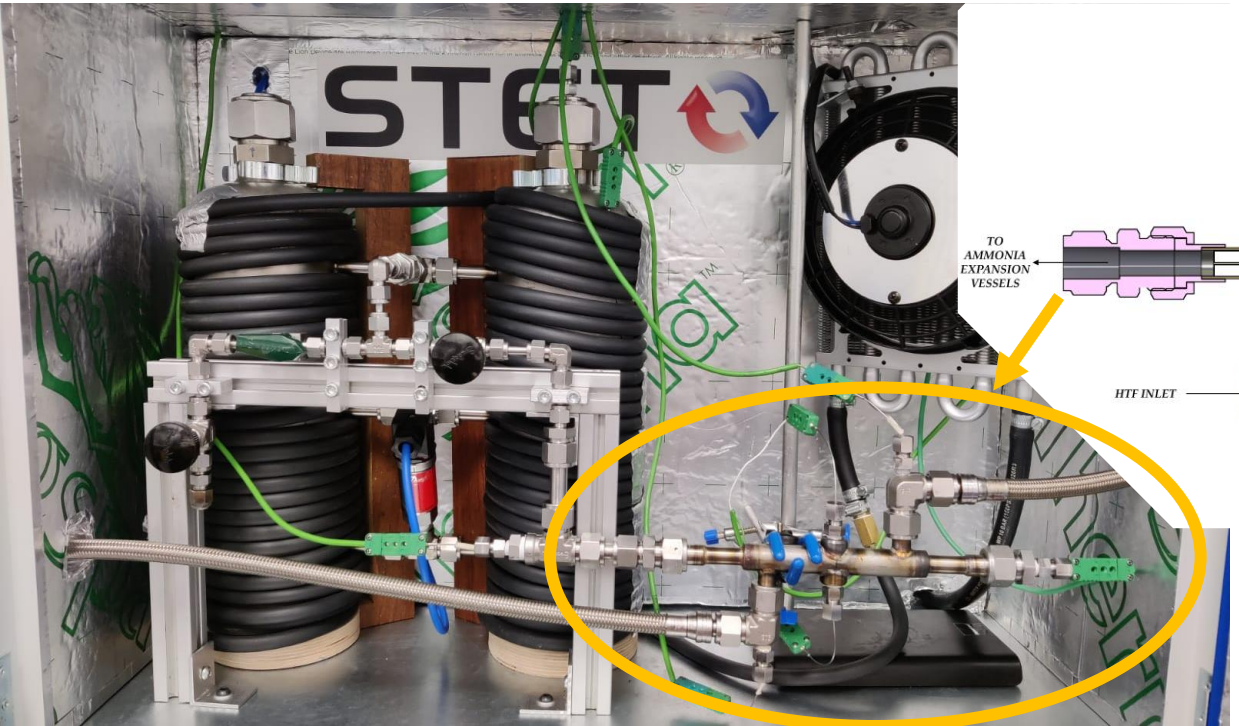
Ammonia-Salt HP / TT Updates

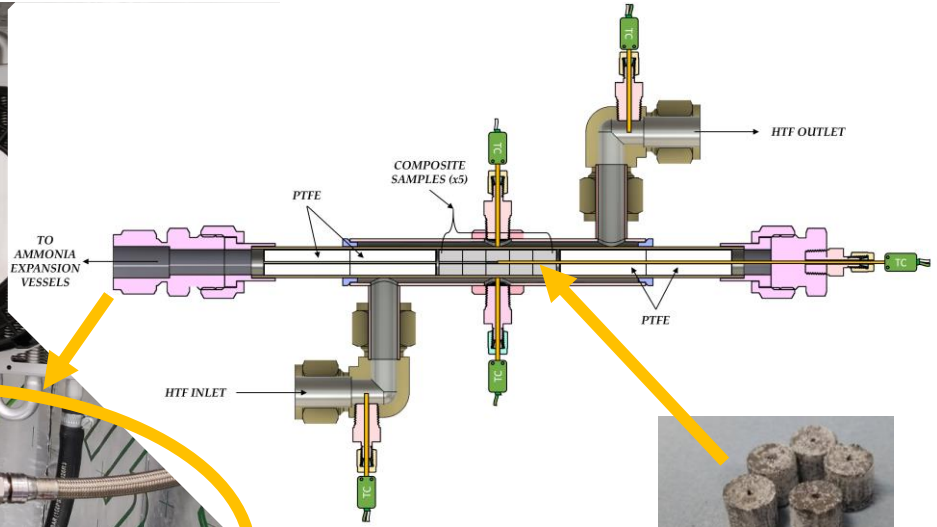
George Atkinson | STET | The University of Warwick

Mission Innovation Workshop | Online | Thursday 14th October2021

Two Experimental Methods, Two Reactor Configurations

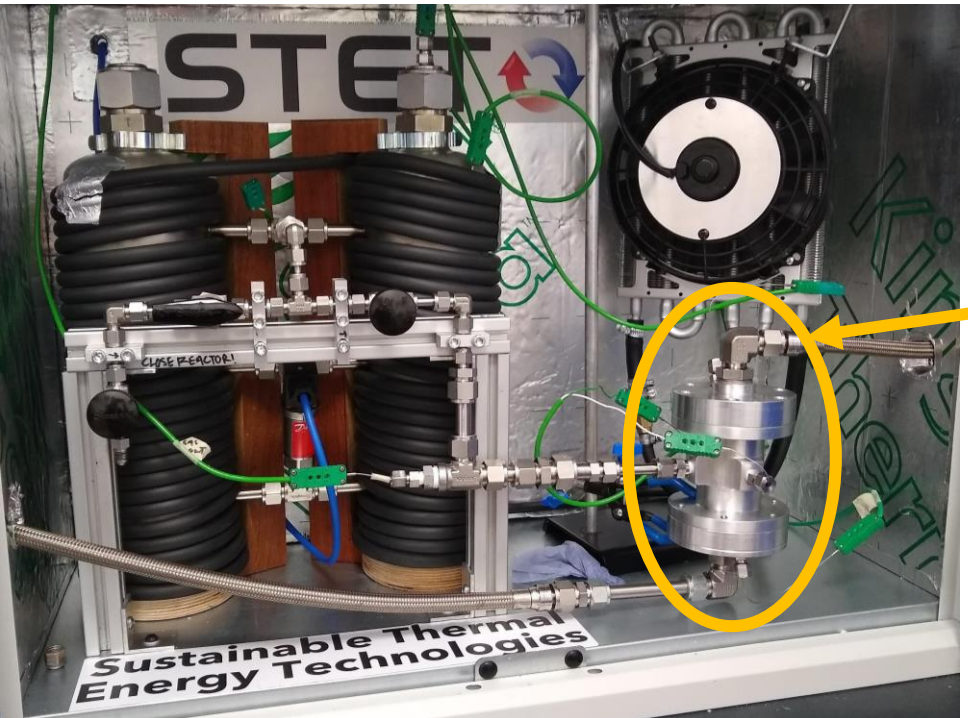
- **Tube-side** LTJ reactor housing up to 5 ENG-salt samples.

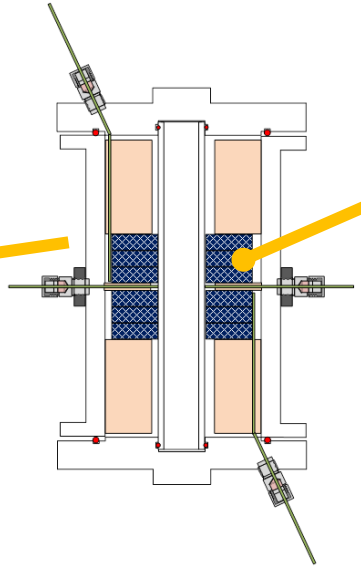




Two Experimental Methods, Two Reactor Configurations

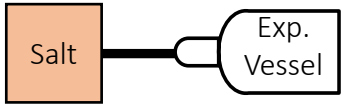
- **Shell-side** LTJ reactor housing 2-8 ENG-salt samples.



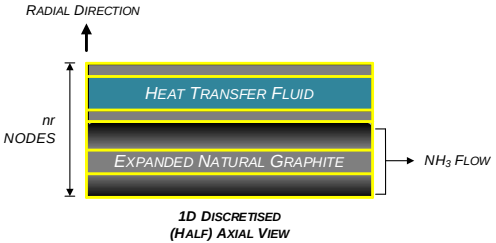


Modelling Methods

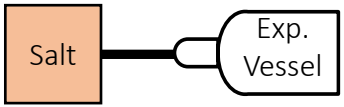
- Starting with previous work by Hinmers and Critoph[1, 2].



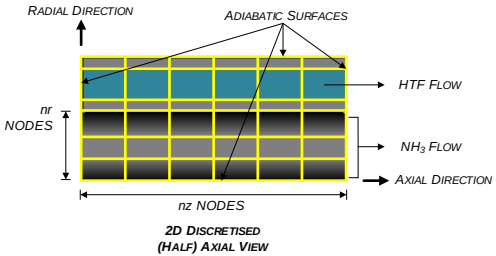
- 1D radially discretised finite difference model.



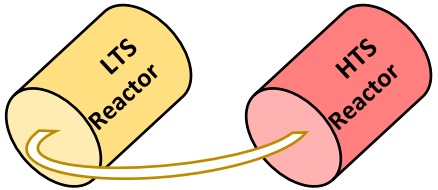
Model Development



- Advance the model to a 2D radial and axially discretised finite difference model.



- Use the same 2D mass-based model to simulate a tube side resorption cycle.
- Output meaningful performance metrics - SMP and COP



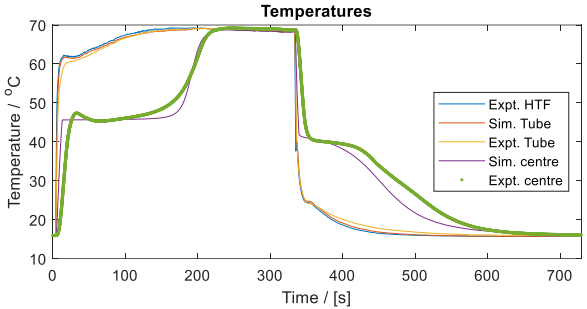
[1] Hinmers, S.; Critoph, R.E. Modelling the Ammoniation of Barium Chloride for Chemical Heat Transformations. Energies 2019, 12, 4404. https://doi.org/10.3390/en12234404

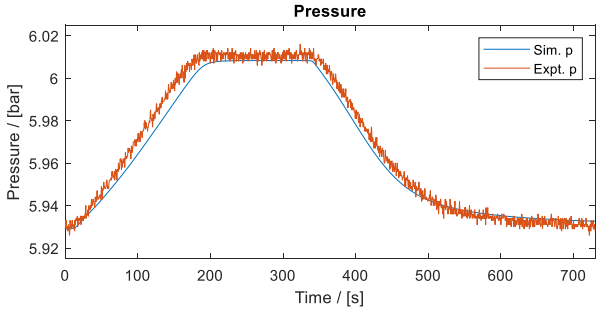
[2] Atkinson, G.H.; Hinmers, S.; Critoph, R.E.; van der Pal, M. Ammonium Chloride (NH_4Cl)—Ammonia (NH_3): Sorption Characteristics for Heat Pump Applications. Energies 2021, 14, 6002. https://doi.org/10.3390/en14186002

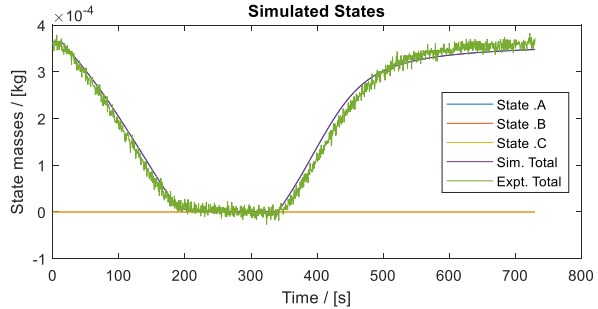
Tube-side

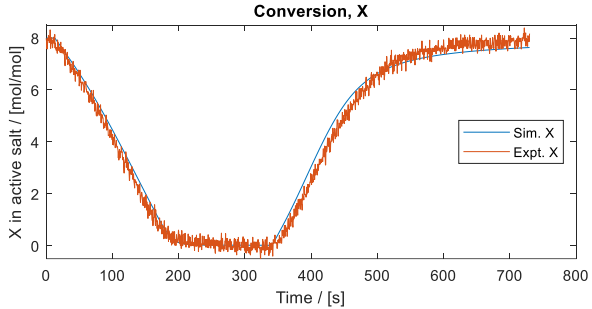
Large Temperature Jump Outputs ($BaCl_2$)

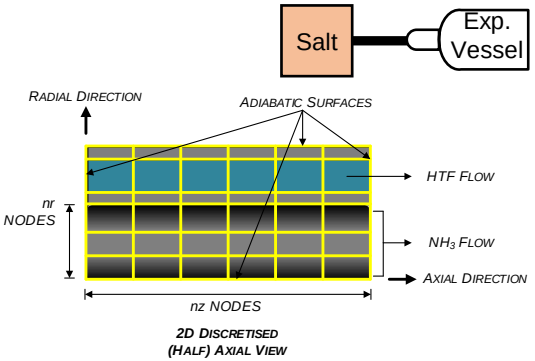
- $BaCl_2$ an option for LTS.
- But low-pressure desorption likely to cause mass transfer issues.







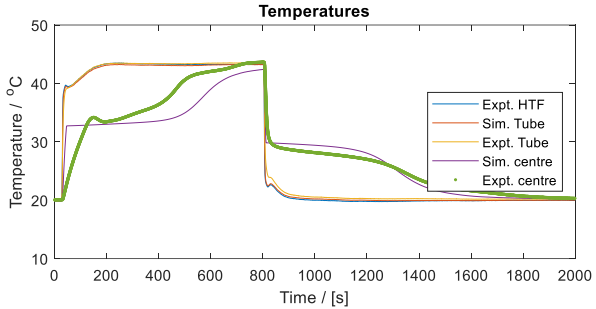


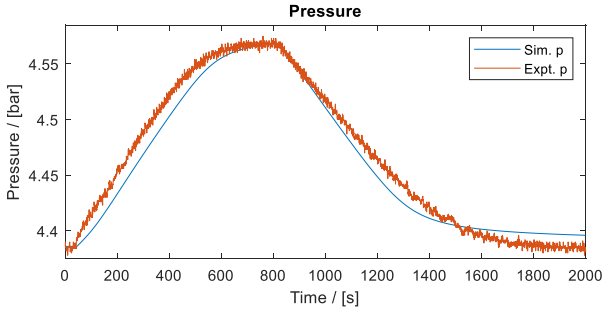


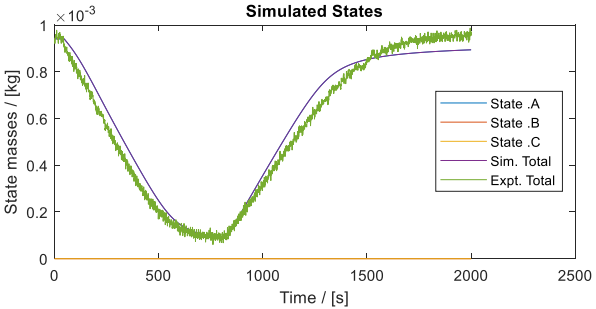
Tube-side

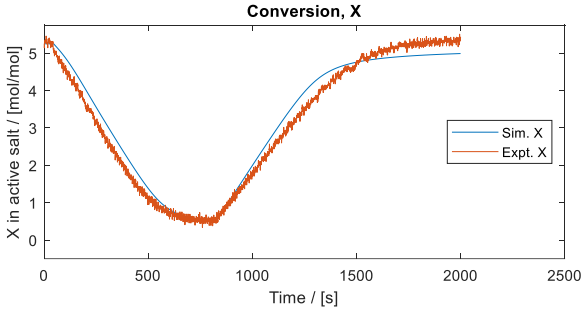
Large Temperature Jump Outputs (**NaBr**)

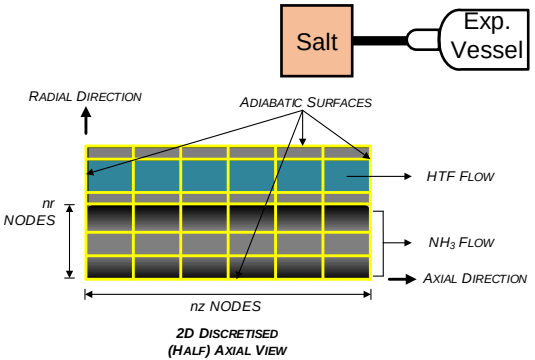
- NaBr tested as an alternative and initial analysis looks promising for LTS applications.







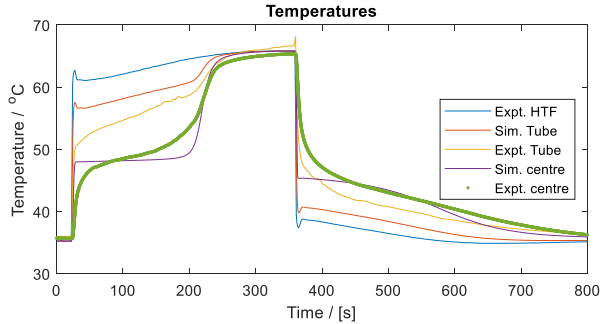


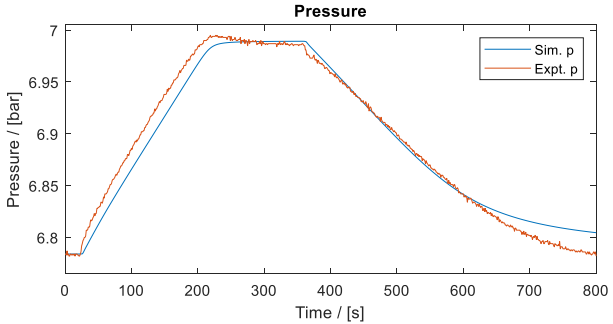


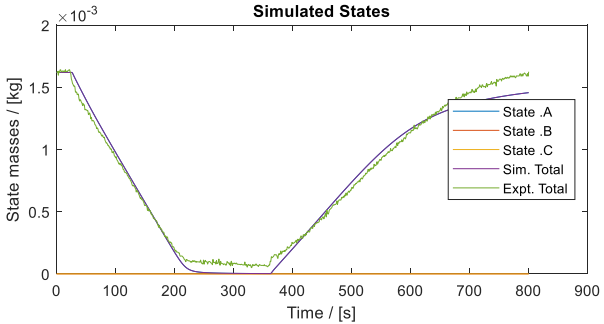
Shell-side

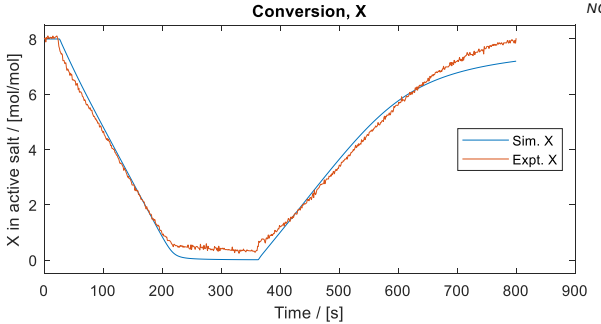
Large Temperature Jump Outputs ($BaCl_2$)

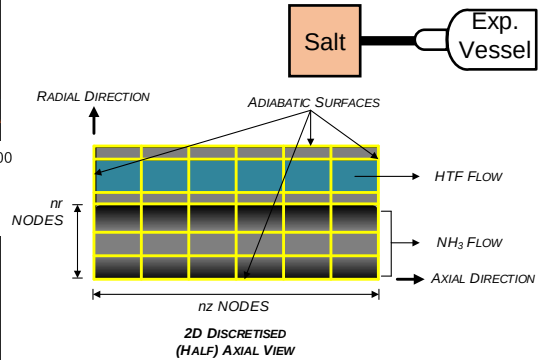
- $BaCl_2$ tested as a single stage salt for comparison with tube-side data, again limited with low-vapour pressure desorption for HP applications.







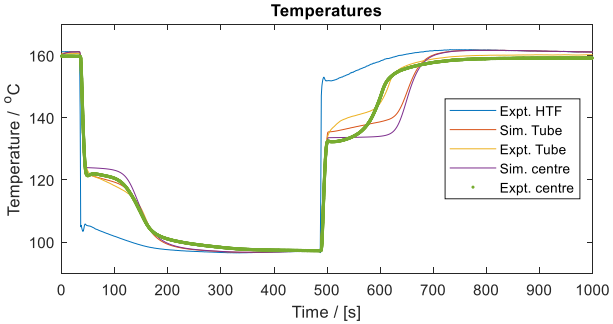


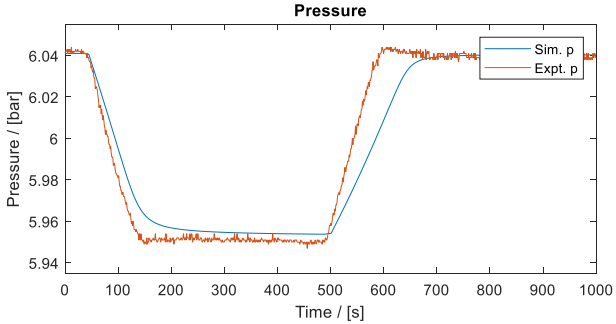


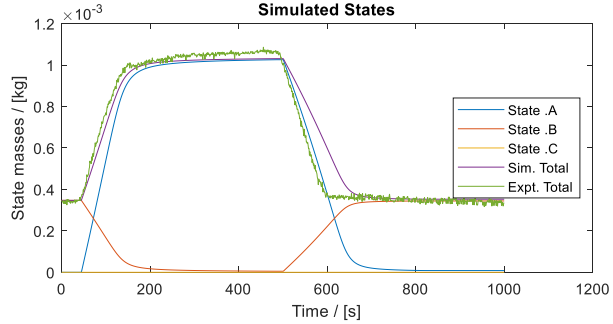
Shell-side

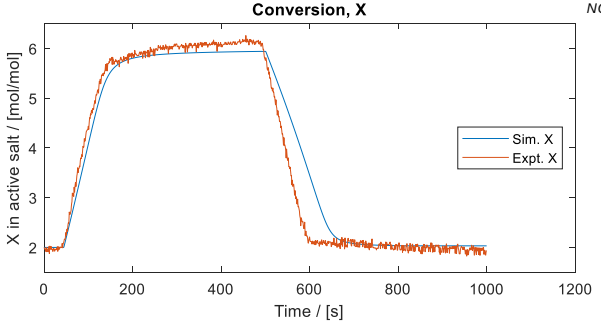
Large Temperature Jump Outputs ($MnCl_2$)

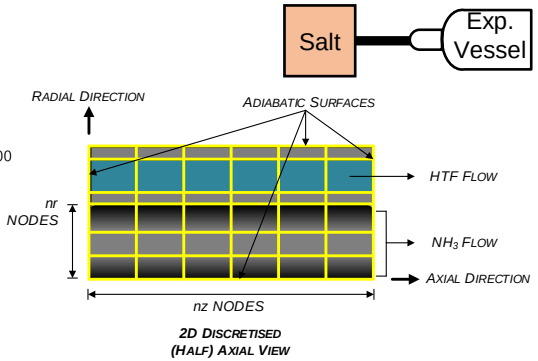
- $MnCl_2$ tested for HTS applications for HP and TT. Data looks promising, with good matching.





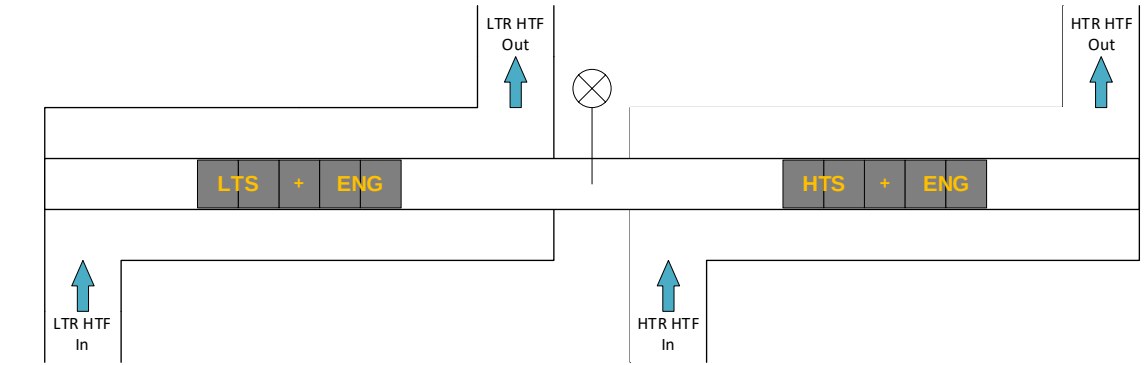






Resorption

Tube-side (hypothetical) Resorption

Reactor Heat Transfer Fluid (HTF) Inlet (In) Temp. / Cycle		
Initial Conditions	T_L	T_M
1. HPP	T_M	T_H
2. LPP	T_L	T_M
3. HPP	T_M	T_H
4. LPP	T_L	T_M

T_L

10 °C

T_M

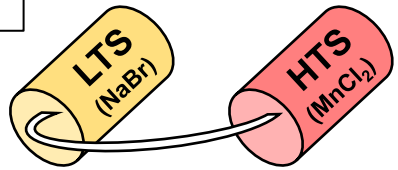
50 °C

T_H

170 °C

Resorption

Resorption Tube-side ($NaBr-MnCl_2$)



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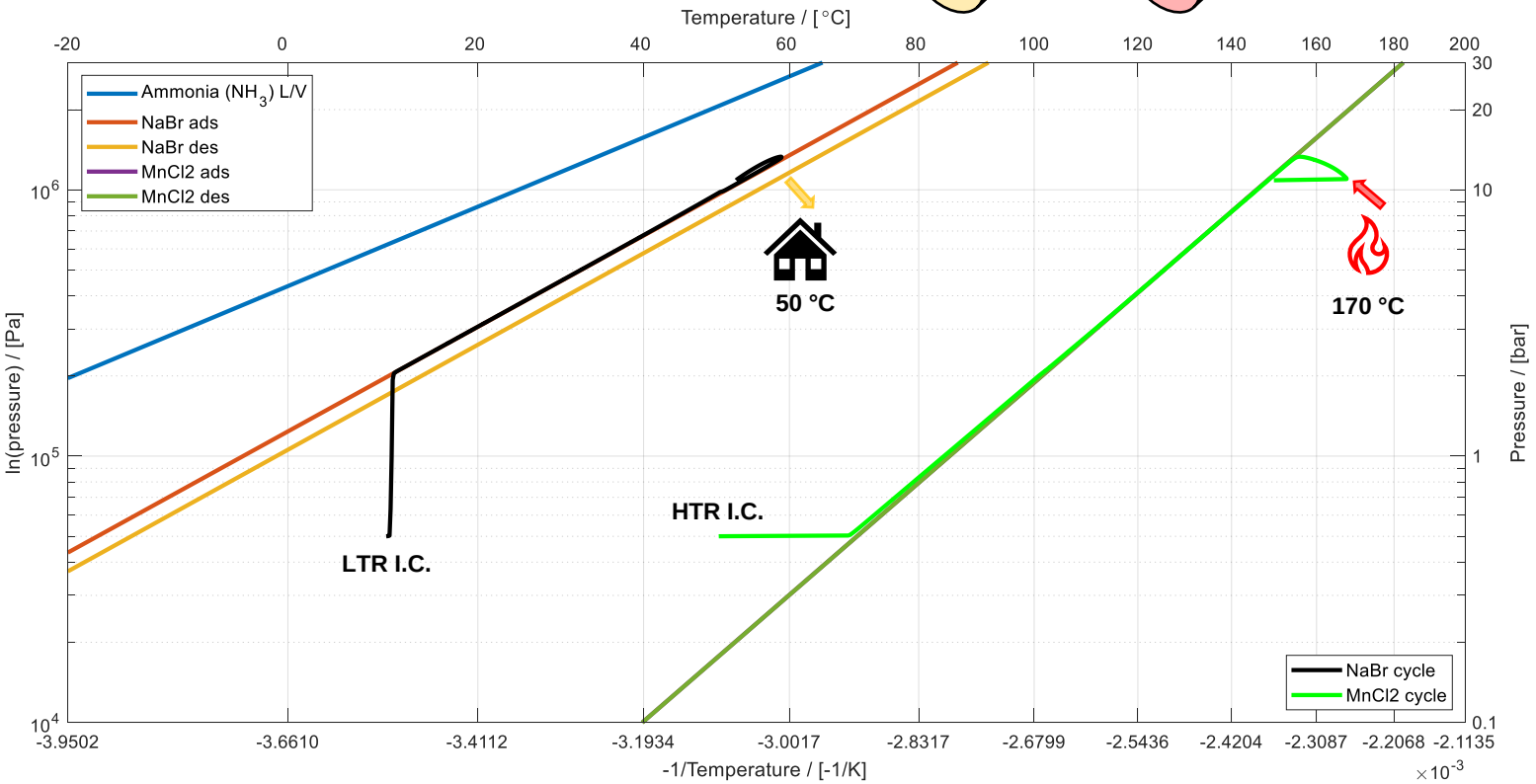
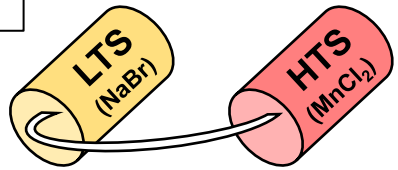


Resorption

Resorption Tube-side ($NaBr-MnCl_2$)



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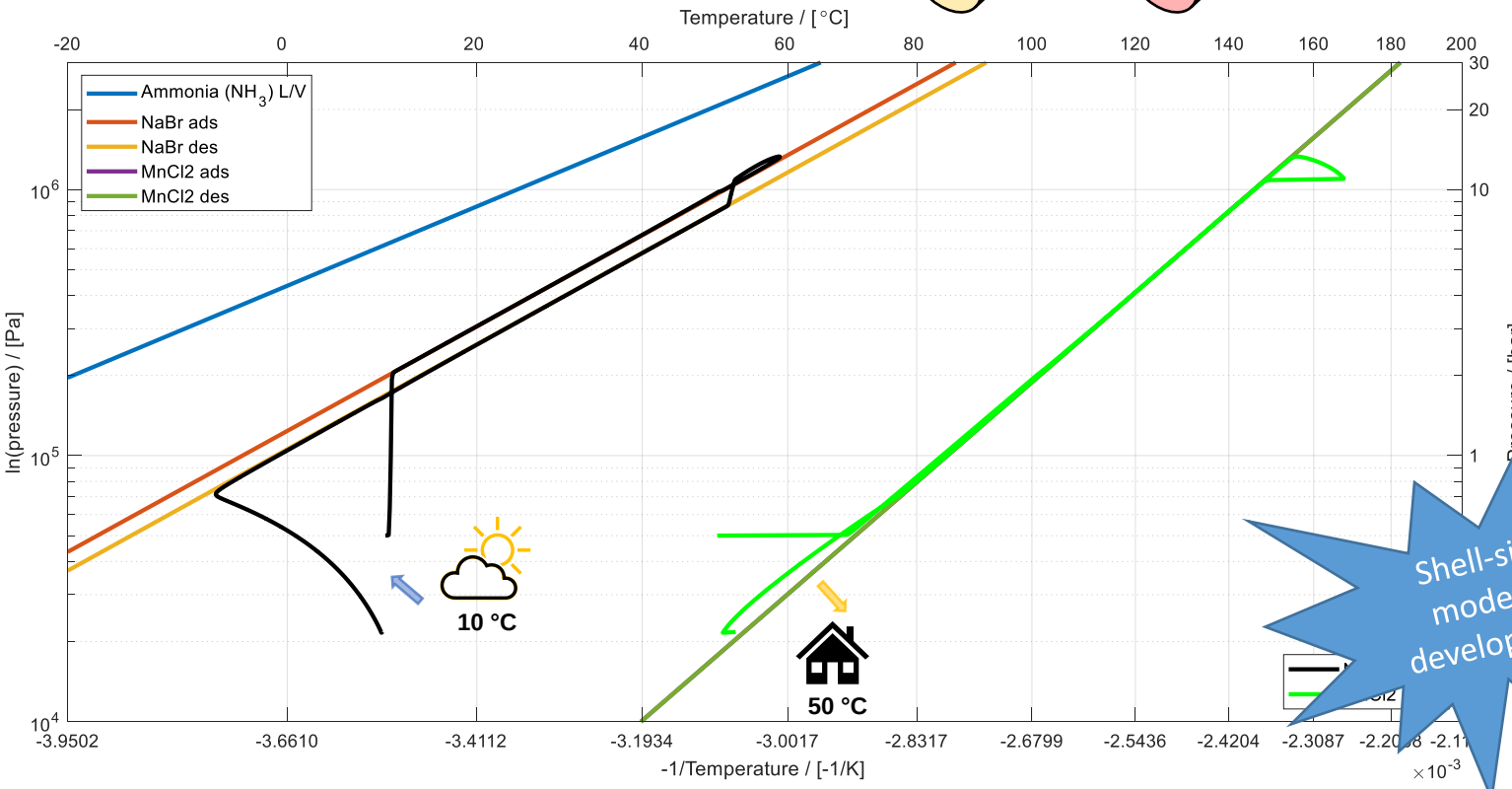
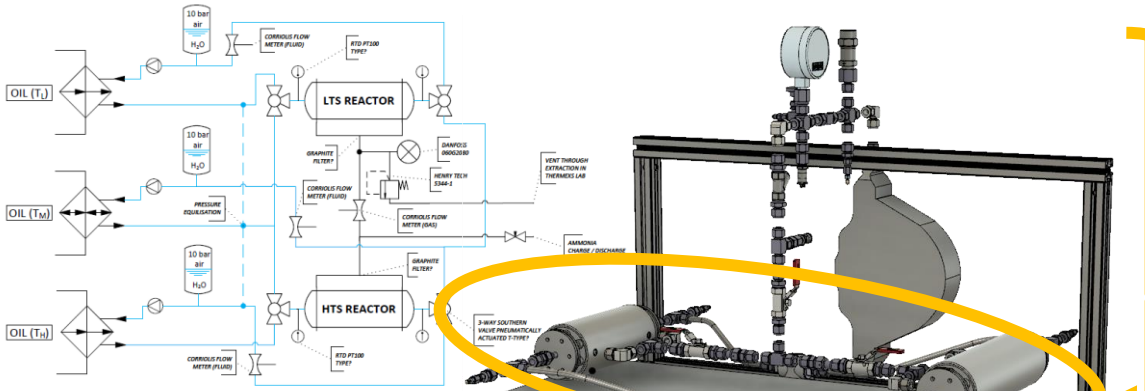


Shell-side model in development

System Design

Proof-of-Concept Heat Pump / Thermal Transformer



Initial Schematic, now designed and implemented in CAD

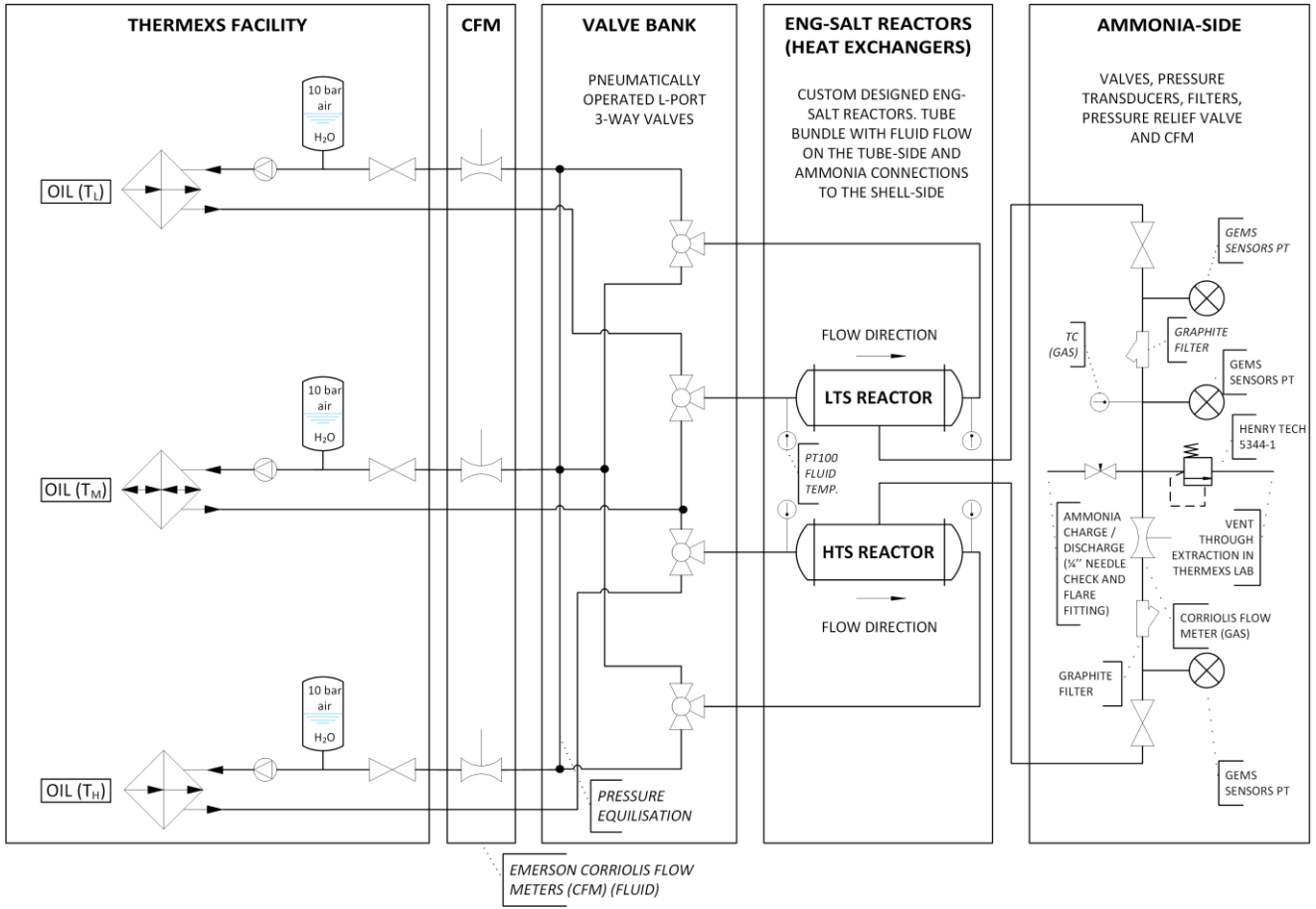
Ammonia-side (mainly)

LTS reactor(s)

HTS reactor

Valve bank and HTF distribution

Schematic Diagram



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Comments

- Connections to ThermExS are using ½'' PTFE lined flexible stainless steel hoses.
- Pipes, valves, reactors etc. are to be insulated using ARMCELL high temperature insulation.
- Temperatures, pressures and flow rates measured using an NI rack and LabView interface.
- Pneumatic circuit to control 3-way valves.

CAD Layout

Frame to support the Coriolis Flow Meter (CFM)

Shelf for the Low Temperature Salt (LTS) reactor(s)

Shelf for the High Temperature Salt (HTS) reactor

Bulkhead connections to/from ThermExS testing facility

Aluminium extrusion frame

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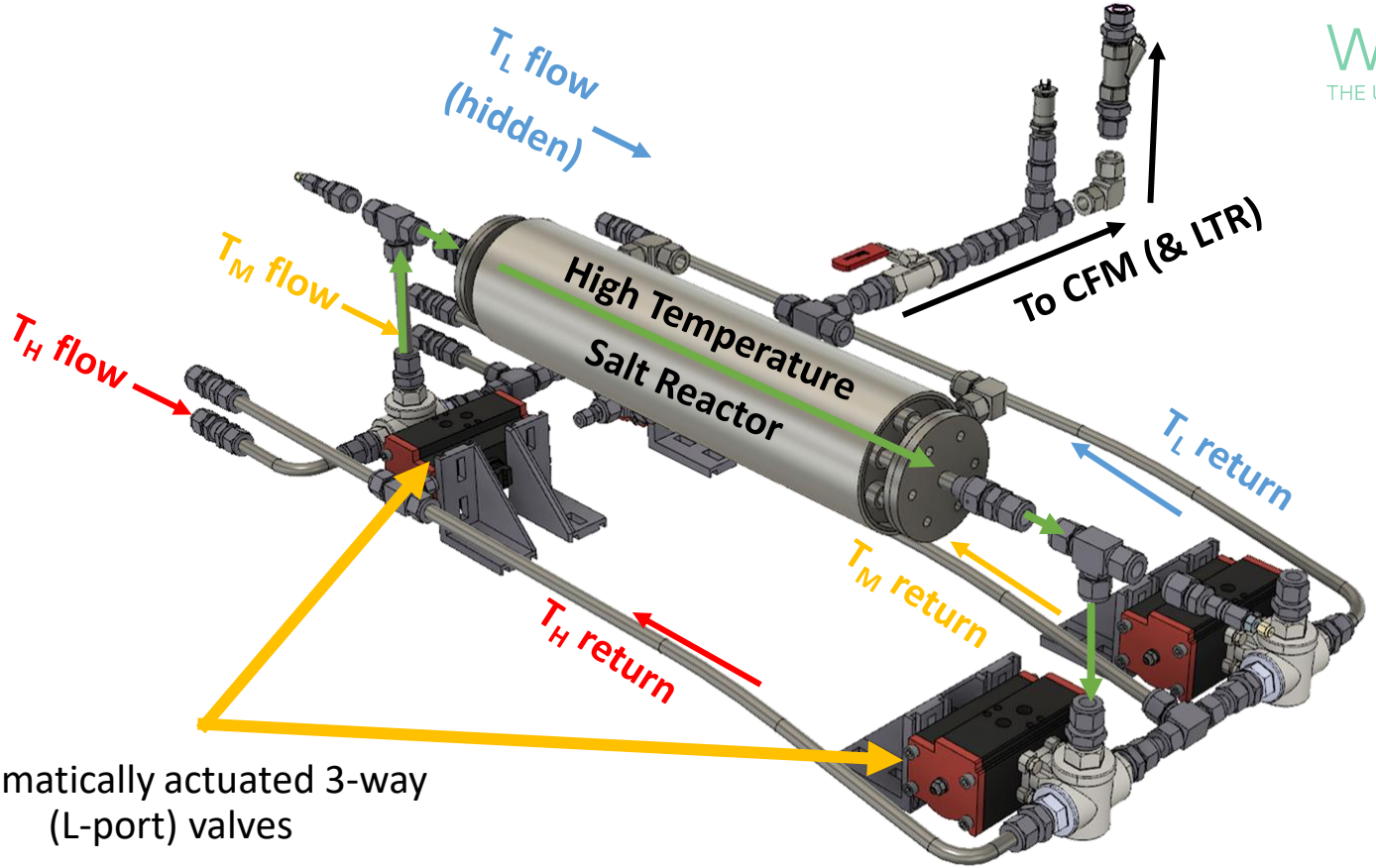
CAD Layout

Flow through reactor



Pneumatically actuated 3-way (L-port) valves

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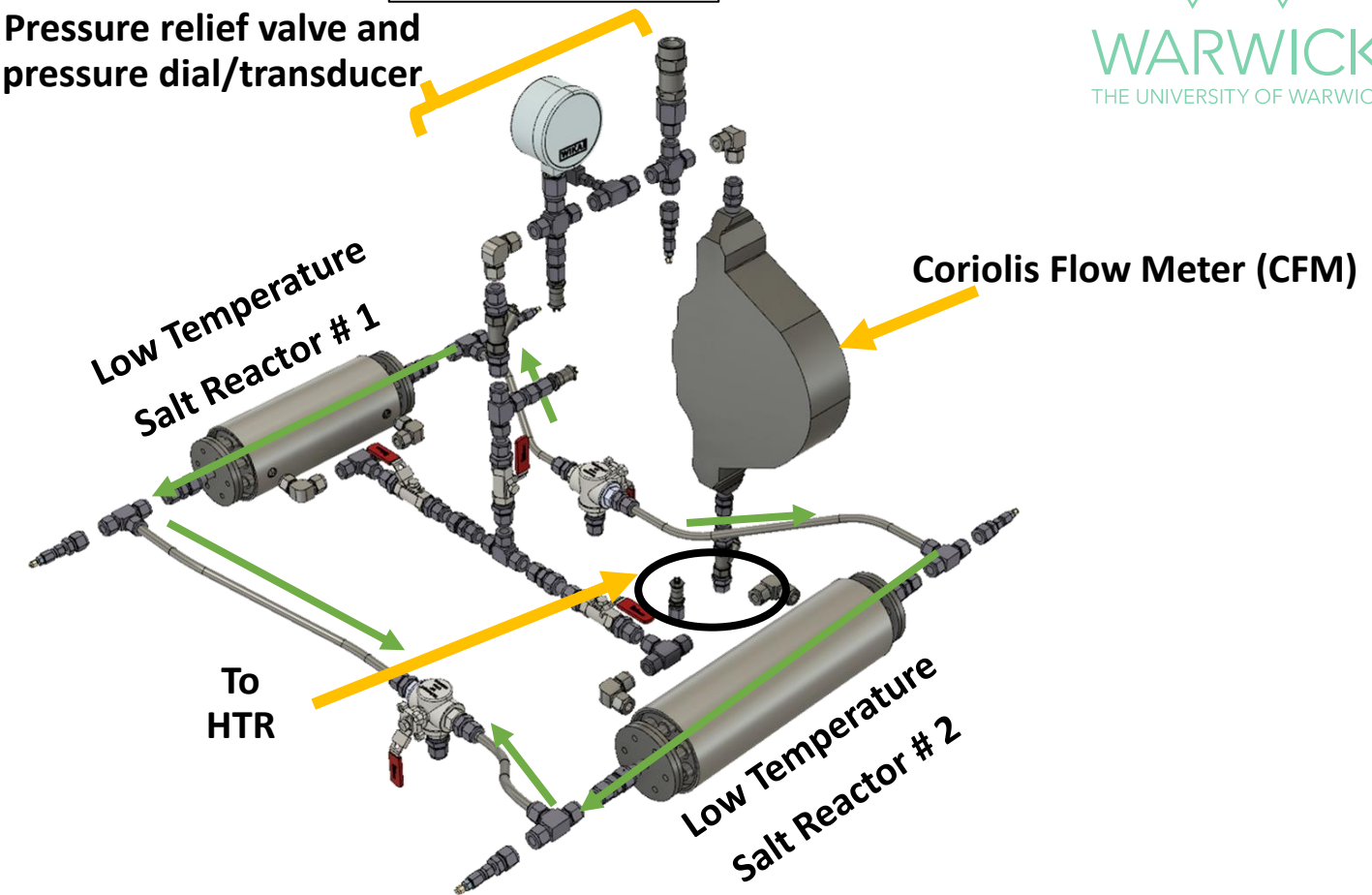
Flow through reactor

CAD Layout



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CAD Layout – Complete Assembly

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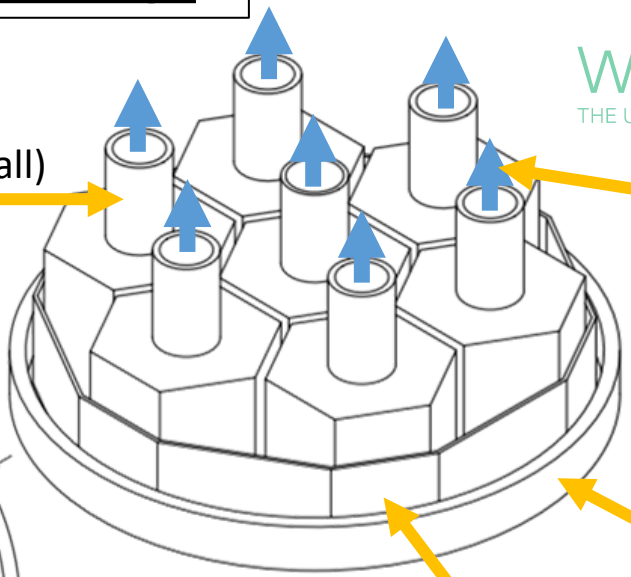
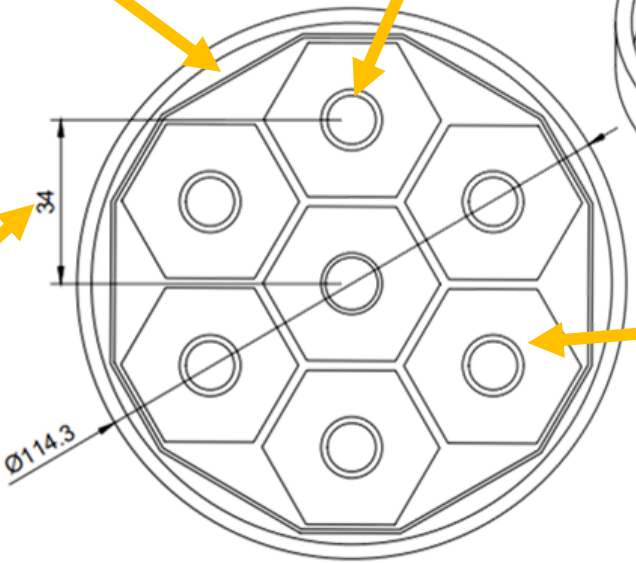
Reactor Design

ENG-Salt Composite HEX





½” tubes (1.24 mm wall)

Insulating gas gap

HTF flow

4.5” OD shell

34 mm pitch

Hexagonal samples

Gas flow channels created by folded aluminium sheet

Conclusions

- Tube-side and shell-side LTJ reactors simulated using a 2D radial and axial MATLAB® model.
- HP / TT rig design is ongoing; custom-sized ENG-salt composite HEXs designed and now to be manufactured.
- **Other news….**
- Ammonium chloride-ammonia paper published in Energies.
- A summary paper, collating experimental and model results submitted to IJR.

Thank you for listening

Any questions?

✉ George.H.Atkinson@warwick.ac.uk

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