Transforming our Approach to Waste Heat

LoT-NET Workshop

13th December 2019

Ammonia-Salt Resorption for Thermal Transformations
Overview

• Problem statement
• Resorption and Thermal Transformers
• Experiments and Tests to date
• What is next?
Government reports identify 48TWh/yr of waste heat sources from industry. Equivalent to a 1/6th of industrial energy use. Element Energy (2014) Imperial College London for DECC.
Resorbtion Thermal Transformers

• Recovers waste heat by upgrading to useful temperature

• Simple concept and design, no pump, no evaporator or condenser

• Components can be cheap to manufacture

• Use of solid salts enables an endless list of possible operations and alternative applications
2-Salt resorption cycle thermal transformer

Phase 1
high pressure

- Endothermic desorption at medium temperature

Phase 2
low pressure

- Exothermic adsorption at low temperature
- Endothermic desorption at medium temperature

LT Salt

HT Salt

Ammonia flow

80°C

120°C

LT Salt

HT Salt

Ammonia flow

30°C

80°C

1000/T

\[ \ln(P) \]

\[ \frac{P_{\text{high}}}{P_{\text{low}}} \]

\[ T_{\text{low}} \]

\[ T_{\text{mid}} \]

\[ T_{\text{high}} \]

Ammonia L/G

LT Salt CaCl₂

HT Salt MnCl₂
Route to thesis

• Samples implanted in a conductive matrix of ENG
• Large Temperature Jump tests, to test the material under real working conditions
• Model the composite material behaviour
• Design a working transformer

Main tested samples with a content:
• 0.317kg salt/kg composite
• 0.531kg salt/kg composite
Large Temperature Jump Reactor

½ inch pipe centre

1 inch pipe jacket

PTFE to fill heated volume

O-ring Swagelok face seal fitting

TC positions
Large Temperature Jump Reactor

- ~12litres expansion vessels
- Huber baths with silicone oil
- Operate from -5 to 170°C
- Water bath controls expansion vessels and unit temperature
Results, full LTJ cycle

- Two scales on graph
- Repeated for different cases
- A new equilibrium line has to be calculated first based on position of phase change
Equilibrium Data

Comparison of Equilibria Data

*Pressure bar* vs. *Temperature °C*

*ln(Pressure)* vs. *-1000/T*

**Comparison of Equilibria Data**

- Adsorption
- Desorption
- Neveu&Castaing
- Saturation Pressure, of Liquid Ammonia

**Saturation Pressure, of Liquid Ammonia**
Empirical reaction mode

\[
\frac{dx}{dt} = [1 - x]^y_0 \cdot Ar \cdot \frac{P - P_{eq}(T)}{P}
\]

Order of reaction \(y_0 = 2\)

Arrhenius term \(Ar = 3.5\)

Pressure

7 bar

Mass Salt

0.759g

Mass Fraction of Salt

0.53g/g

![Graph](image)
Model Results

Order of reaction $y_0 = 1$
Arrhenius term $A_r = 0.1$

Pressure

$7\text{bar}$

Mass Salt

$0.759 g$

Mass Fraction of Salt

$0.53 g/g$
To conclude...

- Salts and resorption enable effective utilisation of heat
- LTJ testing shows materials behaviour under real working conditions
- Modelling tests gives reaction data that enables development of working machines

Questions?