Experimental testing of an absorption-based heat store

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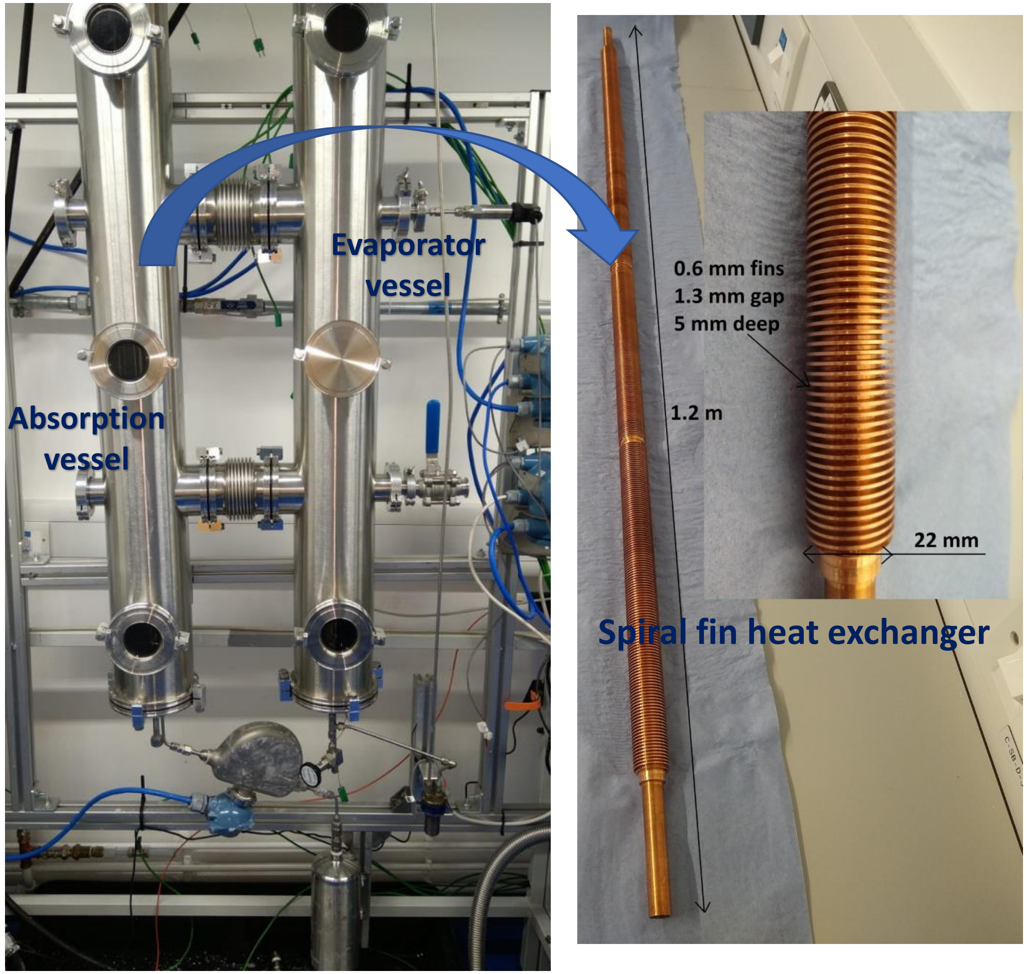
Contents

Motivation

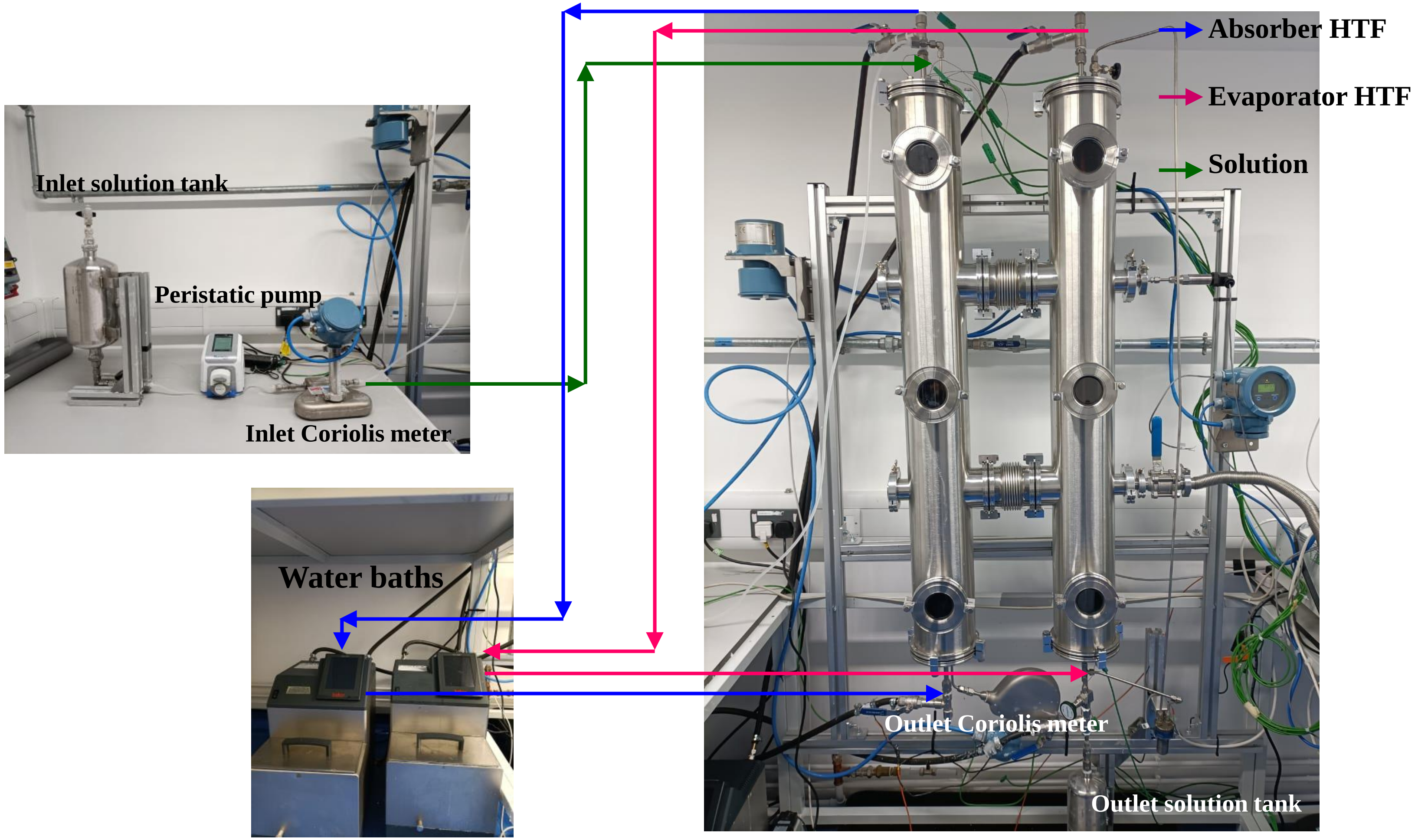
- Heating and cooling needs contribute 40-50% of global energy consumption, with over 40% for domestic applications.
- Thermal energy storage can play an important role in the renewable energy integration and peak load reduction in buildings.
- Thermochemical sorption storage systems are seen to offer among the highest energy storage densities (>1500 MJ/m^3).
- They enable storage at near ambient conditions and reduce heat loss.
- Solution based sorption materials are seen to offer better heat and mass transfer characteristics along with higher energy densities over the solid based ones.
- Among the various commonly used absorbents such as LiCl, LiBr, $CaCl_2$, etc., NaOH has emerged as a potential sorbent with H_2O along with being less expensive.

System description

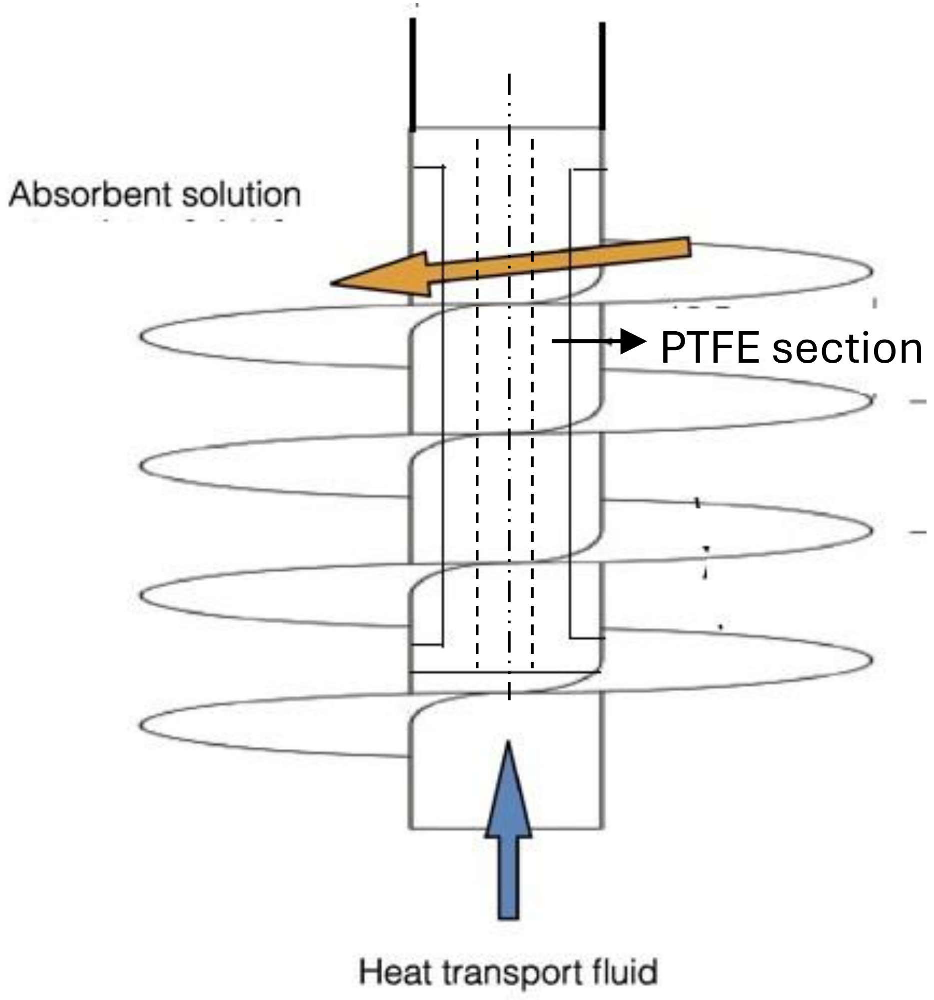


- NaOH-H_2O pair studied for domestic heating applications.
- Absorption performance is evaluated over spiral finned heat exchangers.

Test setup layout

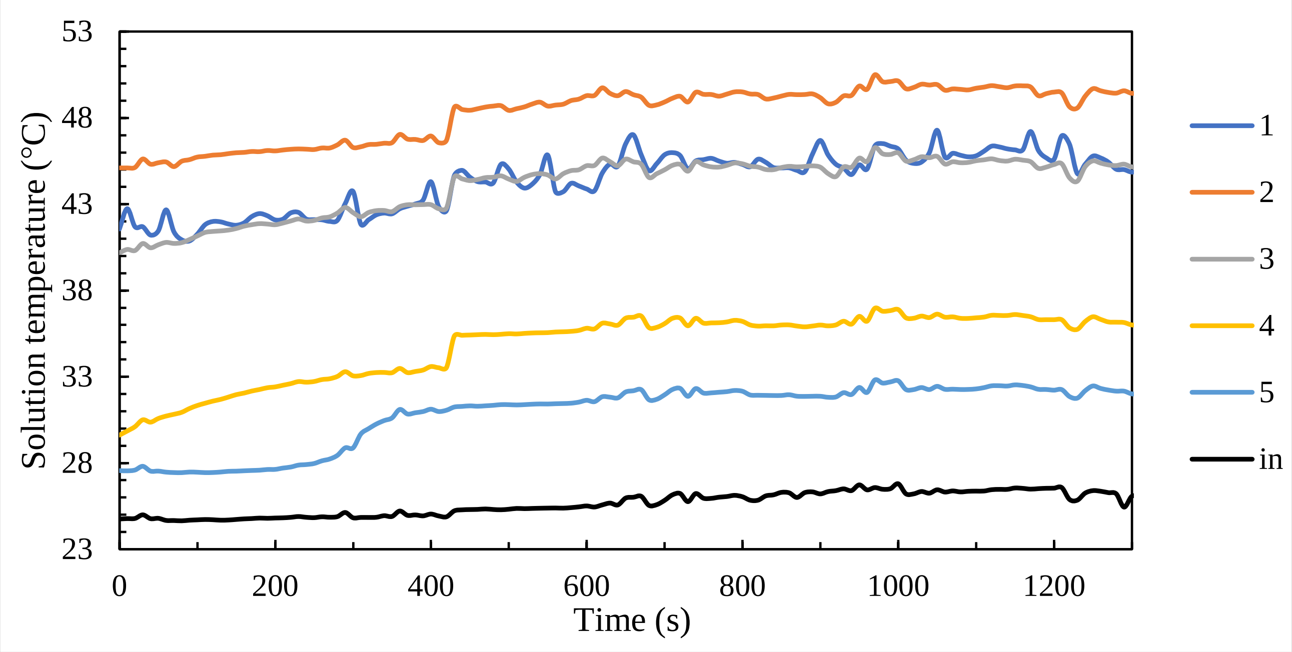


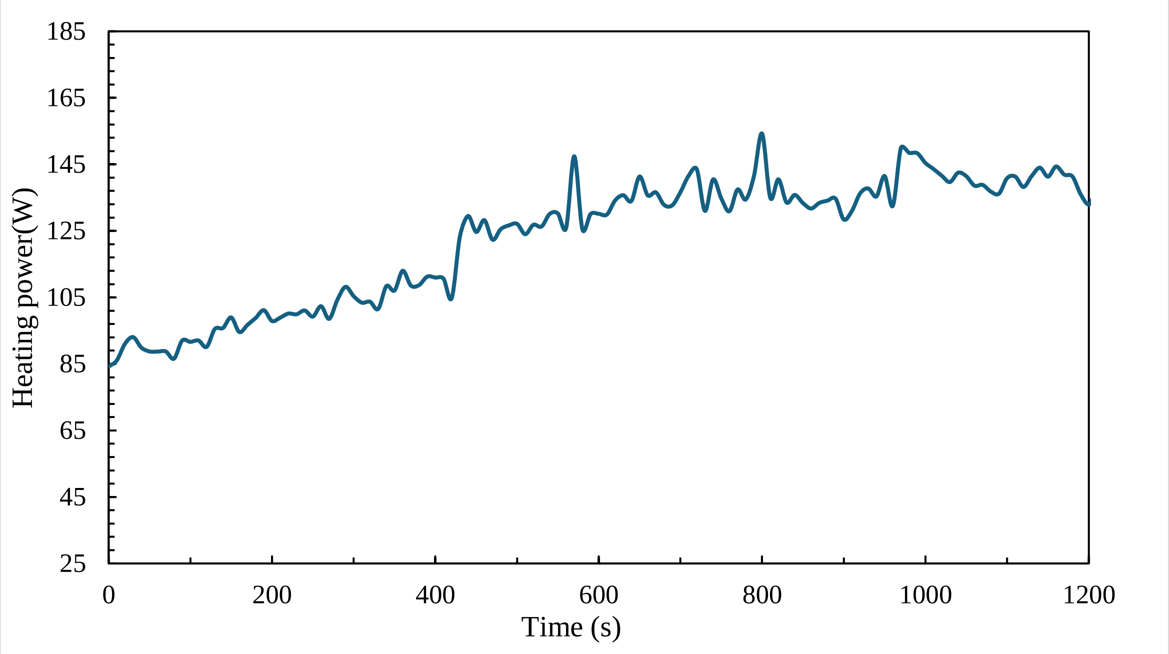
Preheating section



- The PTFE insulating column of 15cms in length enables a temperature rise up to 20C.
- It leads to a reduction in the heat transfer area.
- The impact of the preheating section elimination is studied.

Temperature and discharge power profiles





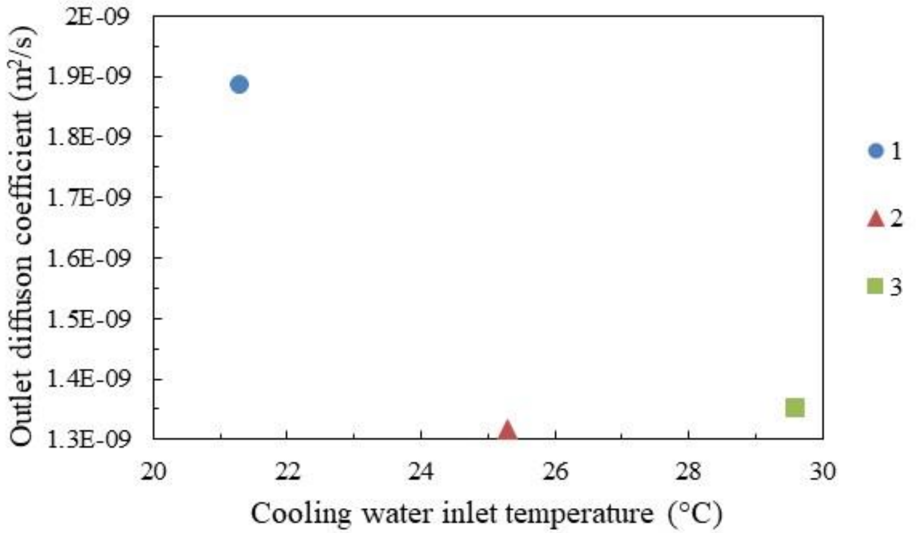
Parametric studies

Spiral finned heat exchanger specifications

Length (m)	Outer diameter (mm)	Pitch (mm)	Fin height (mm)
1.2	12.7	1.9	3

Absorption performance with varying cooling water inlet temperatures

Case	Solution flow rate (g/min)	Cooling water inlet temperature(°C)	Heating power	Solution outlet concentration
1	5.8	21.3	150.7	30%
2	7.5	25.4	99.0	37%
3	6.5	29.6	69.9	39%



Parametric studies (contd.)

Impact of varying evaporator temperatures

Evaporator temperature (°C)	Solution flow rate (g/min)	Cooling water inlet temperature(°C)	Heating power (W)	Solution outlet concentration
20	6.2	27.9	141.4	31%
15.5	6.8	25.0	151.8	31%
11	6.0	21.3	150.7	31%
7	5.7	17.8	124.4	32%

Impact of varying solution flow rates

Case	Solution flow rate (g/min)	Heating power	Solution outlet concentration	Average solution temperature (°C)
1	5.7	80.7	36%	34.4
2	7.5	99.0	37%	36.4
3	9	61.1	42%	32.3

Heat exchanger specifications

- Nickel coated copper based spiral finned heat exchangers are considered for the solution absorption.
- While the evaporator vessel has a fixed heat exchanger, the heat exchangers of the absorption vessel have been varied for the parametric analysis.

Heat exchanger	Length (m)	Outer diameter (mm)	Pitch (mm)	Fin height (mm)
HEX 1	1.04	12.7	1.9	3
HEX 2	1.04	15.8	1.9	6.35

Performance evaluation

The key non dimensional parameters of the heat and mass transfer are evaluated for the average temperature and concentration conditions of the solution.

$$Re = \frac{\rho_{avg} v d_h}{\mu_{avg}}$$

$$Sc = \frac{\mu_{avg}}{\rho_{avg} D_{avg}}$$

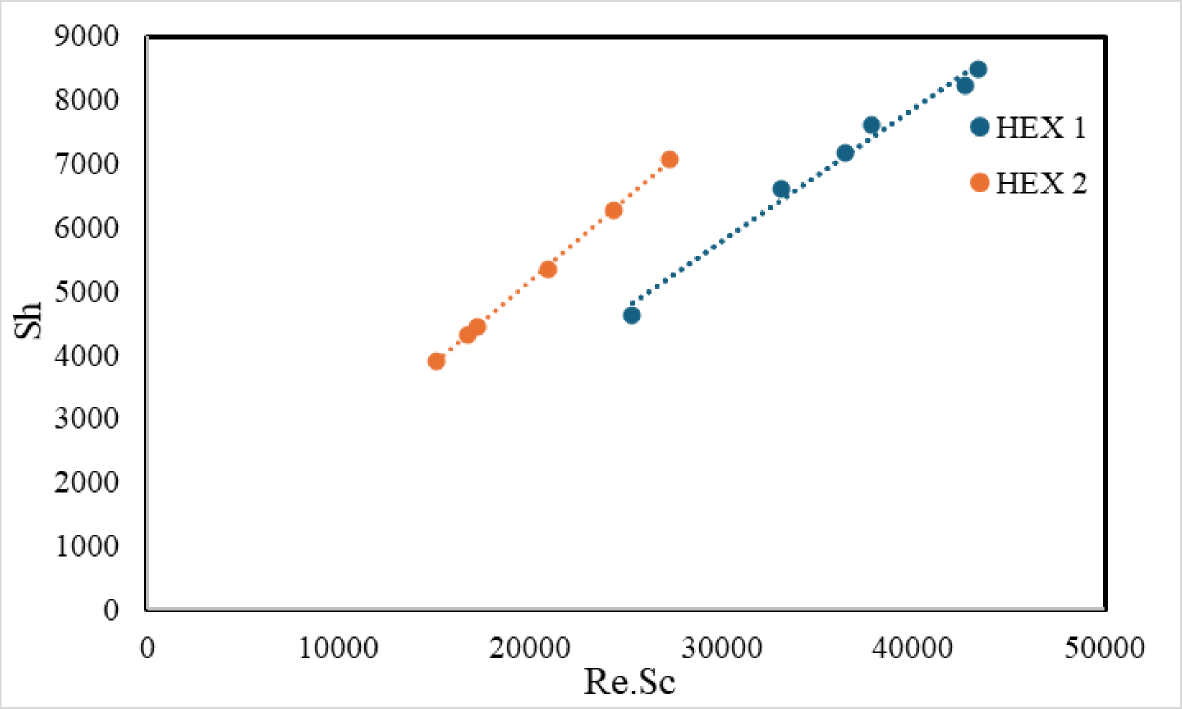
$$Sh = \frac{\dot{m}_v}{A(\rho_{in} - \rho_{out}) D_{avg}}$$

$$Q_{disch} = \dot{m}_w \times 4.18 \times (T_{w,out} - T_{w,in})$$

$$Storage\ density = \frac{Q_{disch}}{\dot{m}_{s,in}}$$

Non dimensional characterization

The mass transfer parameter Sh is plotted against the product of Re and Sc to take into account both the inertial and diffusive components of the solution flow.



- A higher value of the product Re.Sc is observed for higher mass flow rates and lower evaporator temperatures.
- A lower evaporator temperature could be preferred over higher mass flow rate for higher storage density.
- HEX 1 outperforms HEX 2 for all the similar operating conditions and mass flow rates.
- The relatively lower Re number of the flow in HEX 2 is the primary reason for its lower Sh values.

Impact of surfactants

Surfactant	Solution flow rate (g/min)	Cooling water inlet temperature(°C)	Discharge power	Solution outlet concentration
None	6.6	15.1	122.9	35%
1-Octanol 300 ppm	7.0	14.8	121.4	35%
1-Octanol 500 ppm	5.8	14.9	87.6	37%
2-Ethyl-1-Hexanol 100ppm	7.7	14.8	139.6	34%
2-Ethyl-1-Hexanol 300 ppm	6.9	14.8	151.1	33%
2-Ethyl-1-Hexanol 500 ppm	6.8	14.9	125.6	34%

Impact of surfactants (contd.)

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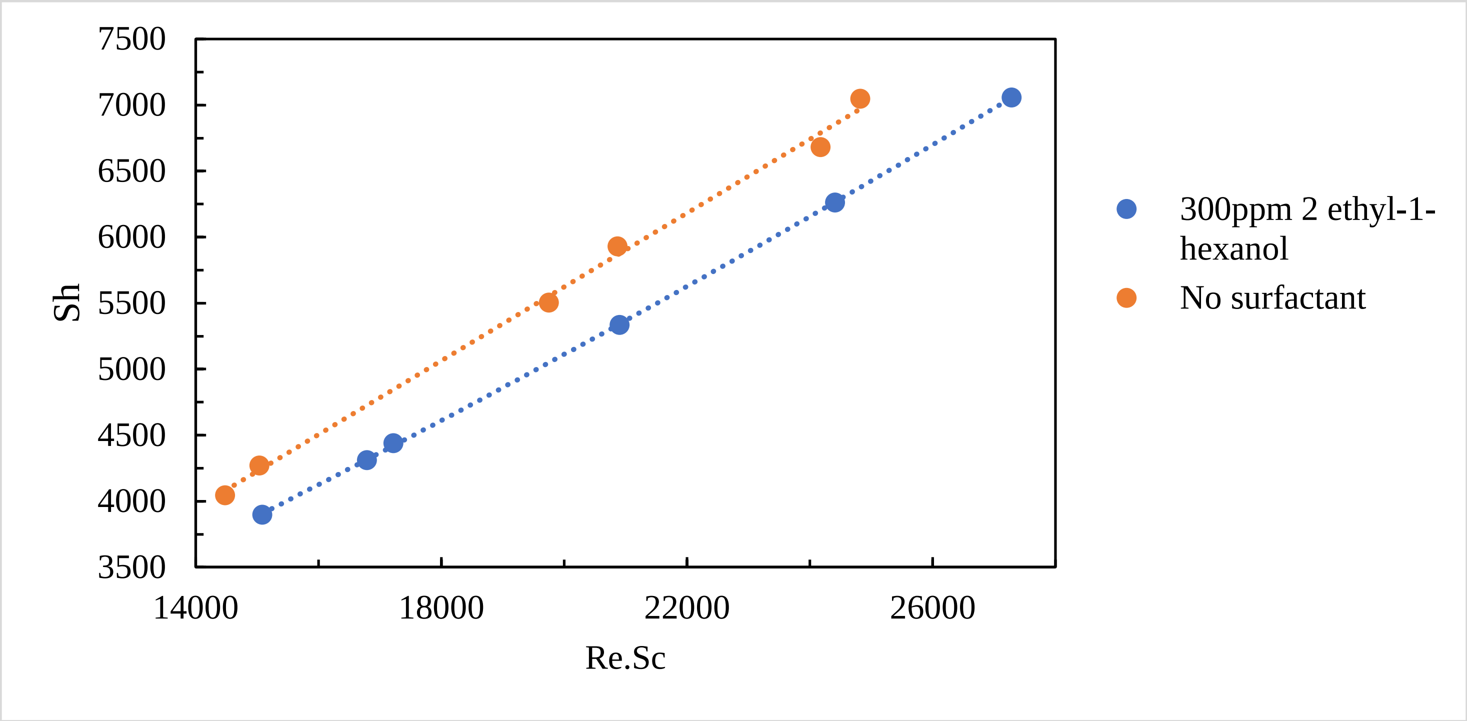
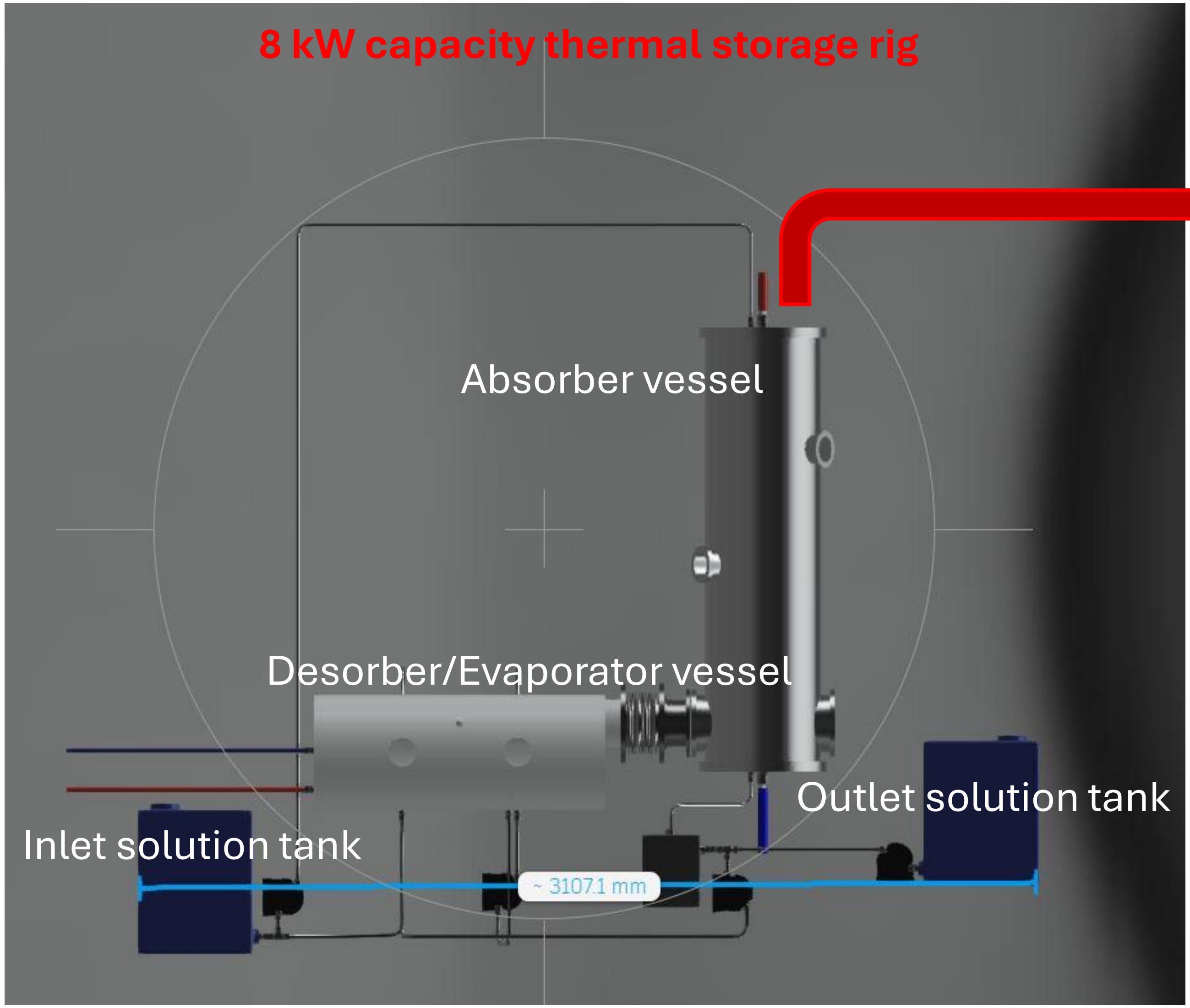
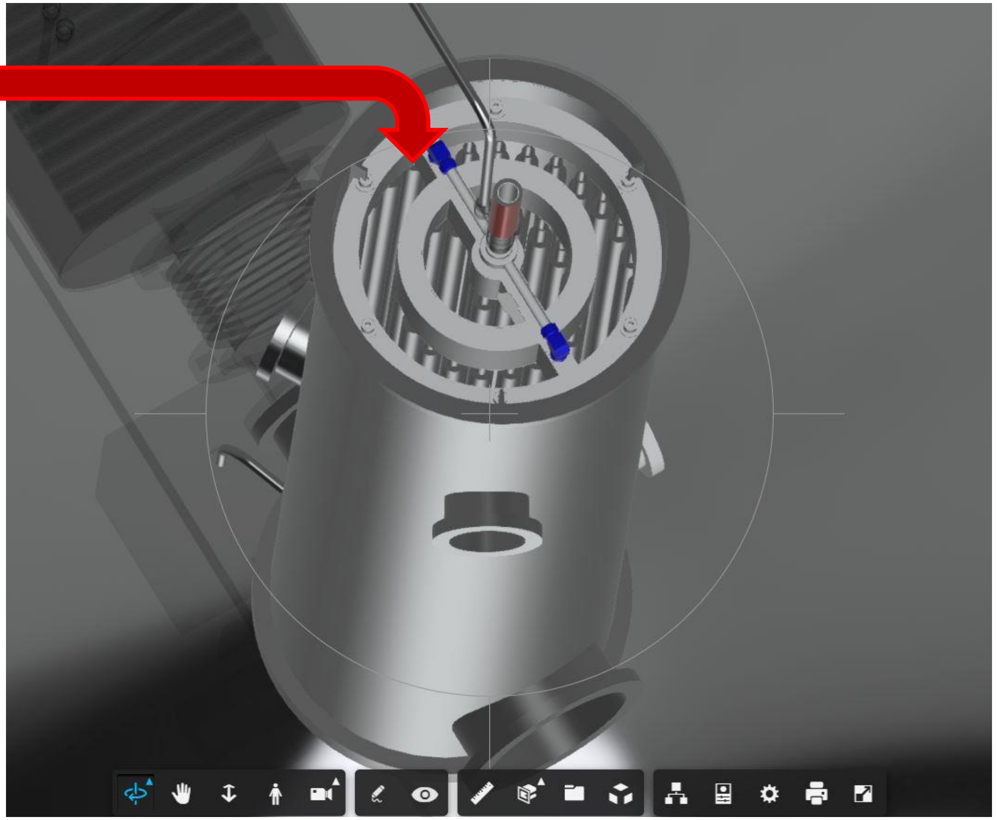


- Higher values of Sh are observed with surfactant for all the similar operating conditions.
- Discharge power is enhanced by 16-20%.
- Surfactant is seen to enable better performance at lower solution flow rates and thus enables higher storage density

Scaled up test rig development



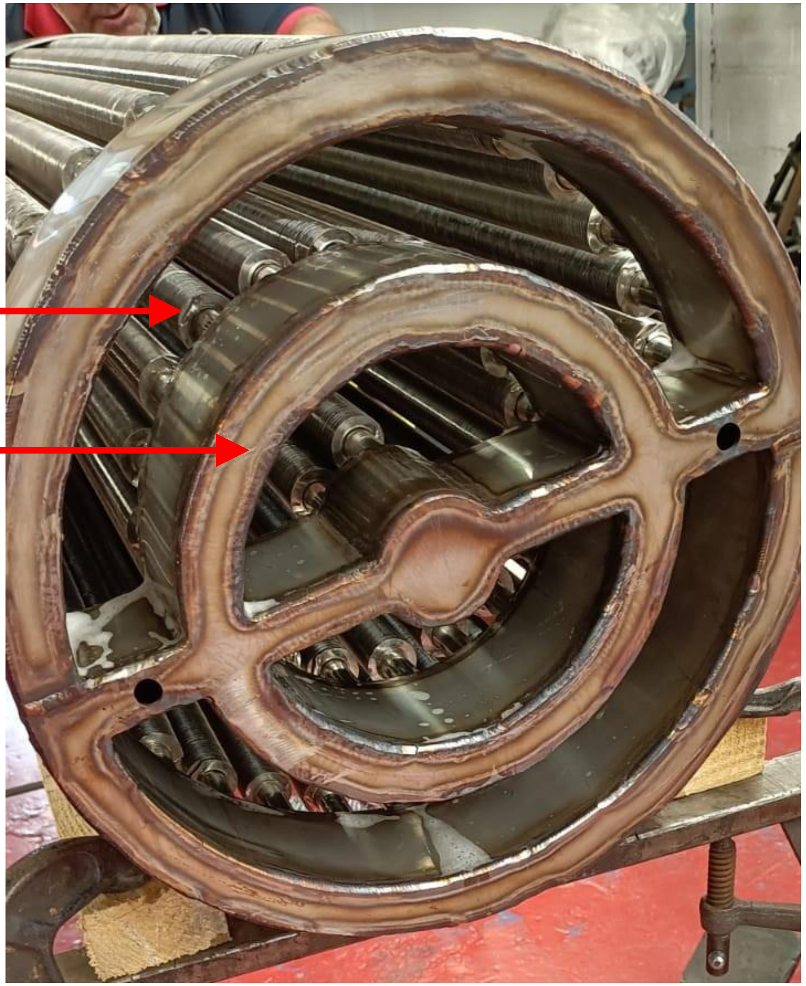


Key components

Absorber tubes

Vapor channel

Water channel



Evaporator tubes

Way forward

- Absorption and desorption performance evaluation of the thermochemical storage
- Integration analysis with heat pumps for space heating applications