Ammonia-salt large temperature jump analysis

MI meeting

14th December2020

ENERGY RESEARCH ACCELERATOR

EPSRC
Engineering and Physical Sciences Research Council

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Outline

- Large temperature jump tests
- Elusive Equilibrium data
- Initial analysis
- Some of the challenges

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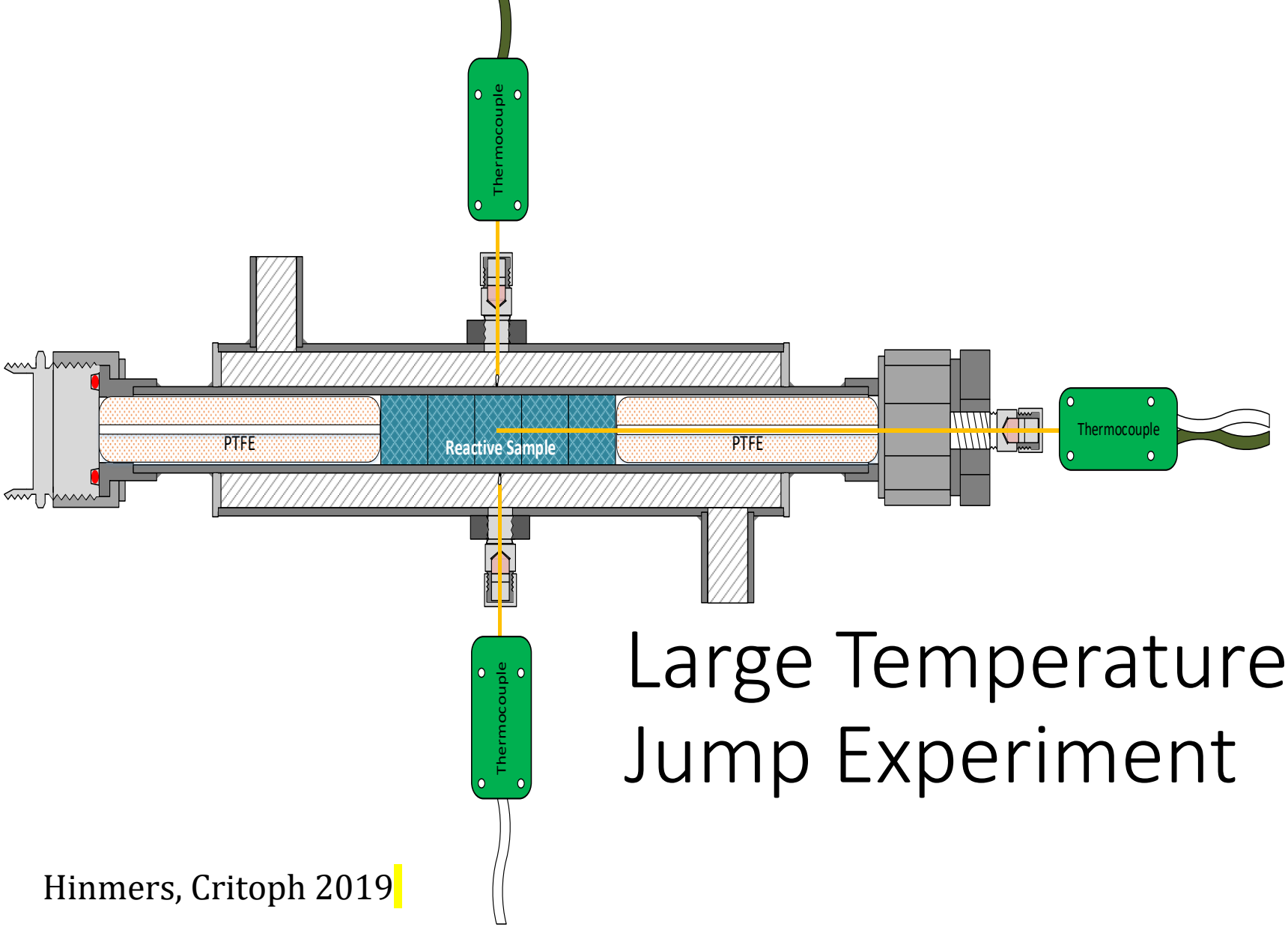
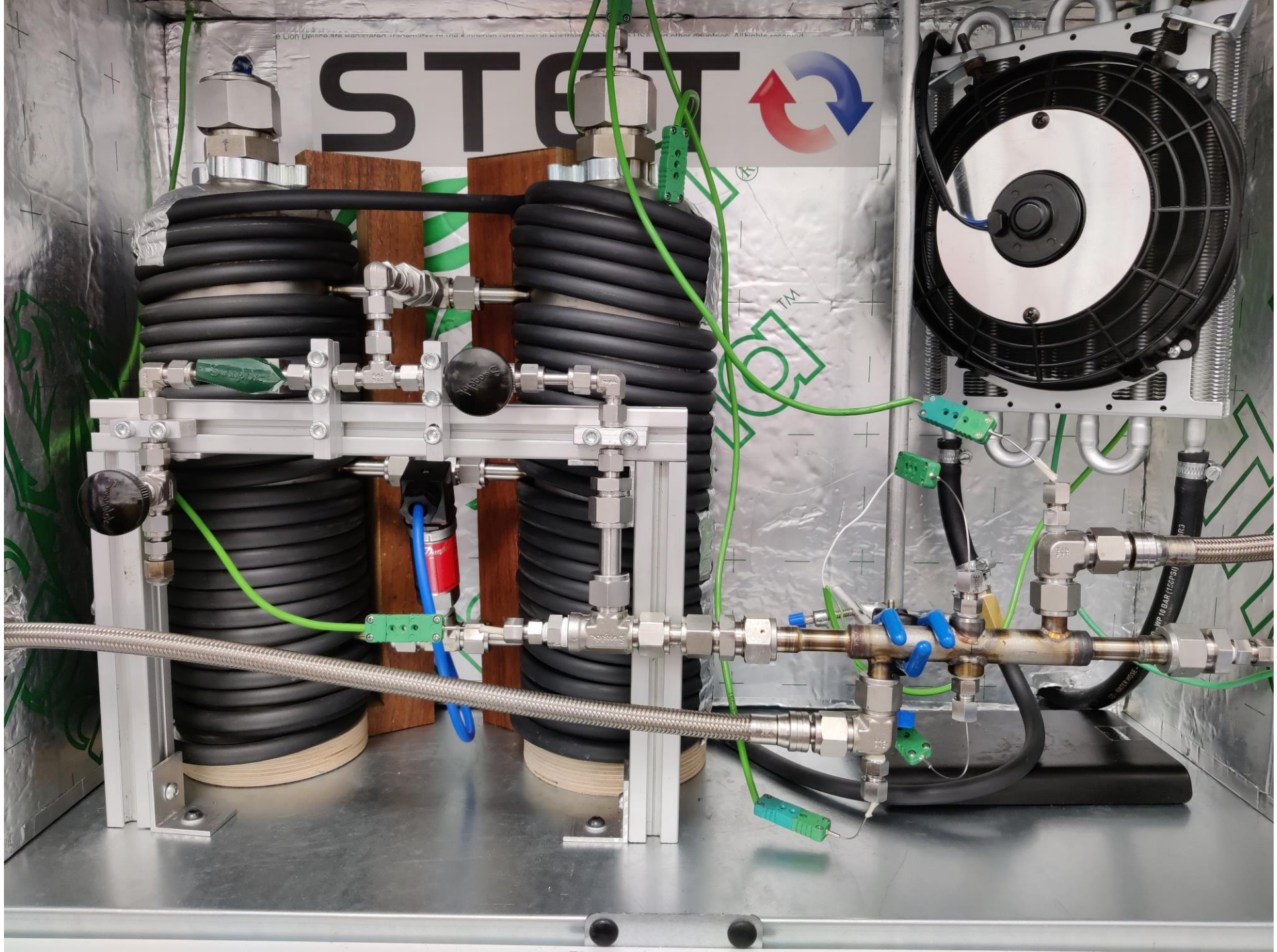


Large Temperature Jump Experiment

Hinmers, Critoph 2019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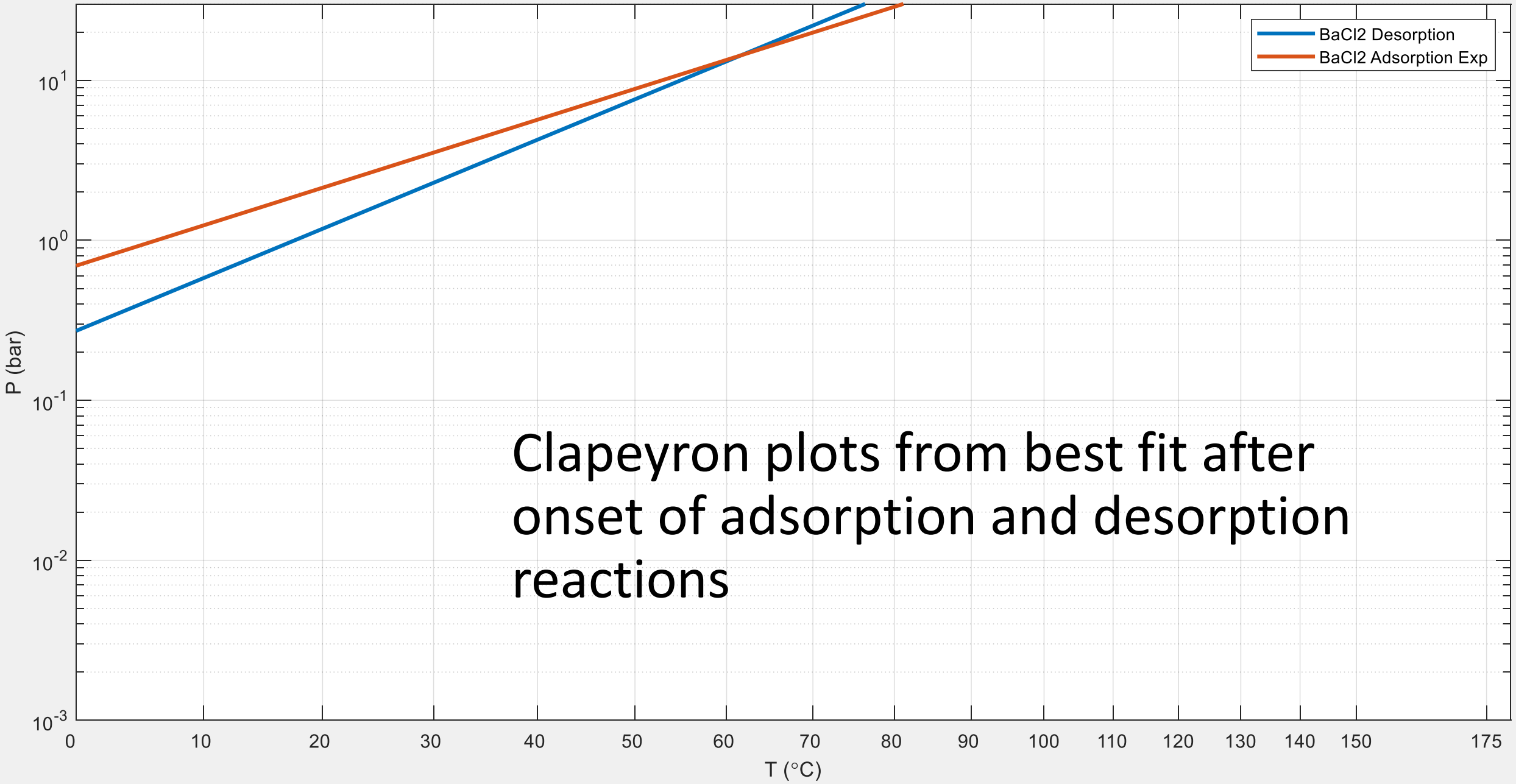
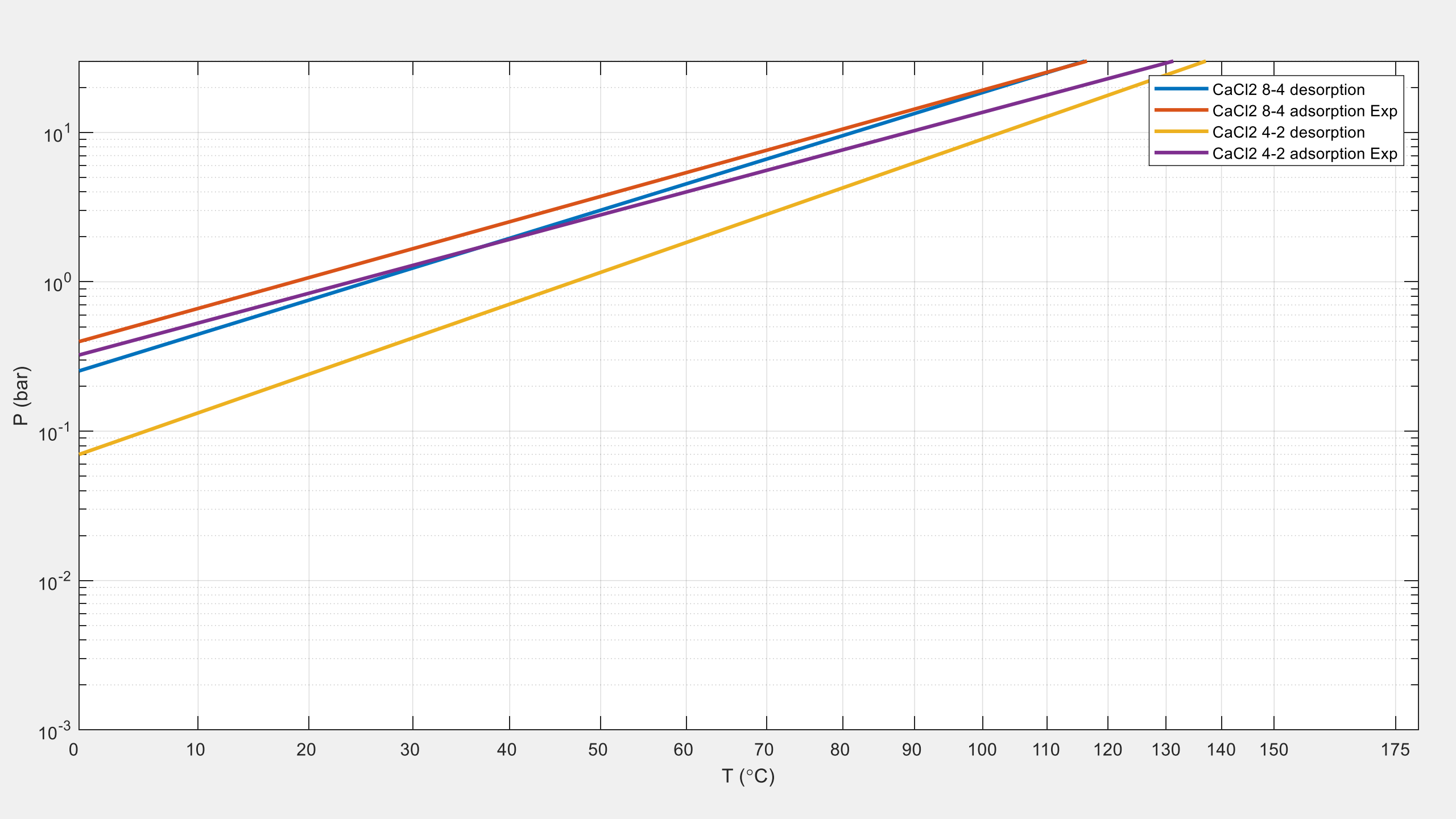
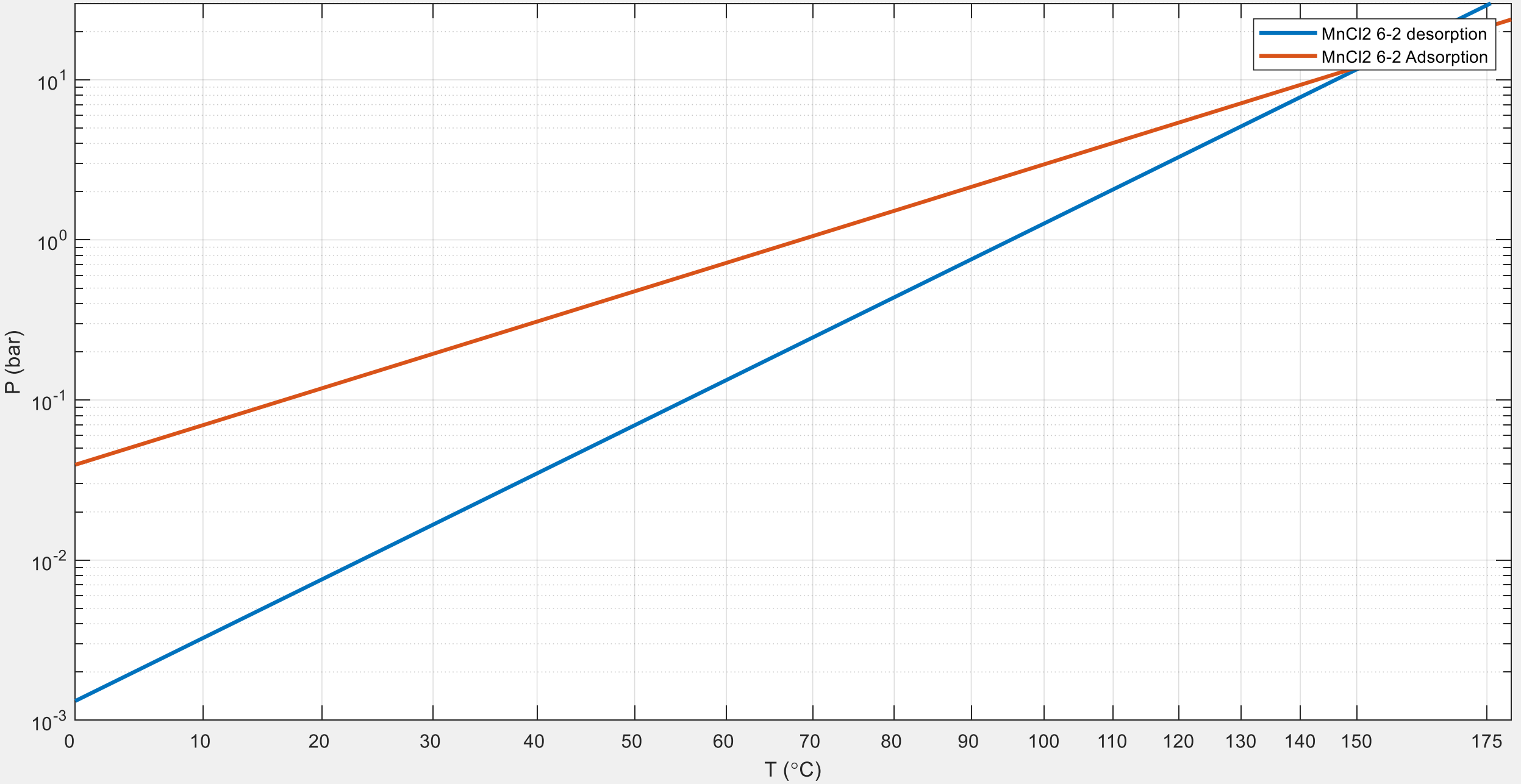
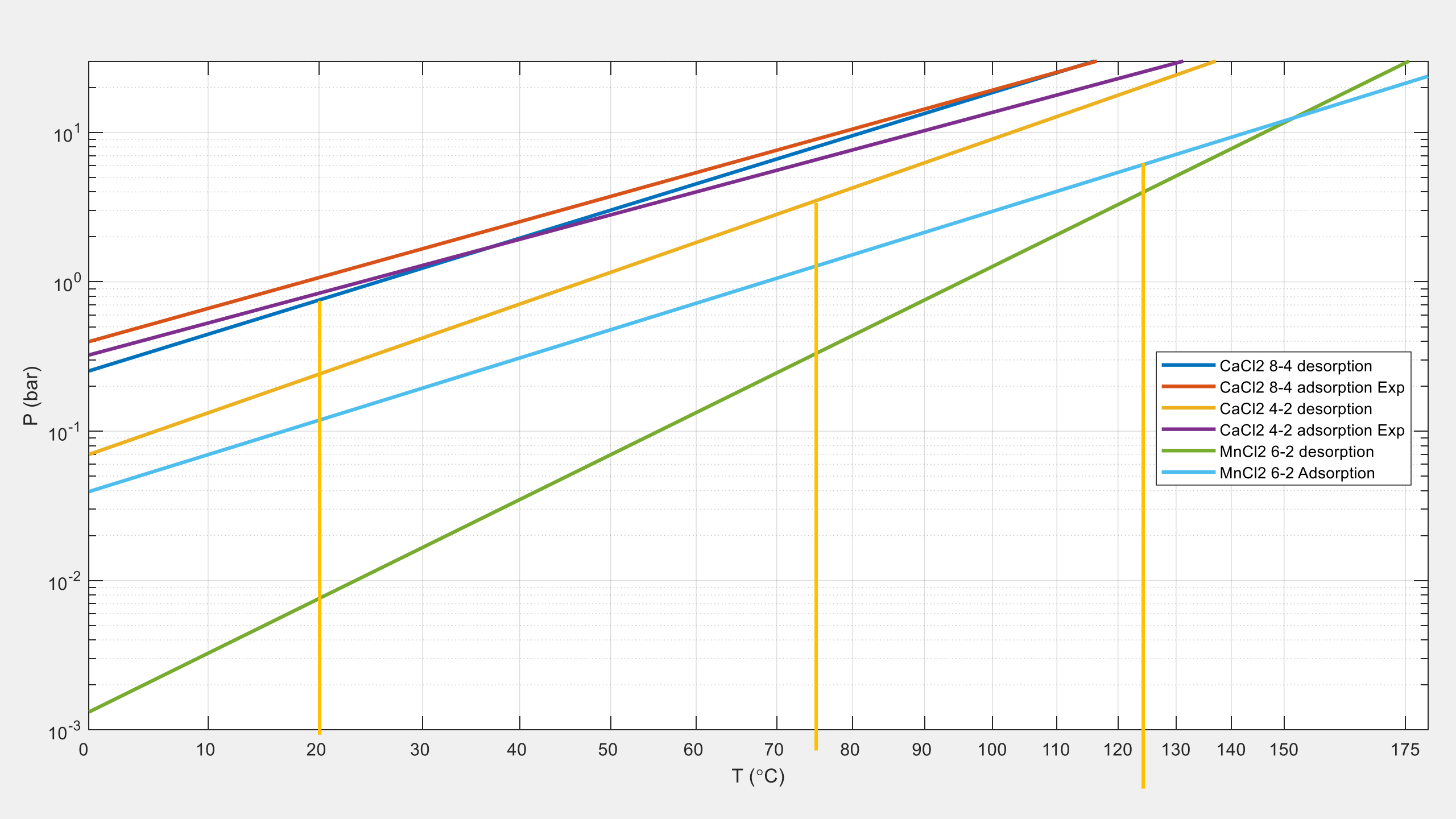


Clapeyron plots from best fit after onset of adsorption and desorption reactions


CaCl2 8-4 desorption
CaCl2 8-4 adsorption Exp
CaCl2 4-2 desorption
CaCl2 4-2 adsorption Exp
P (bar)
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
175
T (°C)


MnCl2 6-2 desorption
MnCl2 6-2 Adsorption
P (bar)
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
175
T (°C)


P (bar)
10^{1}
10^{0}
10^{-1}
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10^{-3}
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CaCl2 8-4 desorption
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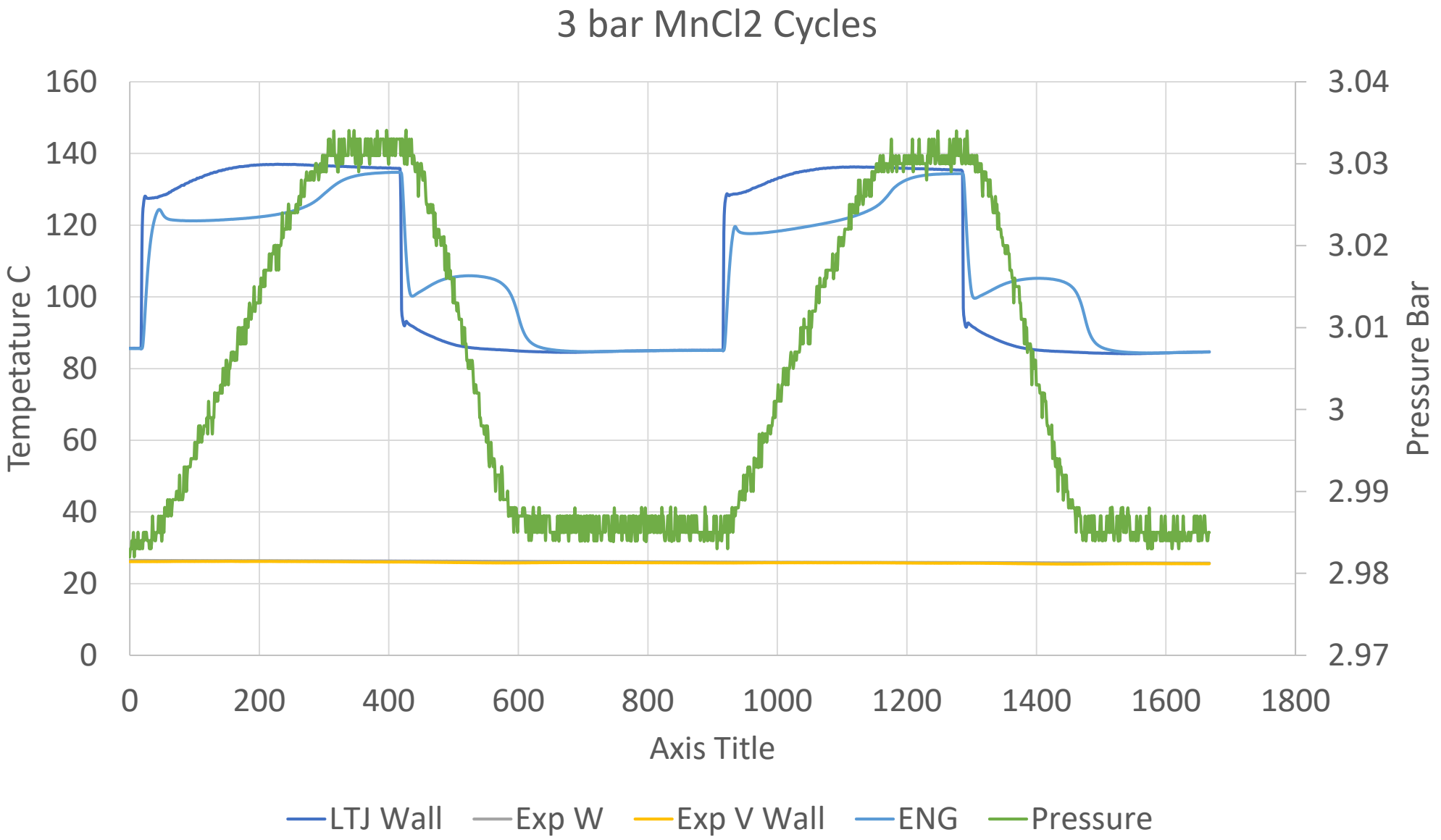
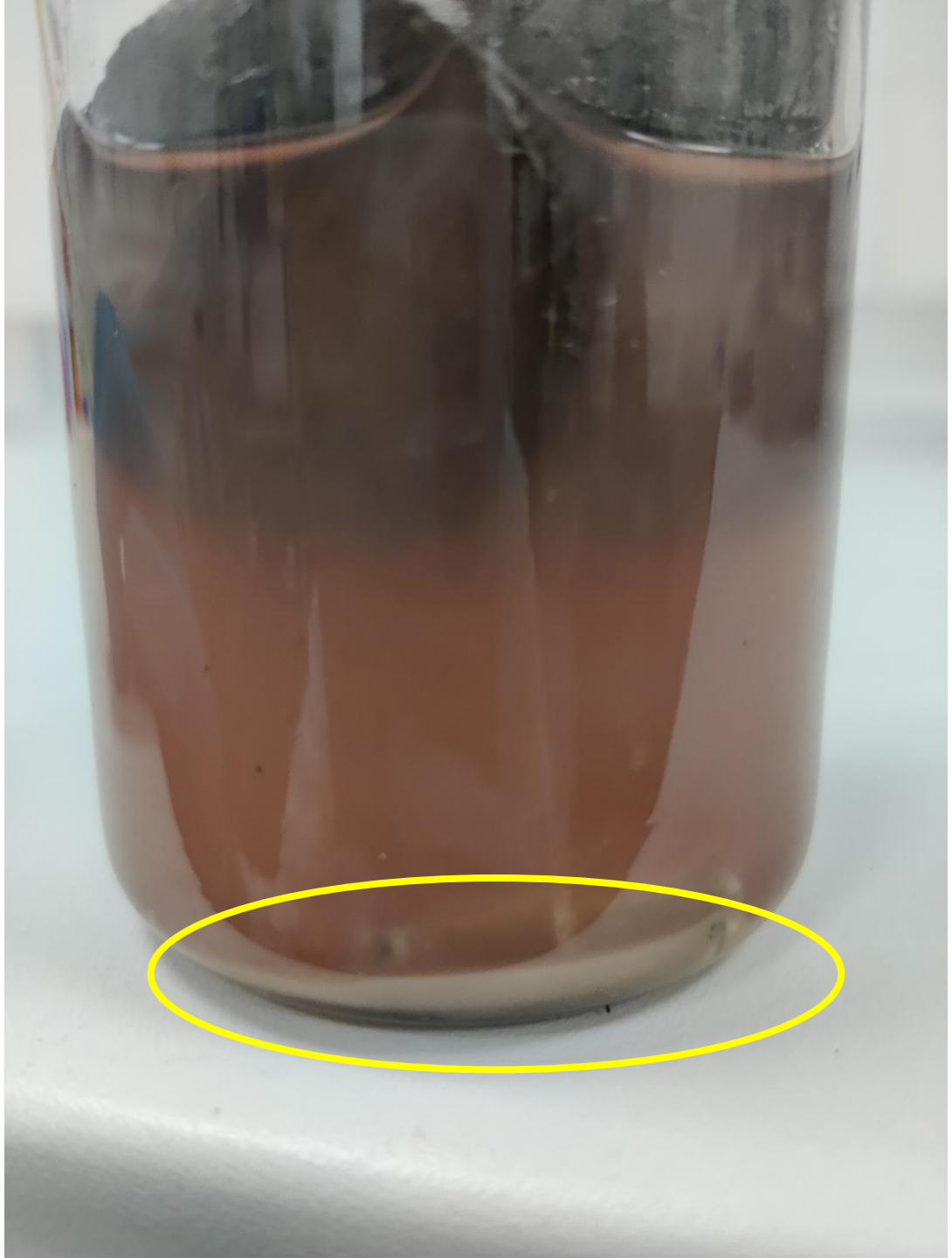
CaCl2 4-2 desorption
CaCl2 4-2 adsorption Exp
MnCl2 6-2 desorption
MnCl2 6-2 Adsorption

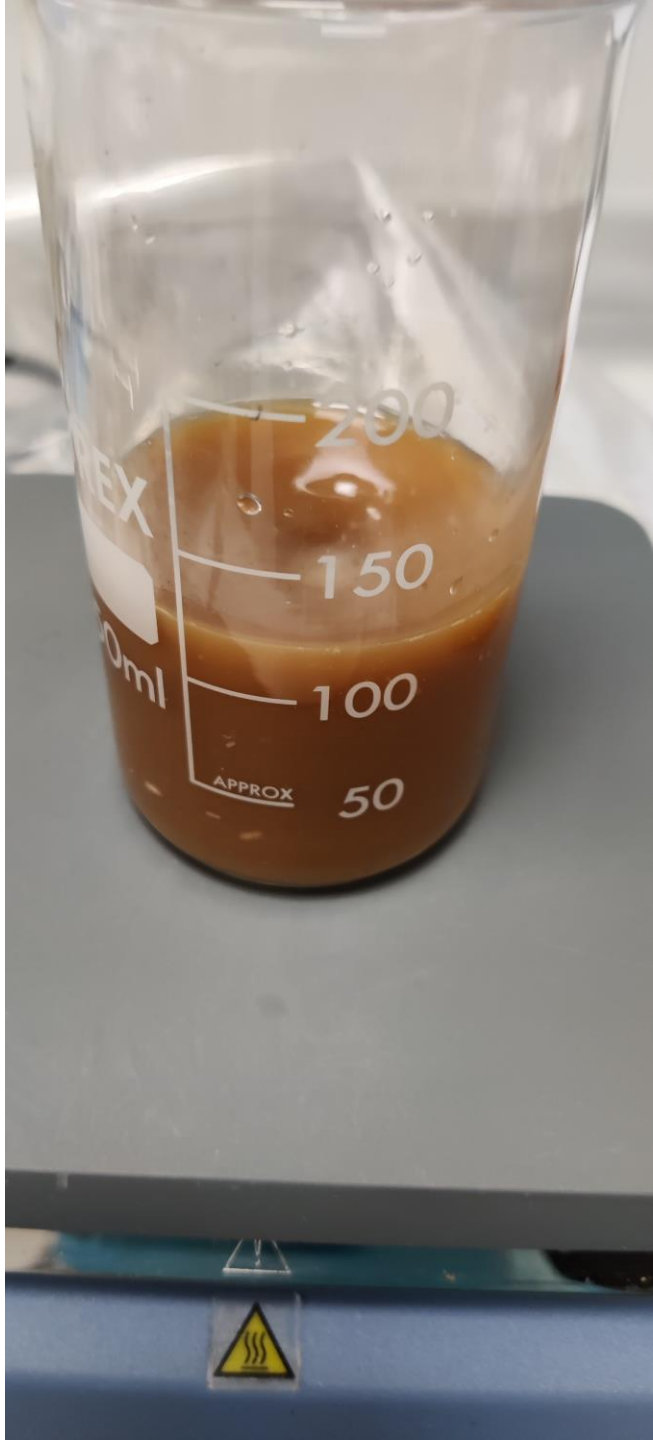
Challenges of working with salts



$MnCl_2$ Challenges

- Appears to have a notable lower ‘active fraction’ of salt than $CaCl_2$ and $BaCl_2$ @0.6
- Pellet form is prone to oxidising and precipitating out of solution (including with ethanol)
- Perhaps MnO_2 forms some of the ‘inactive salt fraction’





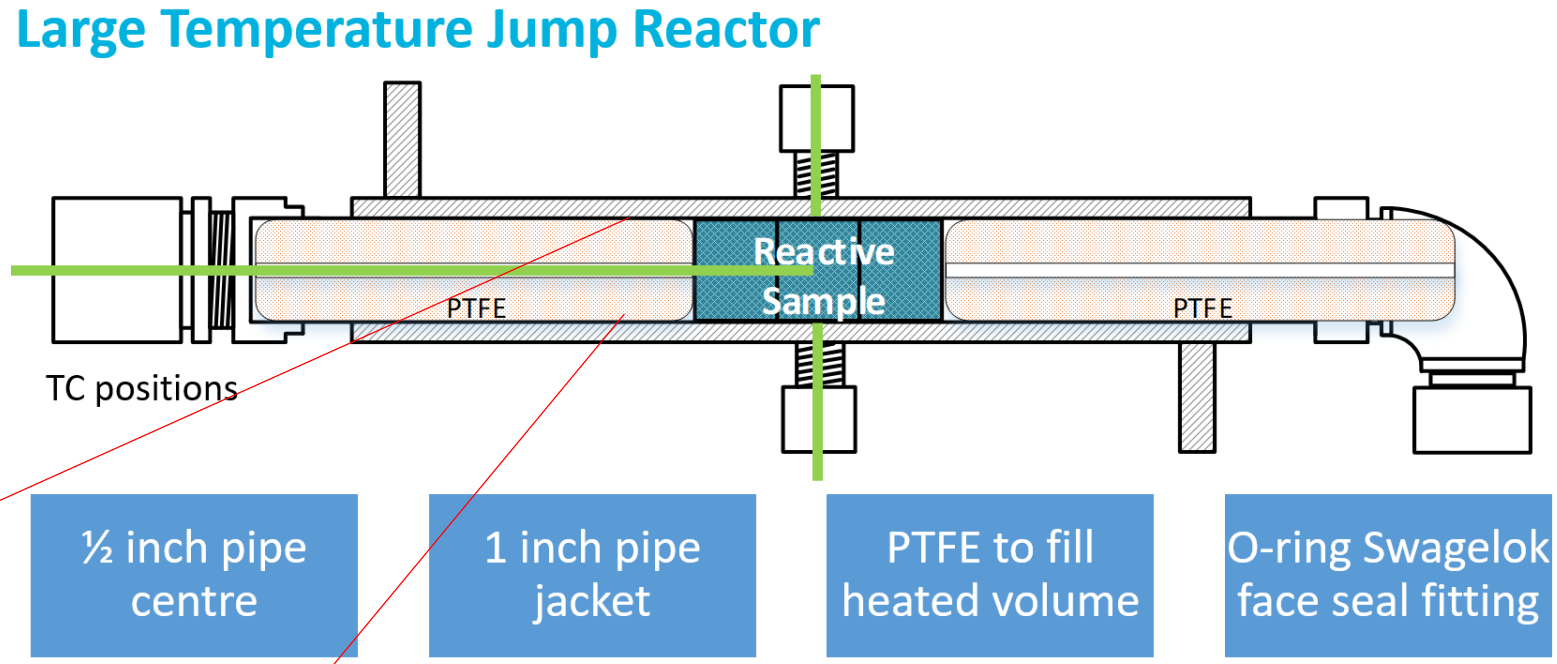
Accurate Thermocouple Readings

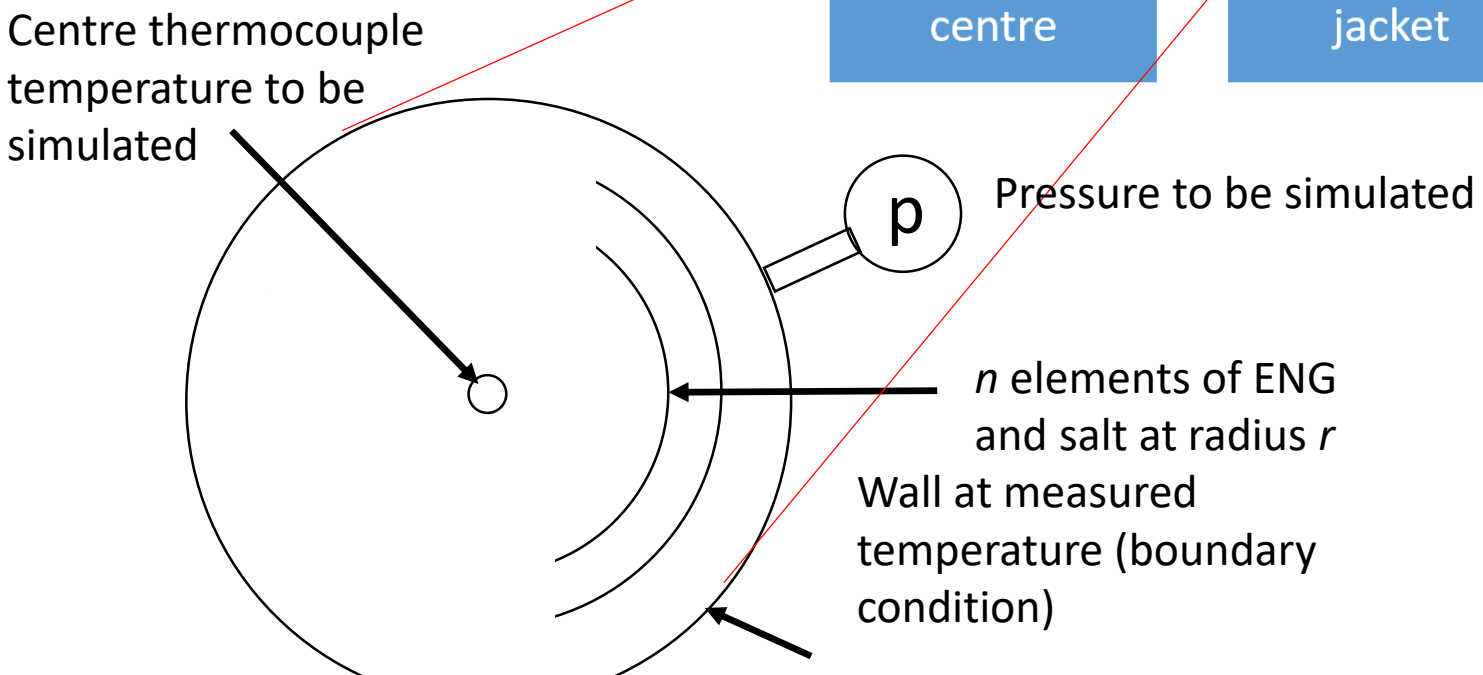
- Grounded thermocouples working as a pair are very tricky
- They can drift/expand due to heating so to ensure contact is difficult particularly within the ammonia volume
- Data acquisition with the pressure transducer into the same module or device was also challenging, as on a standard DAQ device it would put voltages across the device as well as voltage across the rig itself
- Addressed with separate devices and grounding to avoid noise-
  - At one point, flickering lights appeared to produce a frequency that could be picked up in the noise from the mains earth!

Modelling success

LTJ Test modelling

1-d axi-symmetric model





Similar to the linear form used by SJTU

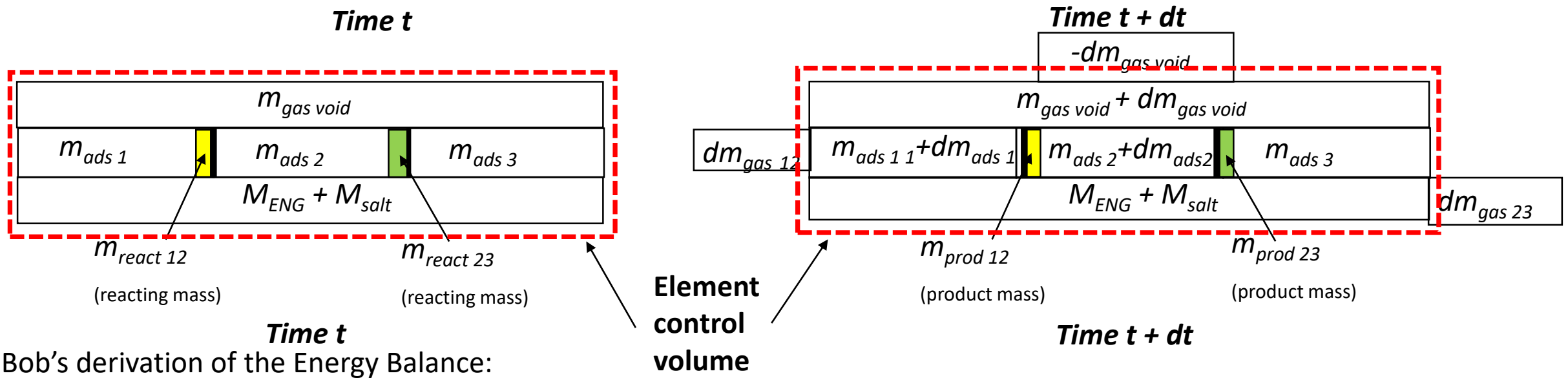
$$\frac{dX}{dt} = (1-X)^y A \frac{p_{eq} - p}{p}$$

Mazet, Amaroux & Spinner 1991

Reaction Engineering

$m_{ads\ 1}$	$m_{ads\ 2}$	$m_{ads\ 3}$
$m_{salt\ 1}$	$m_{salt\ 2}$	$m_{salt\ 3}$

$m_{ads\ 1}+dm_{ads\ 1}$	$m_{ads\ 2}+dm_{ads\ 2}$	$m_{ads\ 3}+dm_{ads\ 3}$
$m_{salt\ 1}+dm_{salt\ 1}$	$m_{salt\ 2}+dm_{salt\ 2}$	$m_{salt\ 3}+dm_{salt\ 3}$

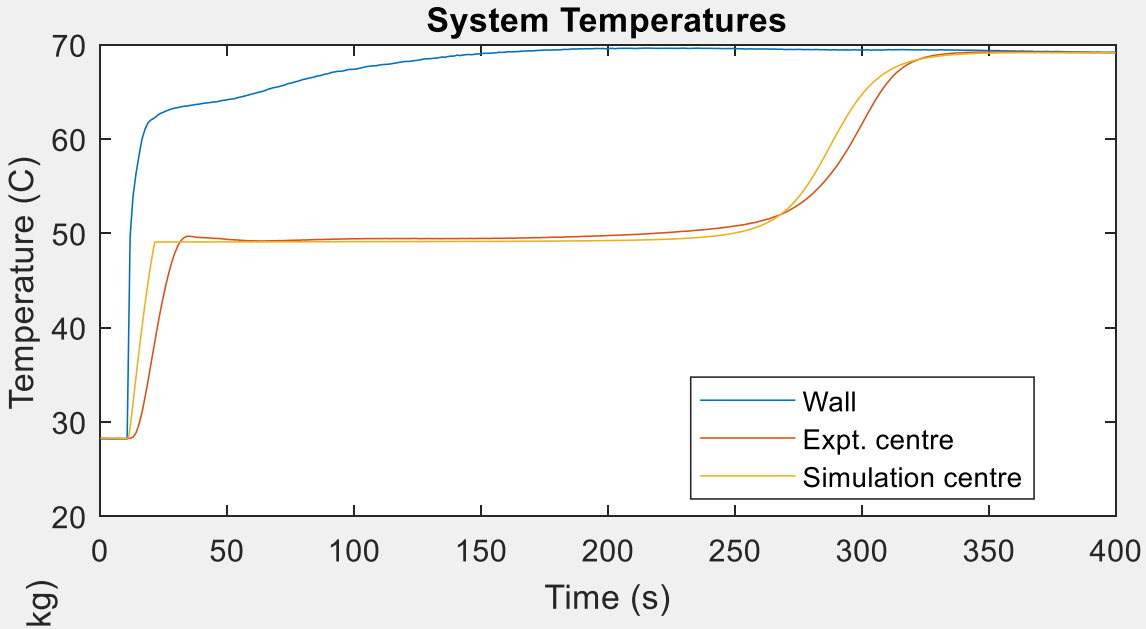


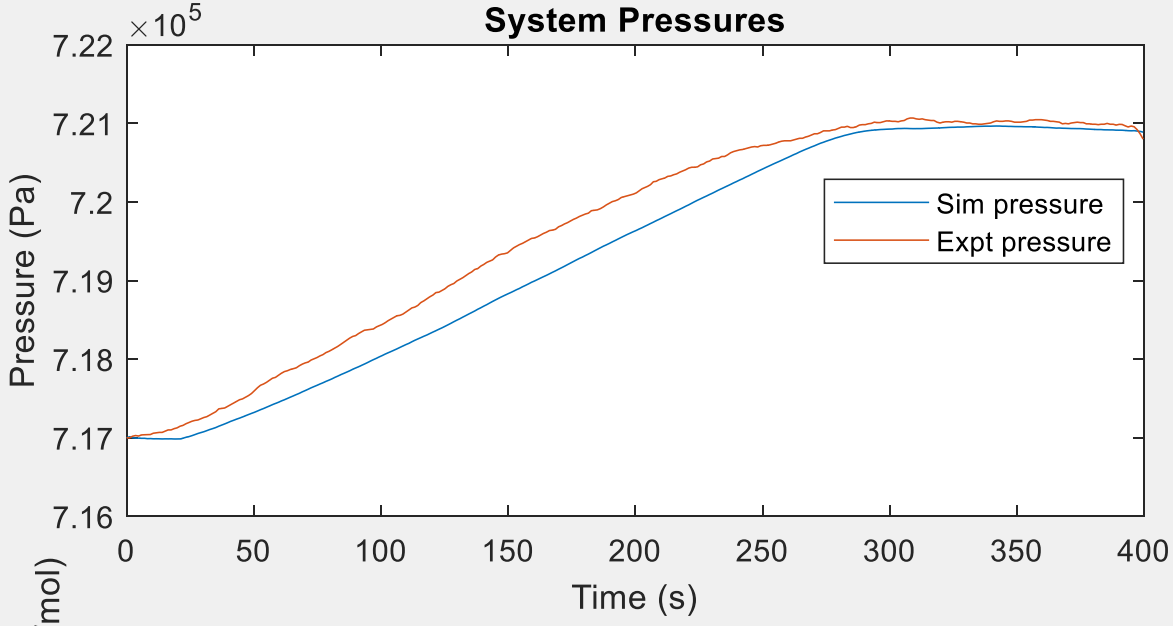
Bob's derivation of the Energy Balance:

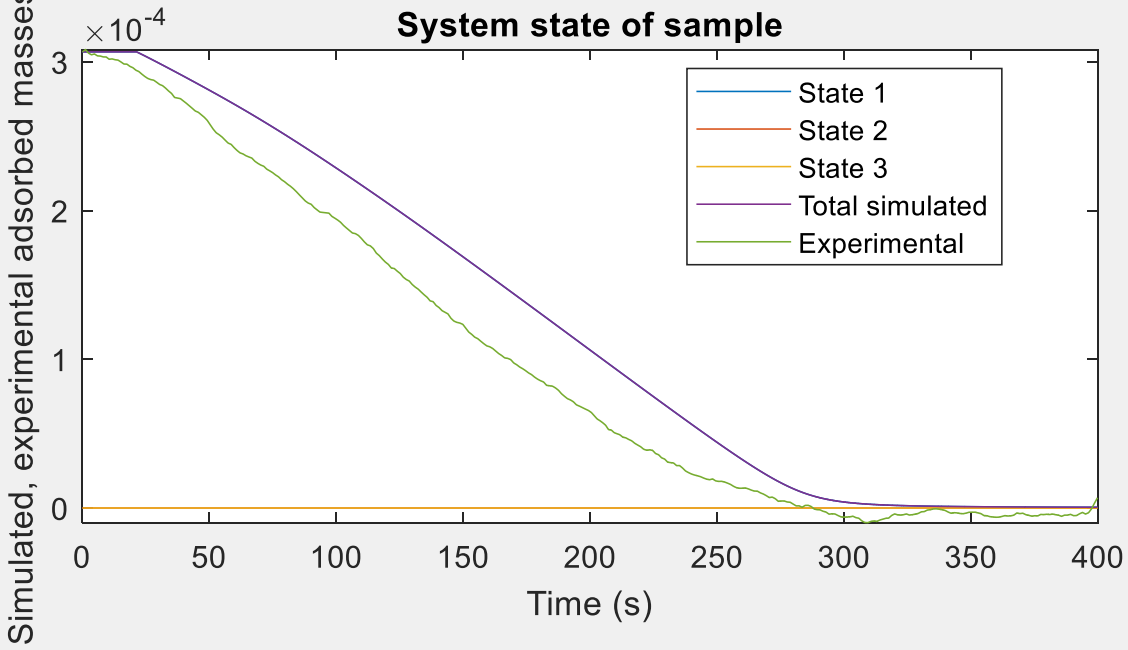
$$dT = \frac{dQ - dm_{gas\ 12}\Delta h_{12} - dm_{ads\ 12}pv_{ads}\left(1-\frac{B}{A}\right) - dm_{gas\ 23}\Delta h_{23} - dm_{ads\ 23}pv_{ads}\left(1-\frac{C}{B}\right) + V_{void}\frac{dp}{1+dp/T}}{Mc_p + \sum_1^3 m_{ads}\,c_{v\,ads} + m_{gas\ void}\,c_{v\,gas} - V_{void}\frac{pT}{1+dp/T}}$$

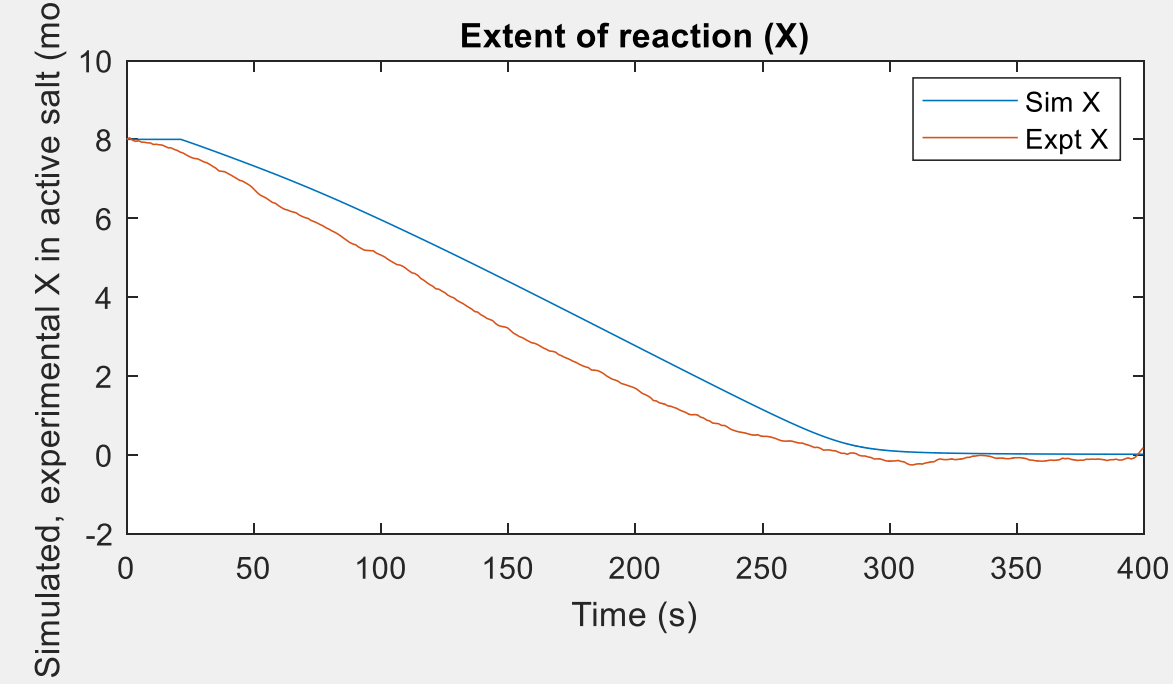
Proof is in the plotting…..

Barium Chloride 7bar LTJ test

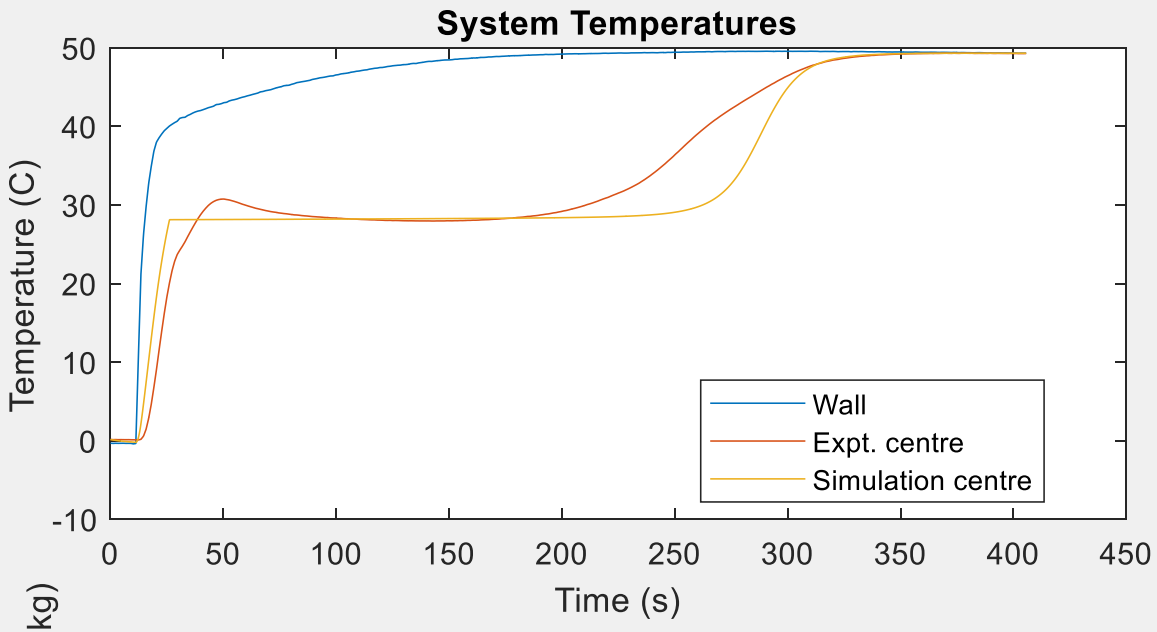


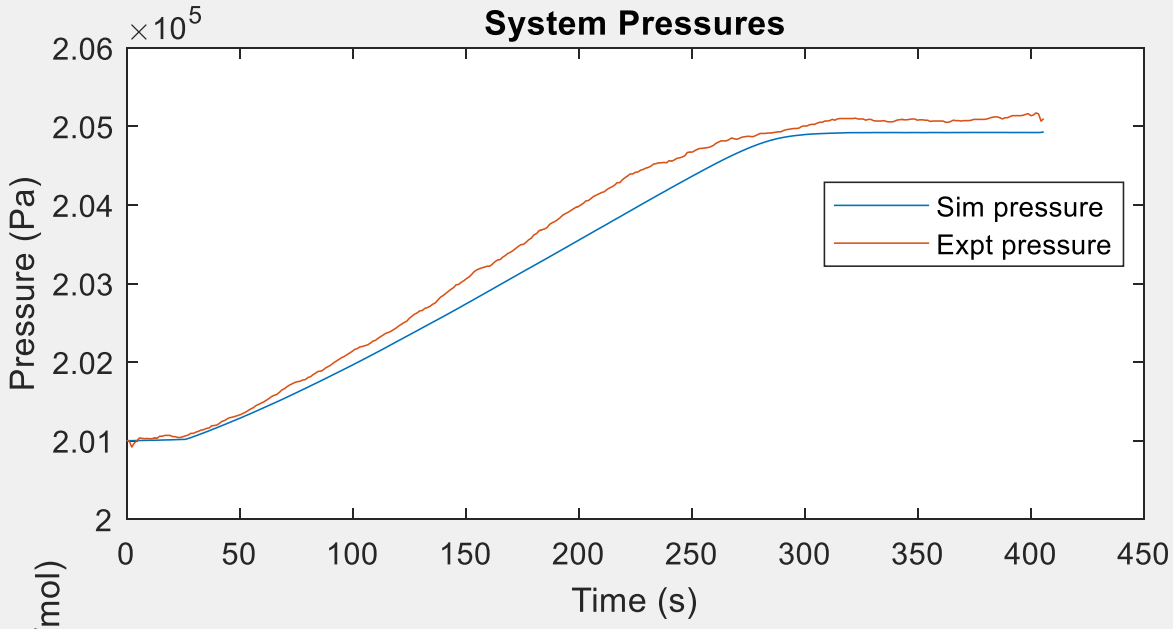


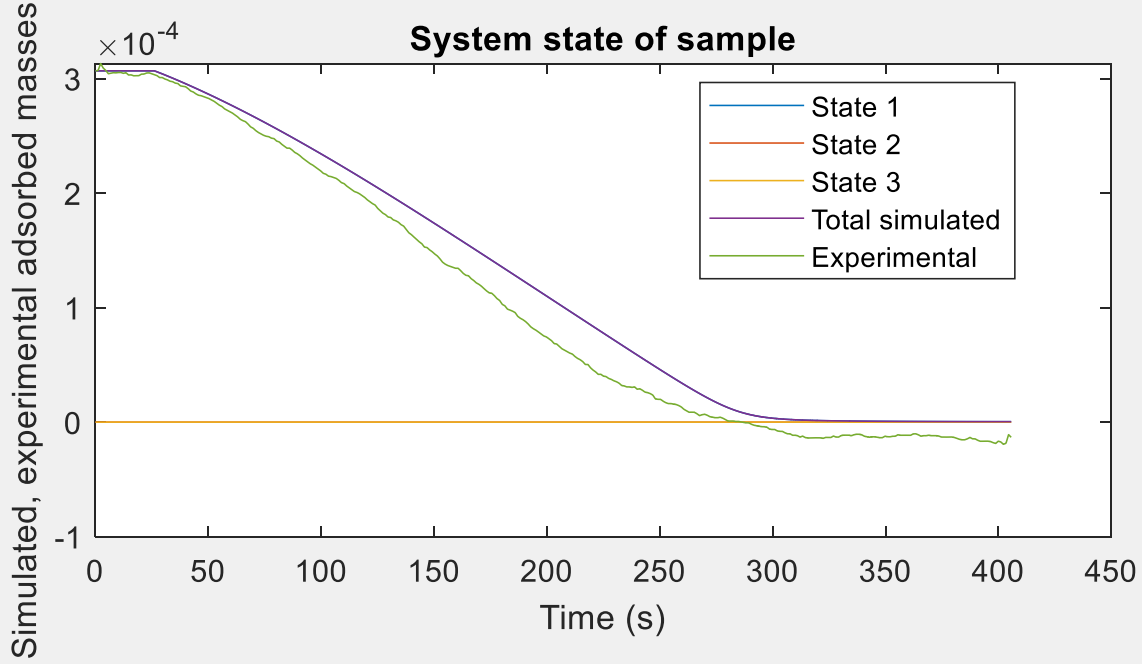


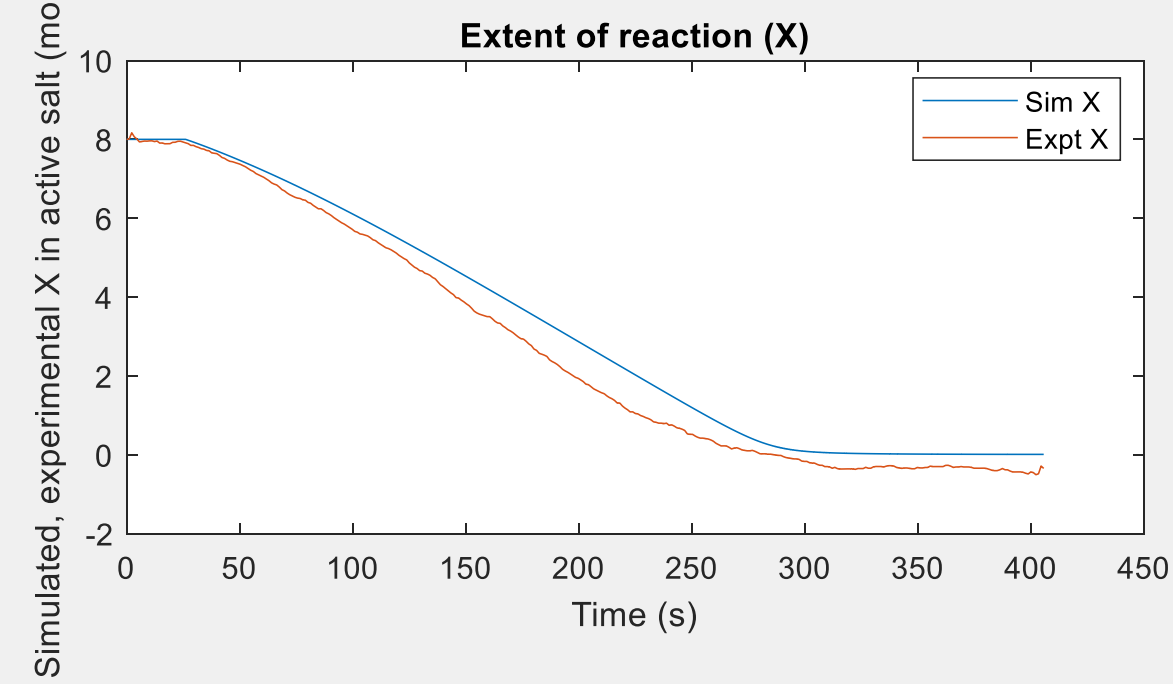


Barium Chloride 2bar LTJ test

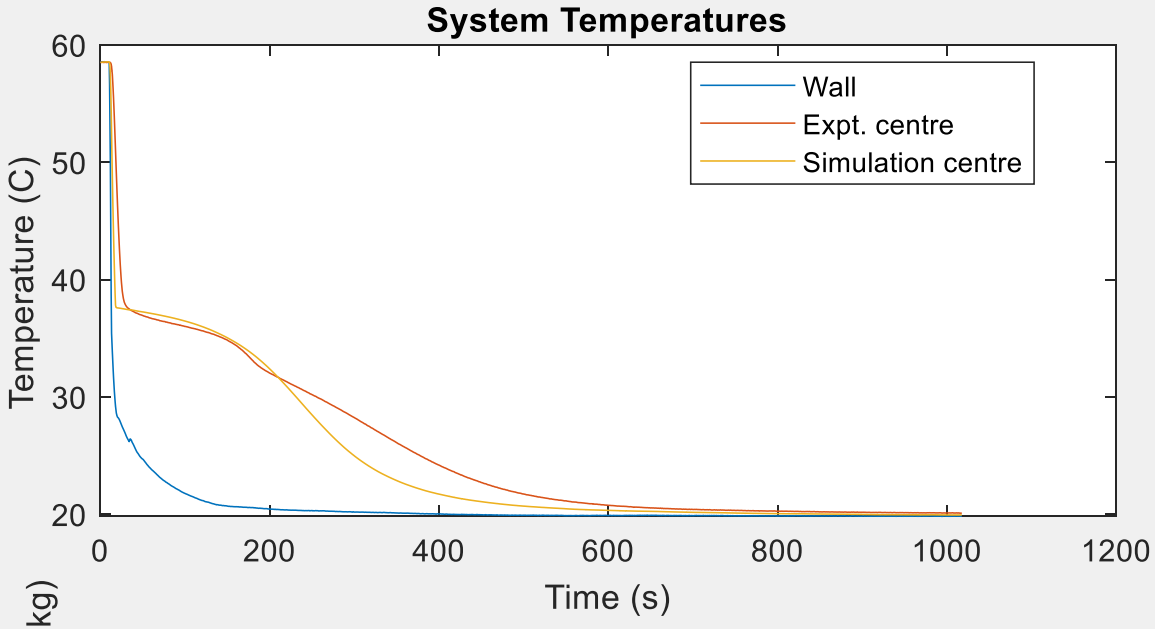


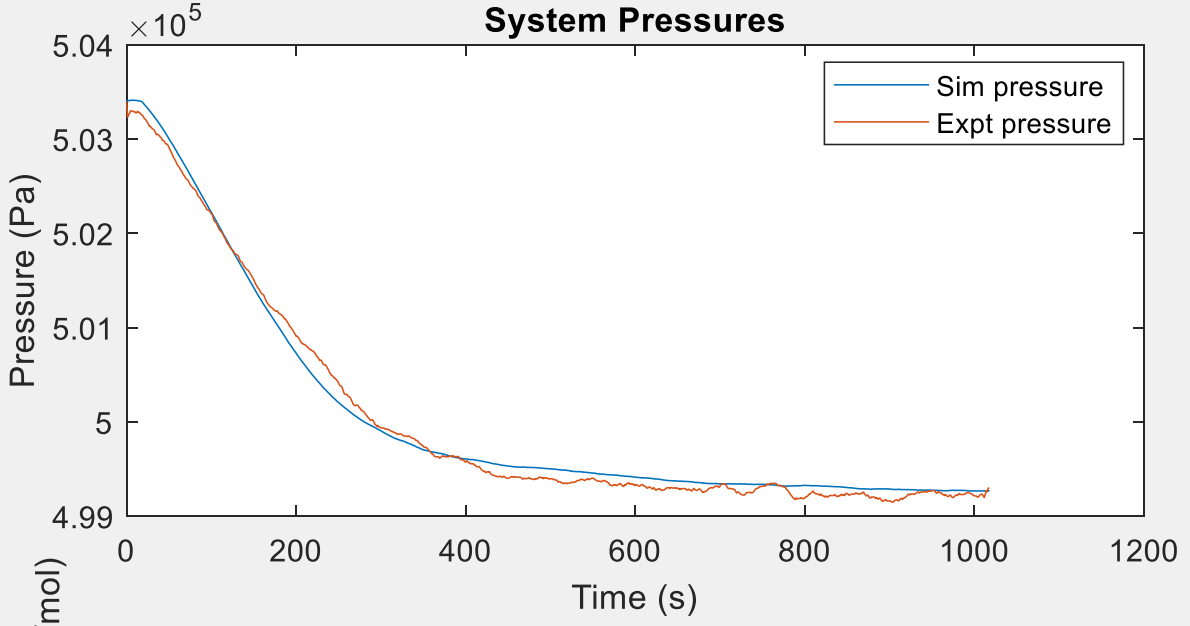


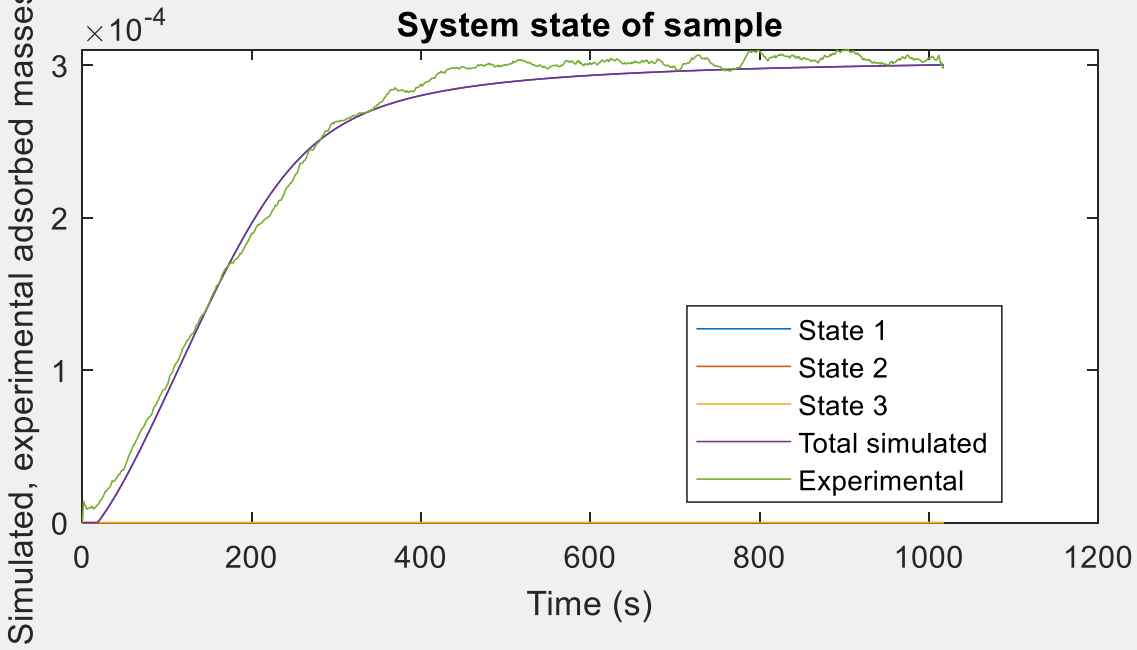


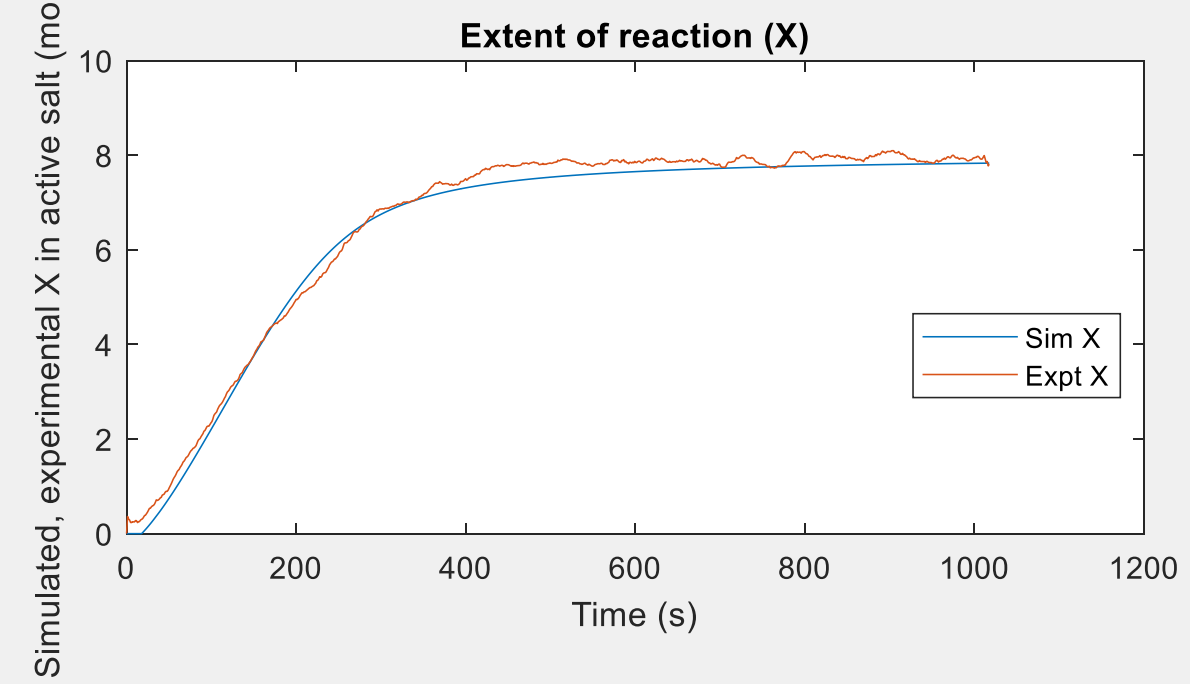


Barium Chloride 5bar LTJ adsorption test

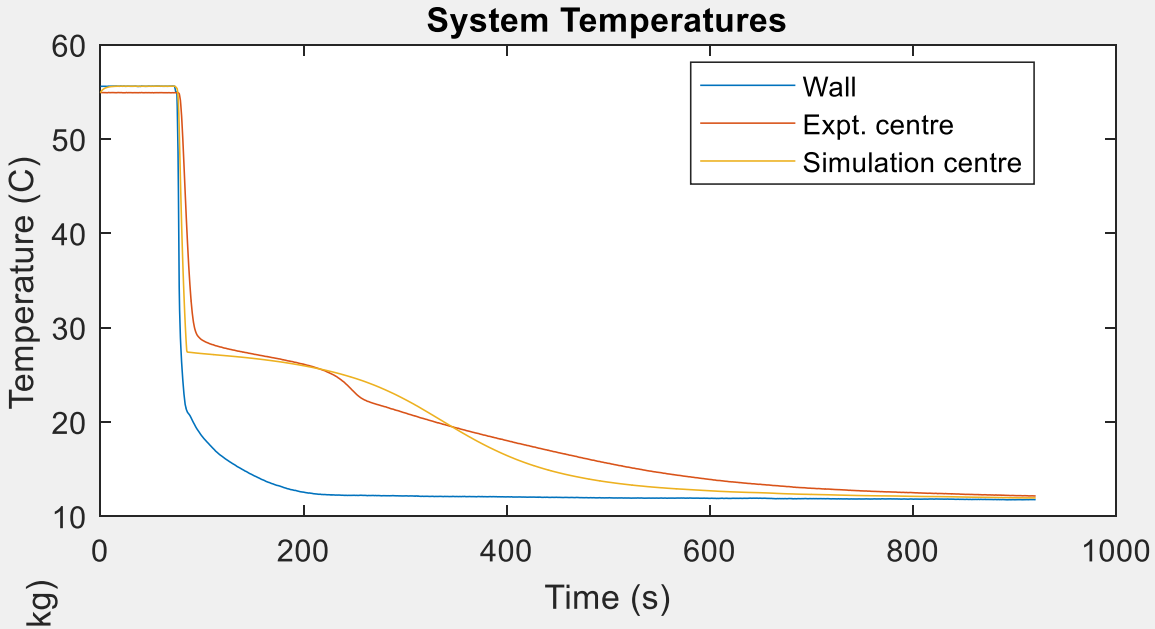


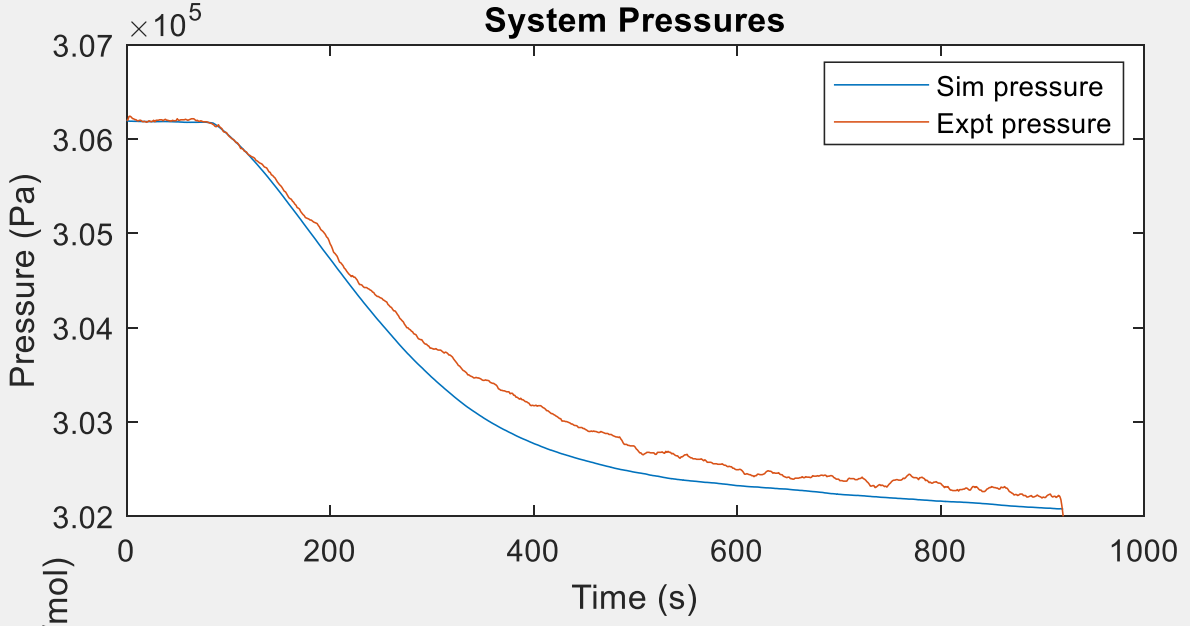


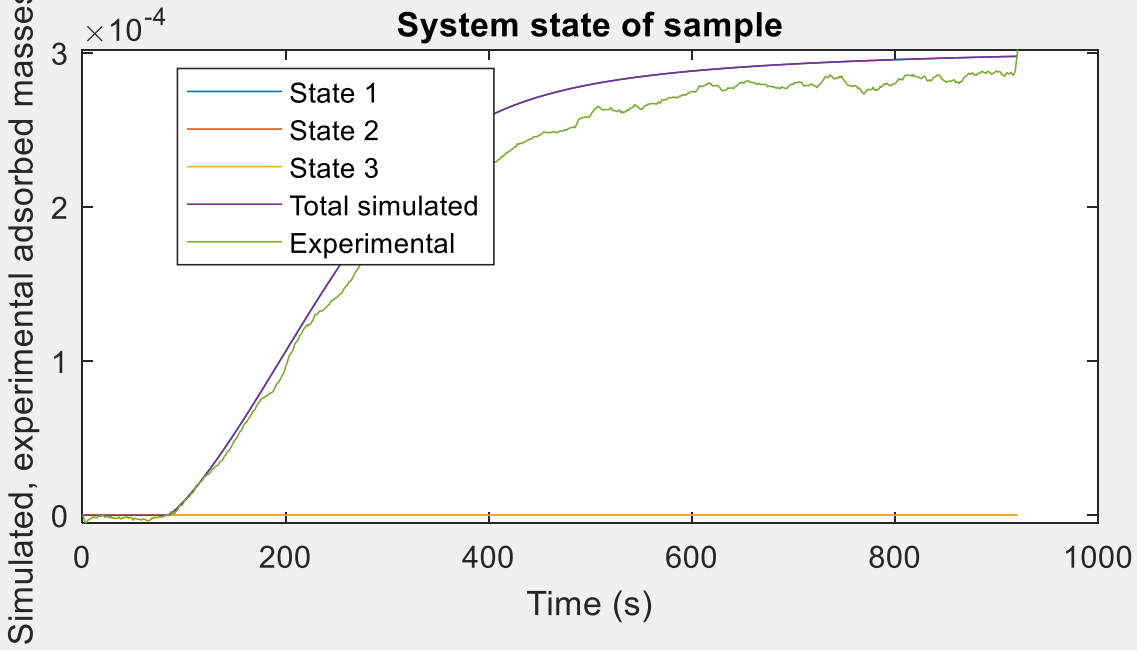


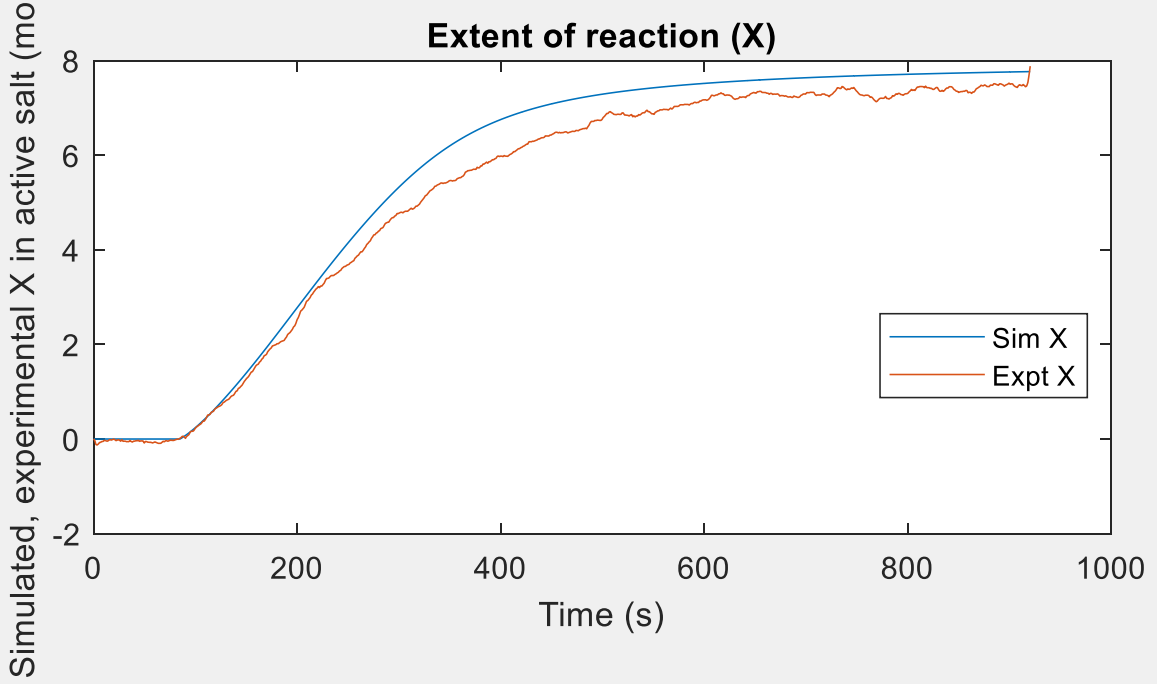


Barium Chloride 3bar LTJ adsorption test

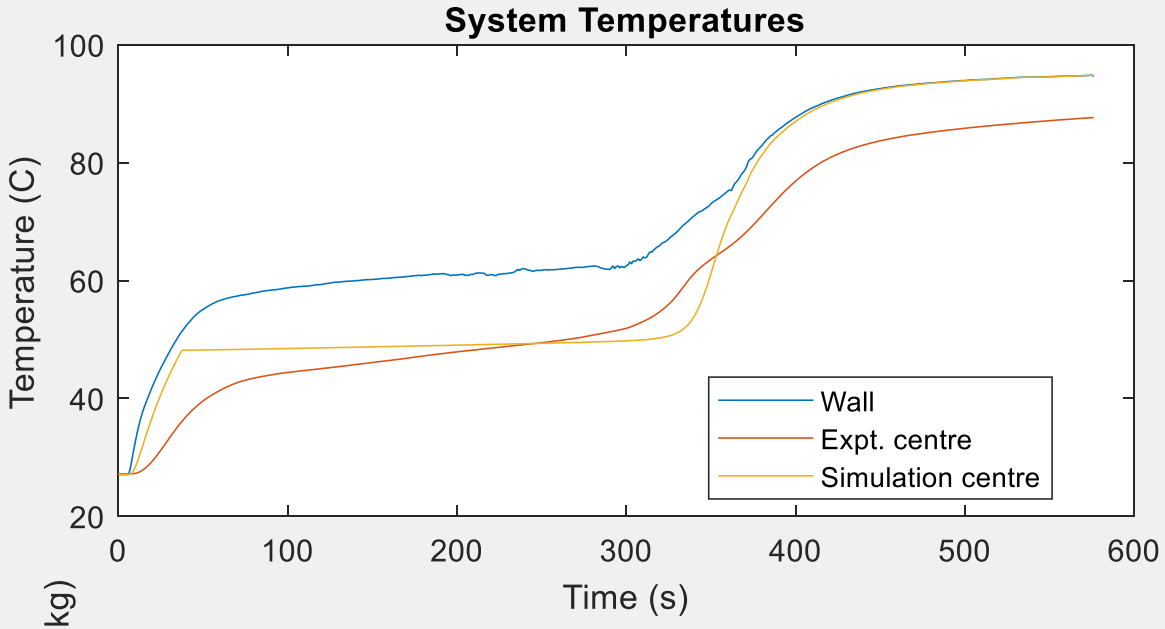


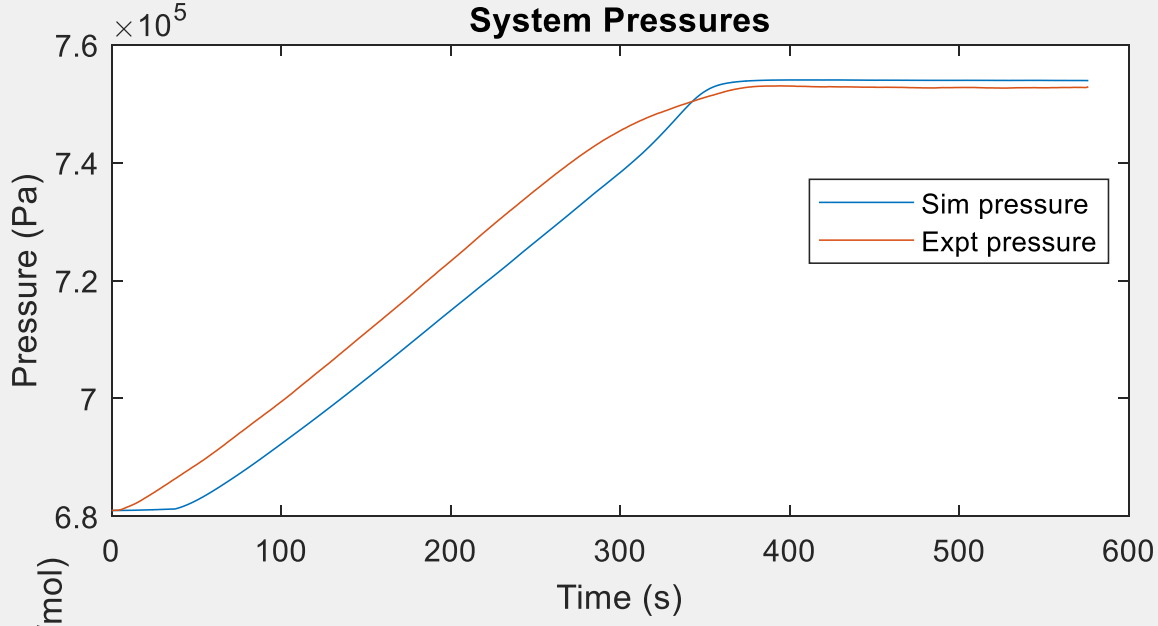


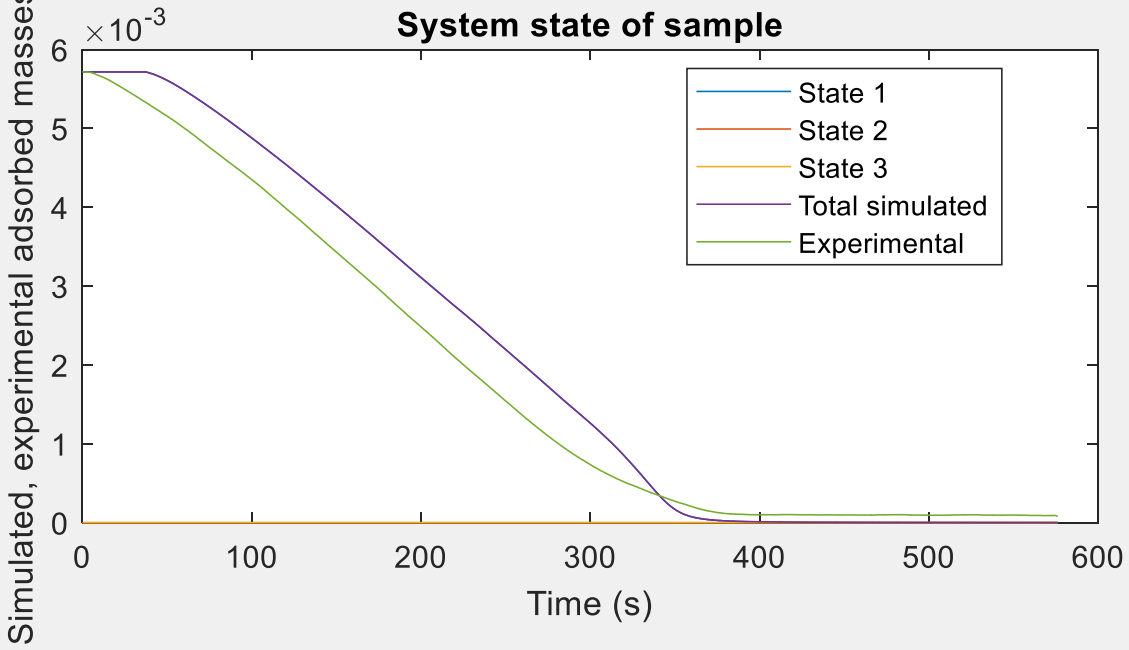


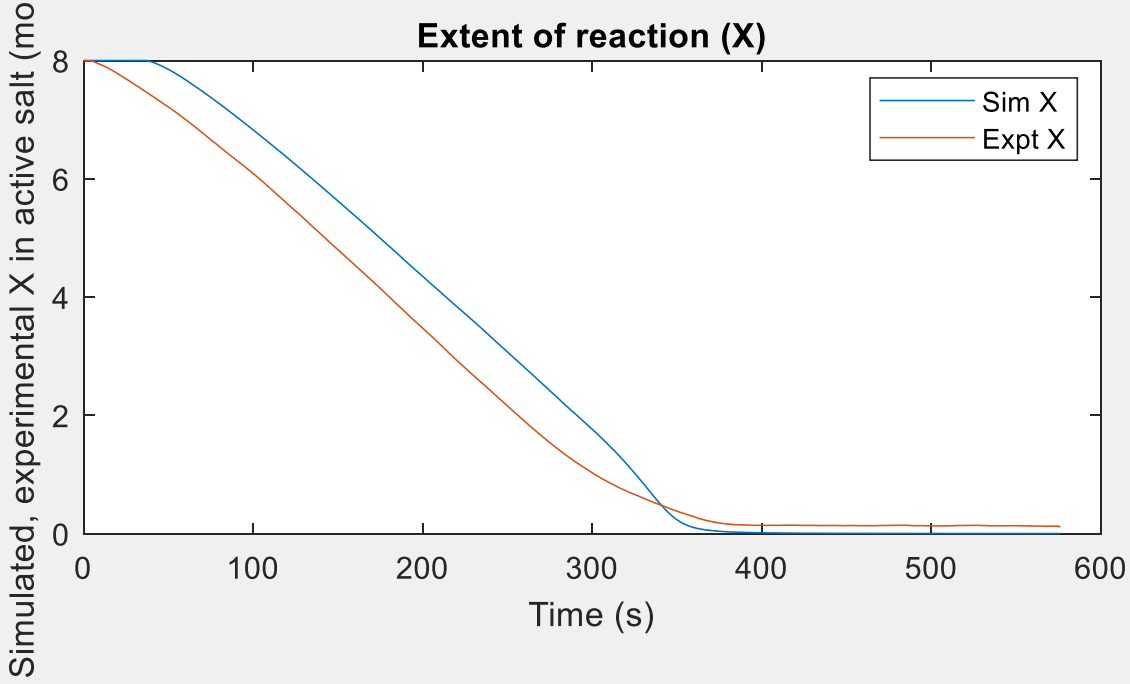


Barium Chloride Shell LTJ test









To conclude

- Model is predicting well and keen to discuss this
- Also would be pleased for any insight into the salts deviant behaviour
- From the results it is possible to work out a (peak) power/volume value and use this as a basis for designing a machine

Thank you for listening

Any questions?

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