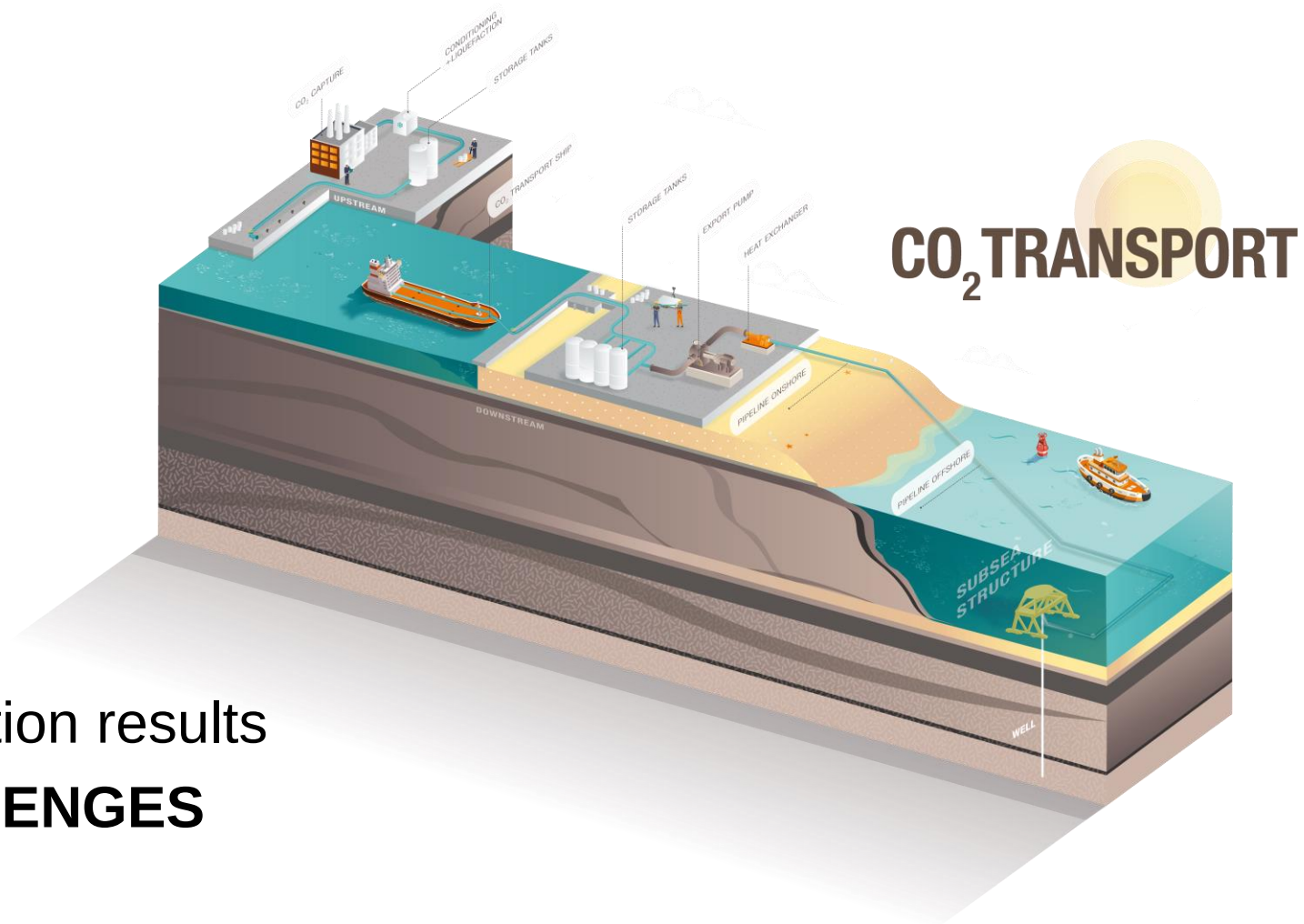


INTRODUCTION

INTRODUCTION – PROBLEM STATEMENT

Design cost-efficient facilities for CCUS and operate them safely

- Depressurization of vessels containing hydrocarbon fluids:
  - No solid formation
  - Available models in process software validated over many decades

- For vessels containing pure CO_2 or CO_2-rich fluids:
  - Solid CO_2 formation → More complex models
  - Only scarce experimental data exist.

→Tuning / validation of these complex models require new experimental data

→Lack of validated software for blowdown of CO_2-rich mixtures

INTRODUCTION – CARDICE JIP

Main objectives of the CARDICE JIP

- CO_2 blowdown experiments at pilot scale, for different initial conditions…
- … to improve and qualify VessFire as a tool for blowdown of CO_2 vessels

Partners

- Gassnova
- Equinor
- Total

Sub-contractors

- Ineris (experiments)
- Petrell (simulations)

Duration & budget

- 2017-2019
- 6 MNOK (50% support from Gassnova)

EXPERIMENTAL SET-UP

EXPERIMENTAL SET-UP – OVERALL DESCRIPTION

Setup

- 2m^3 spherical HP/LT vessel (re-use)
- 10cm of rubber foam insulation

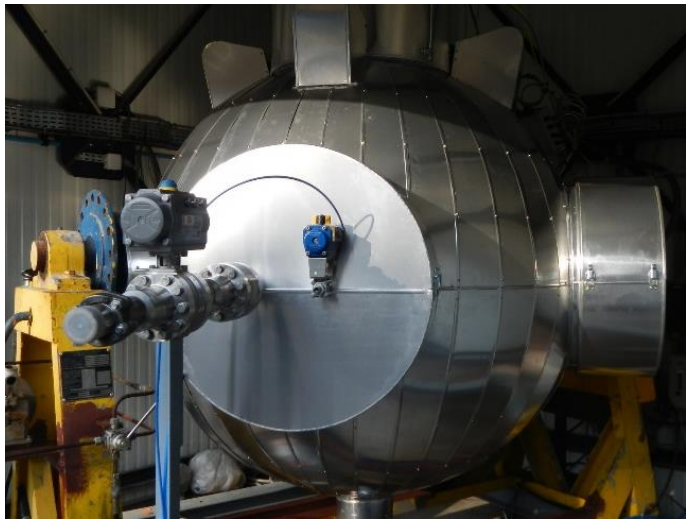
Compositions

From pure CH_4 to pure CO_2

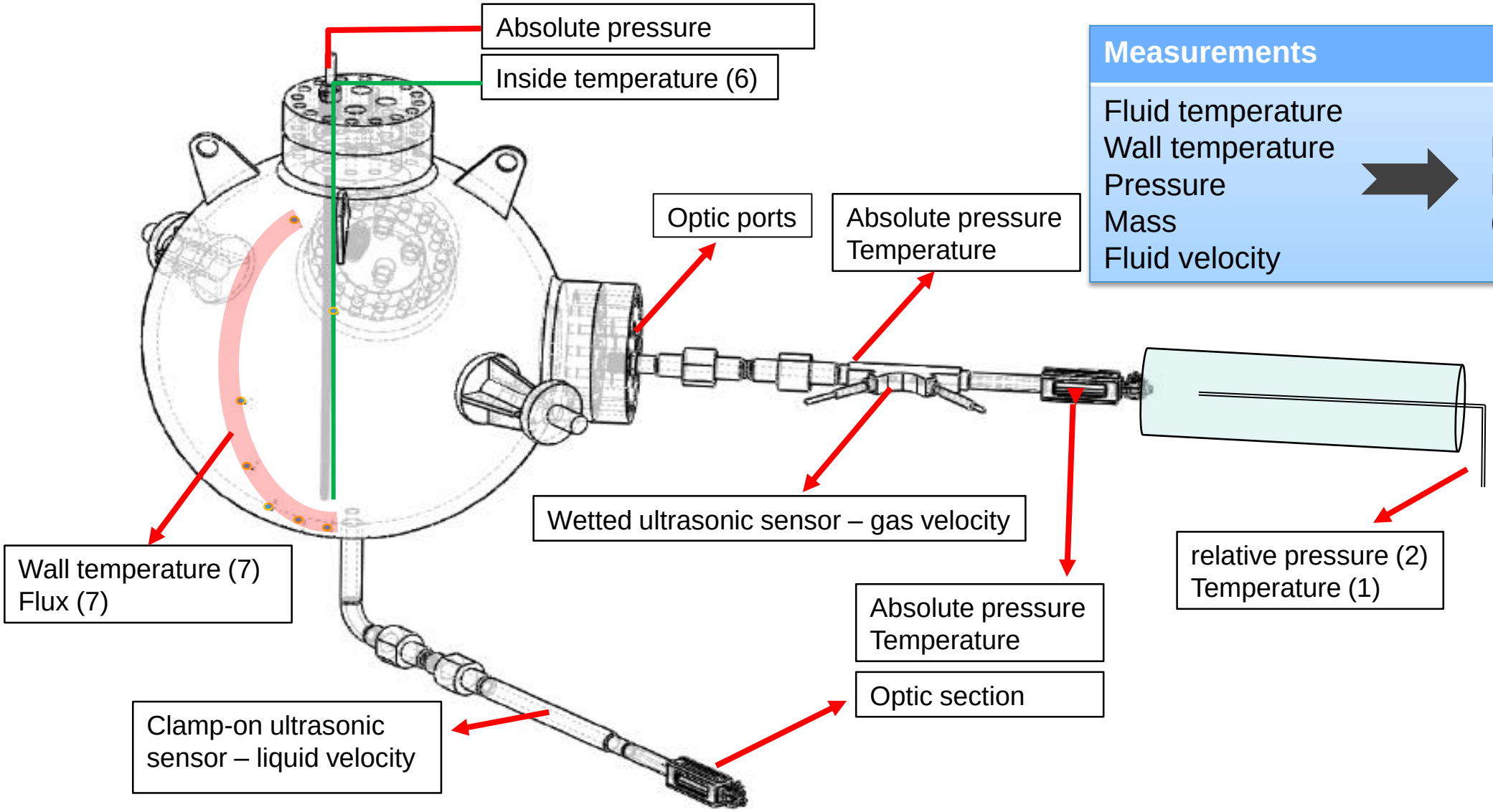
Initial conditions

- From 135 down to 10 bara
- From 20° down to -40°C

Gas or liquid release



EXPERIMENTAL SET-UP – INSTRUMENTATION



Measurements	Estimations
Fluid temperature Wall temperature Pressure Mass Fluid velocity	Fluid density Flow rate (amount of solid)

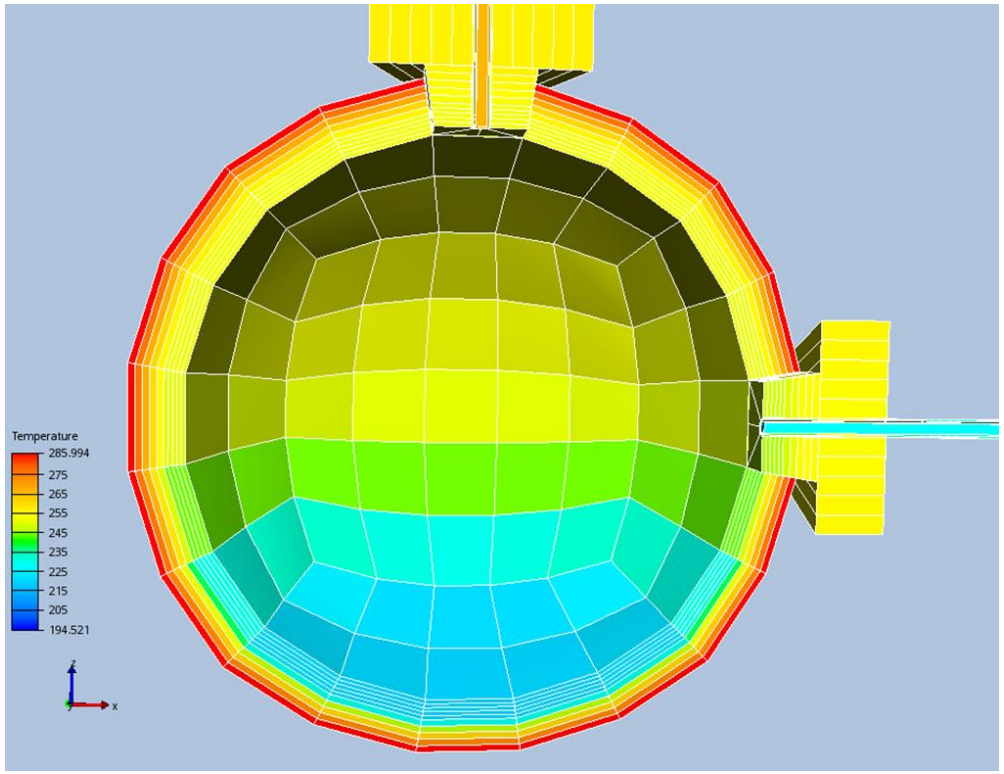
EXPERIMENTAL SET-UP – SITE

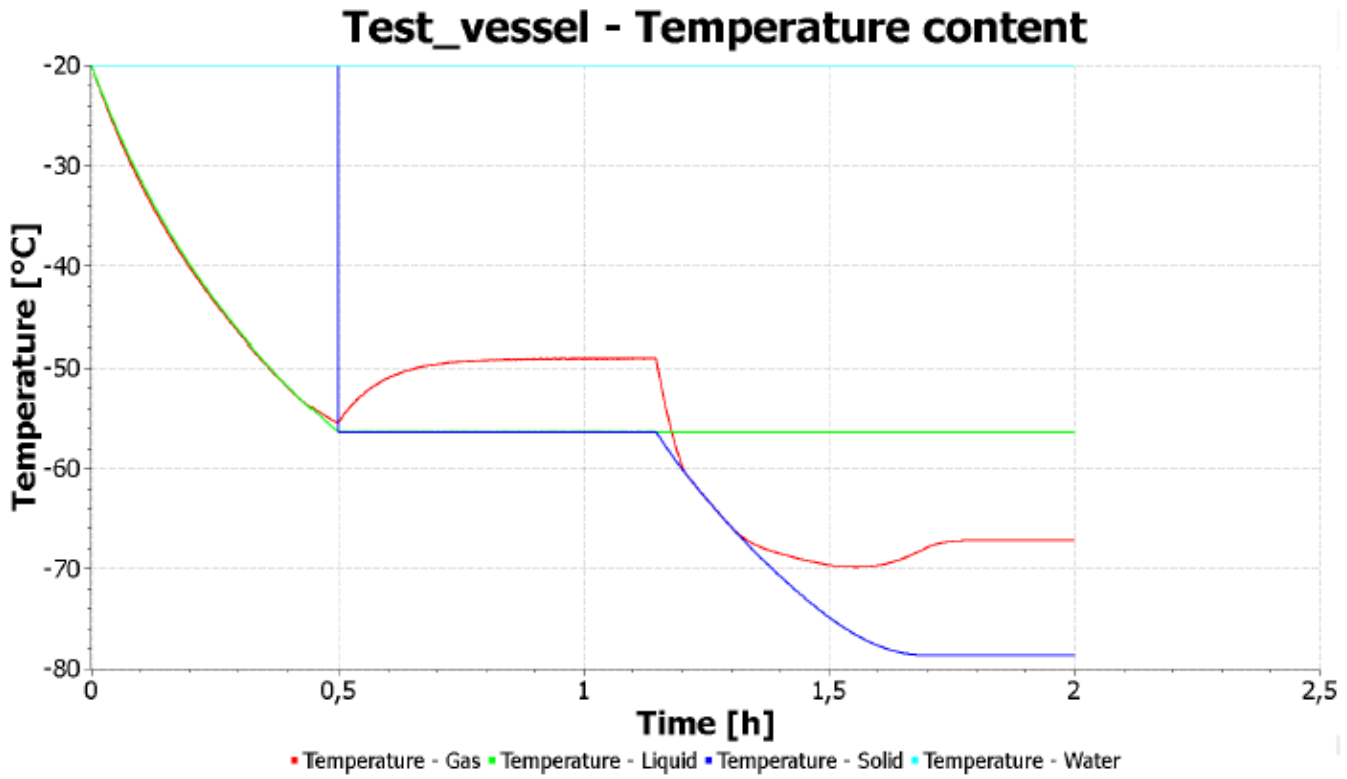
Location:
Ineris,
Verneuil-en-Halatte,
FRANCE

VESSFIRE

VESSFIRE – GENERAL DESCRIPTION

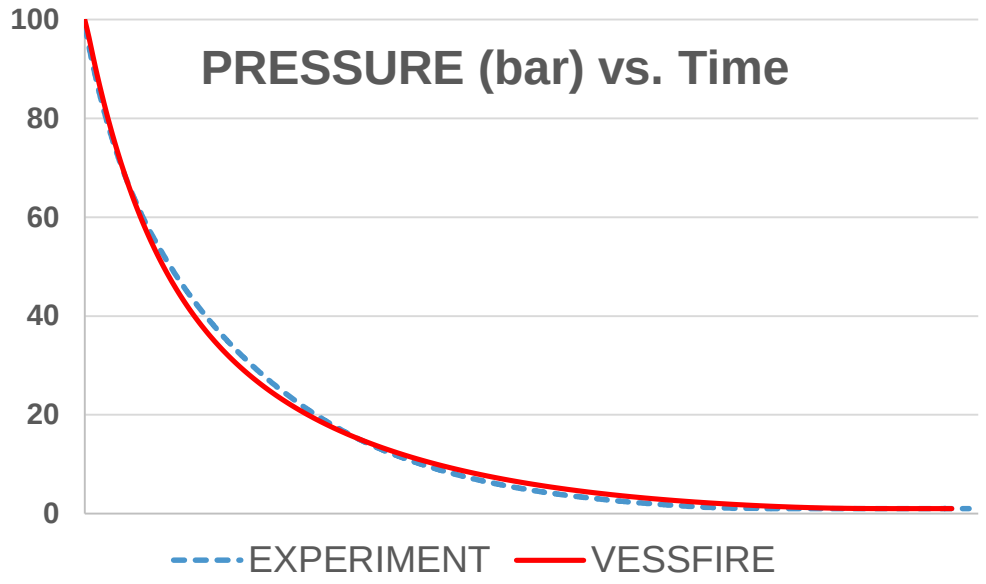
- Developed by Petrell (Norway) since 1998
- Pseudo 3D tool based on finite-element method and fluid dynamics modelling
- Non-equilibrium thermodynamic…
- … with vapor, liquid and solid phases, including phase changes

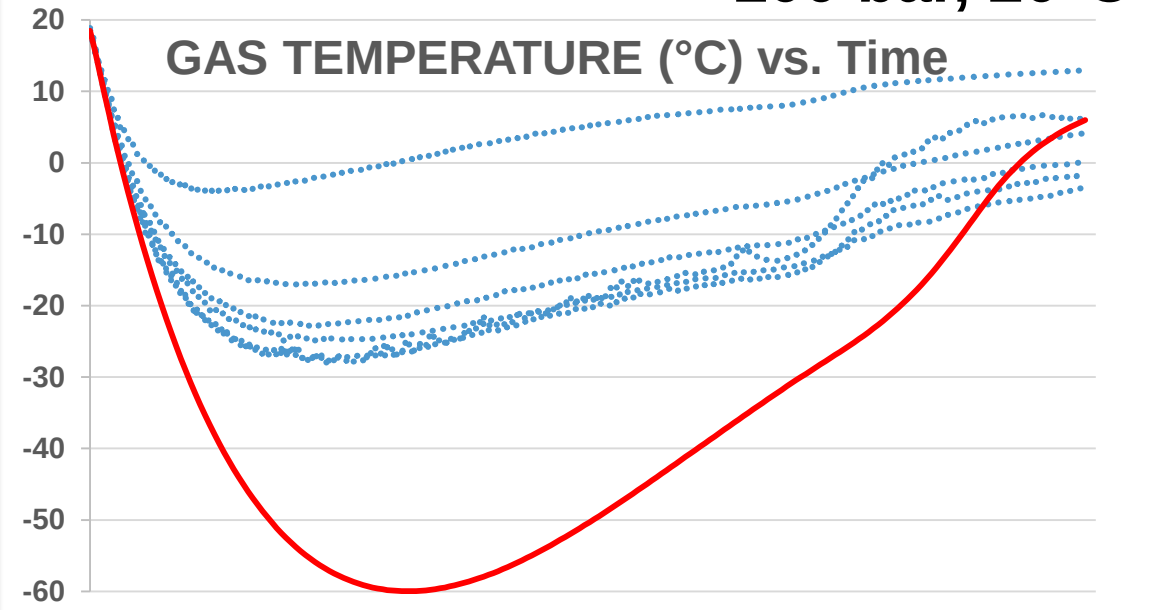


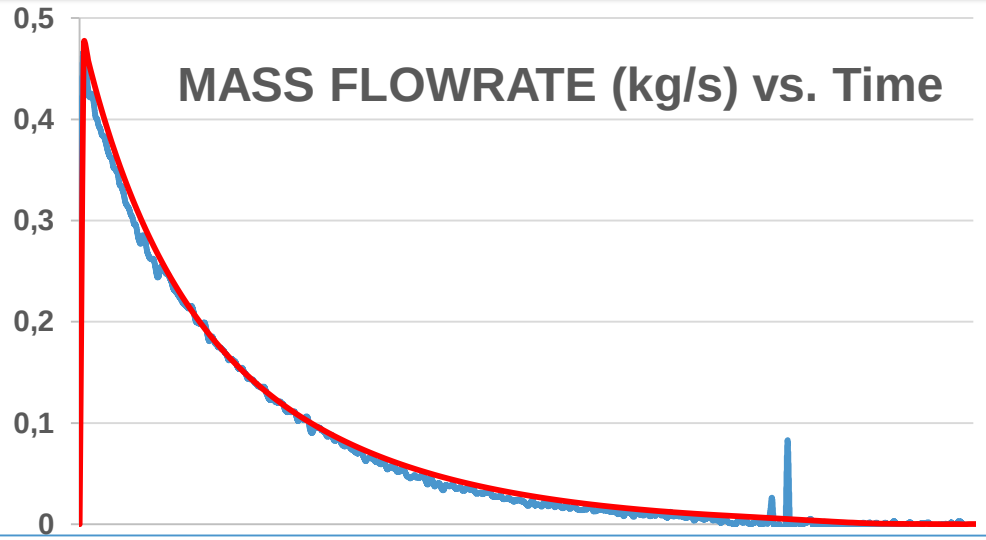


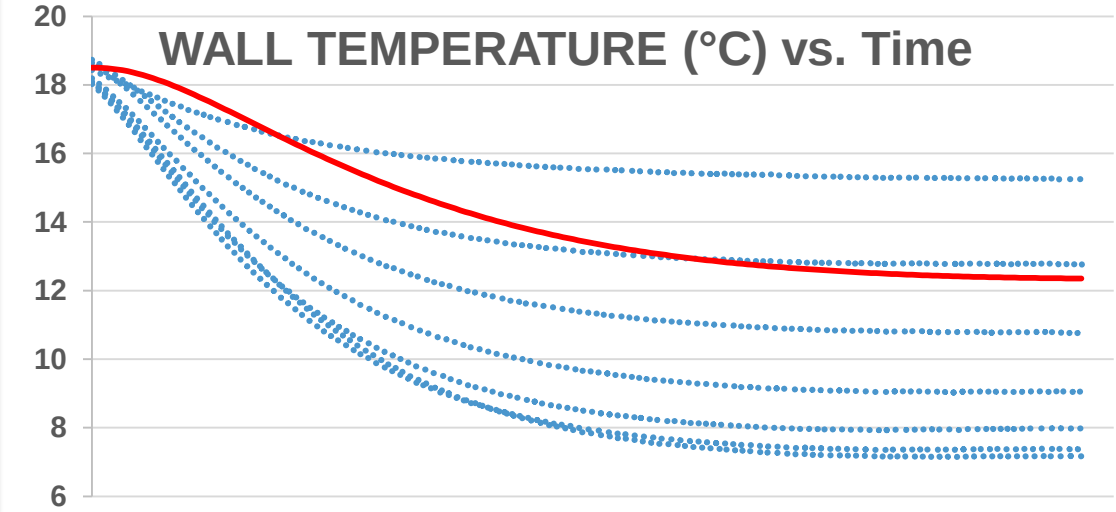
VESSFIRE – EXPERIMENTAL VS. SIMULATION RESULTS

Pure CH_4, gas only
100 bar, 20°C



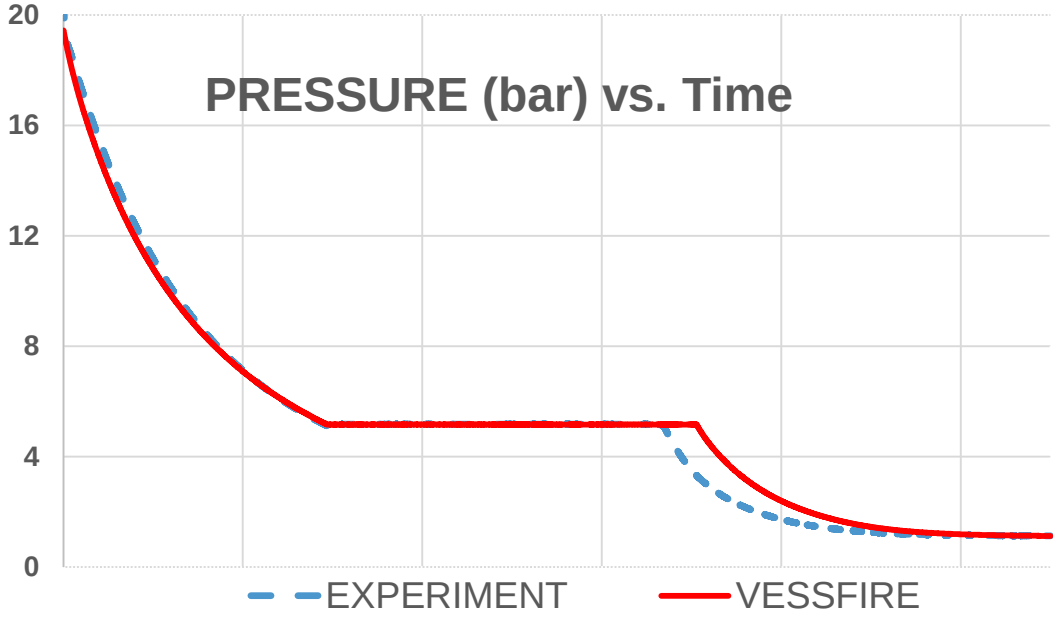


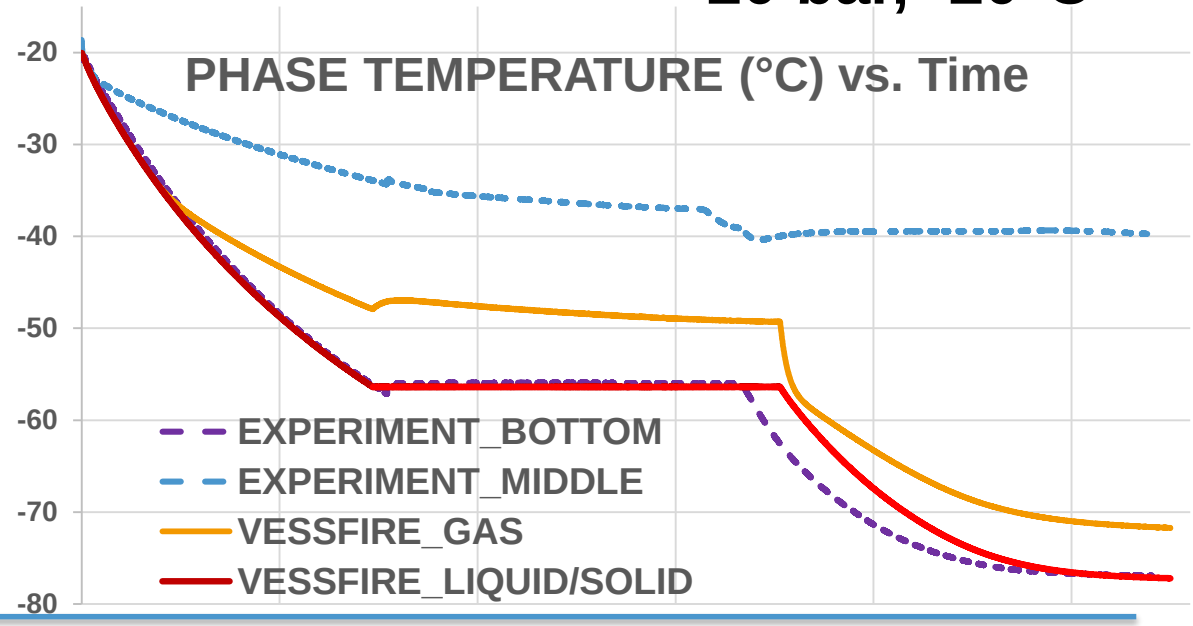


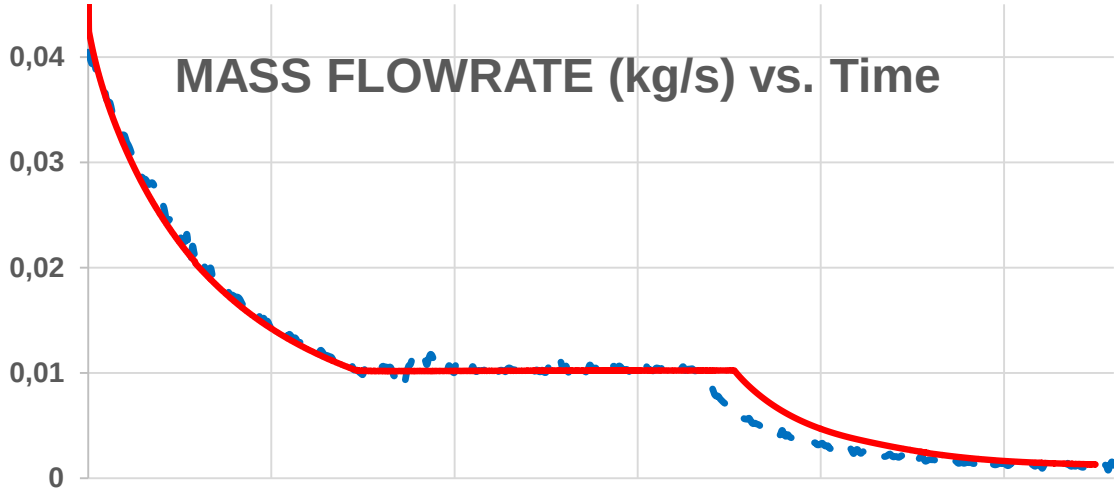


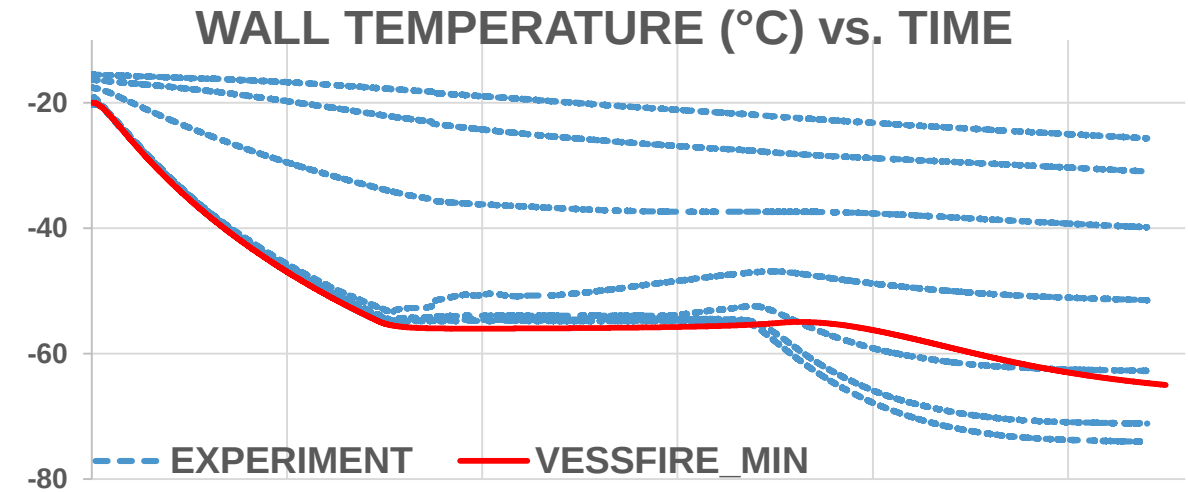
VESSFIRE – EXPERIMENTAL VS. SIMULATION RESULTS

Pure CO_2, G/L
20 bar, -20°C









CONCLUSIONS & CHALLENGES

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- **Experiments**
  - ~ 1-year of paper work & discussions (instrumentation, sphere modification…)
  - All tests conducted successfully, with large amounts of solid CO_2 produced in some tests
  - No safety issue

- **Vessfire PRELIMINARY assessment**

Fluid state	P	Q_m	T_{gas}	T_{liq}	$T_{w,min}$
Gas only				N/A	
Gas & liquid (& solids)					

- **Challenges**

Experiments	Vessfire
- Ultrasonic flowmeters - Mechanical integrity concerns - Post-processing of data	- Heat transfer between gas and walls - Simulation speed - Robustness for liquid release