Experimental Setup for Determining Ammonia-Salt Adsorption and Desorption Behavior Under Typical Heat Pump Conditions

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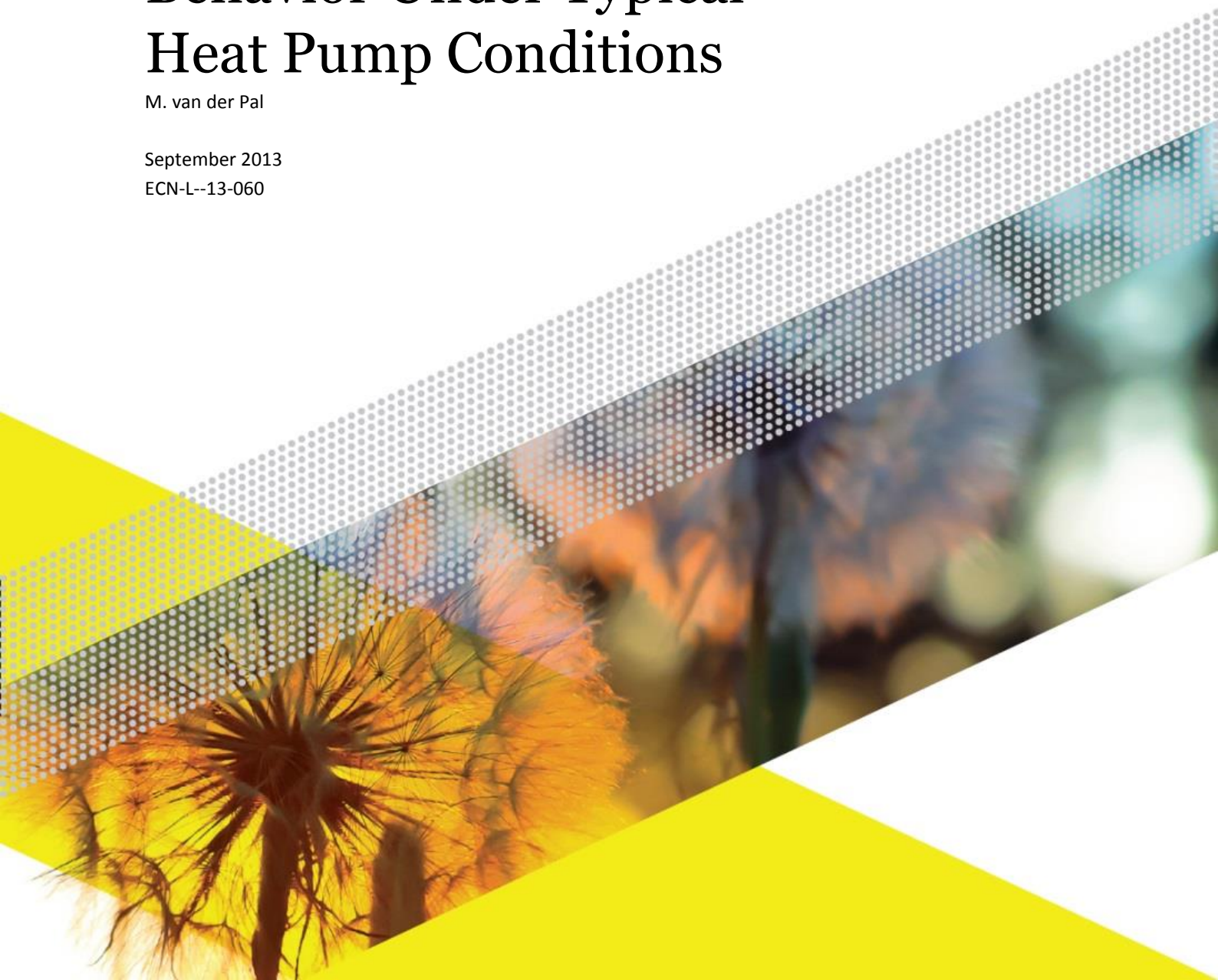
September 2013
ECN-L--13-060



EXPERIMENTAL SETUP FOR DETERMINING AMMONIA-SALT ADSORPTION AND DESORPTION BEHAVIOR UNDER TYPICAL HEAT PUMP CONDITIONS

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September 4-6, 2013

A bit of history…

- “OPTISORP” resorption type II heat pump system for upgrading waste heat was designed and constructed based on various measurement on sorbent level:
  - HP-DSC
  - PT-diagram
  - (dis)charge amounts and rate of composite
- Performance of Optisorp lower than expected
- Many explanations were suggested but no definite conclusions could be drawn

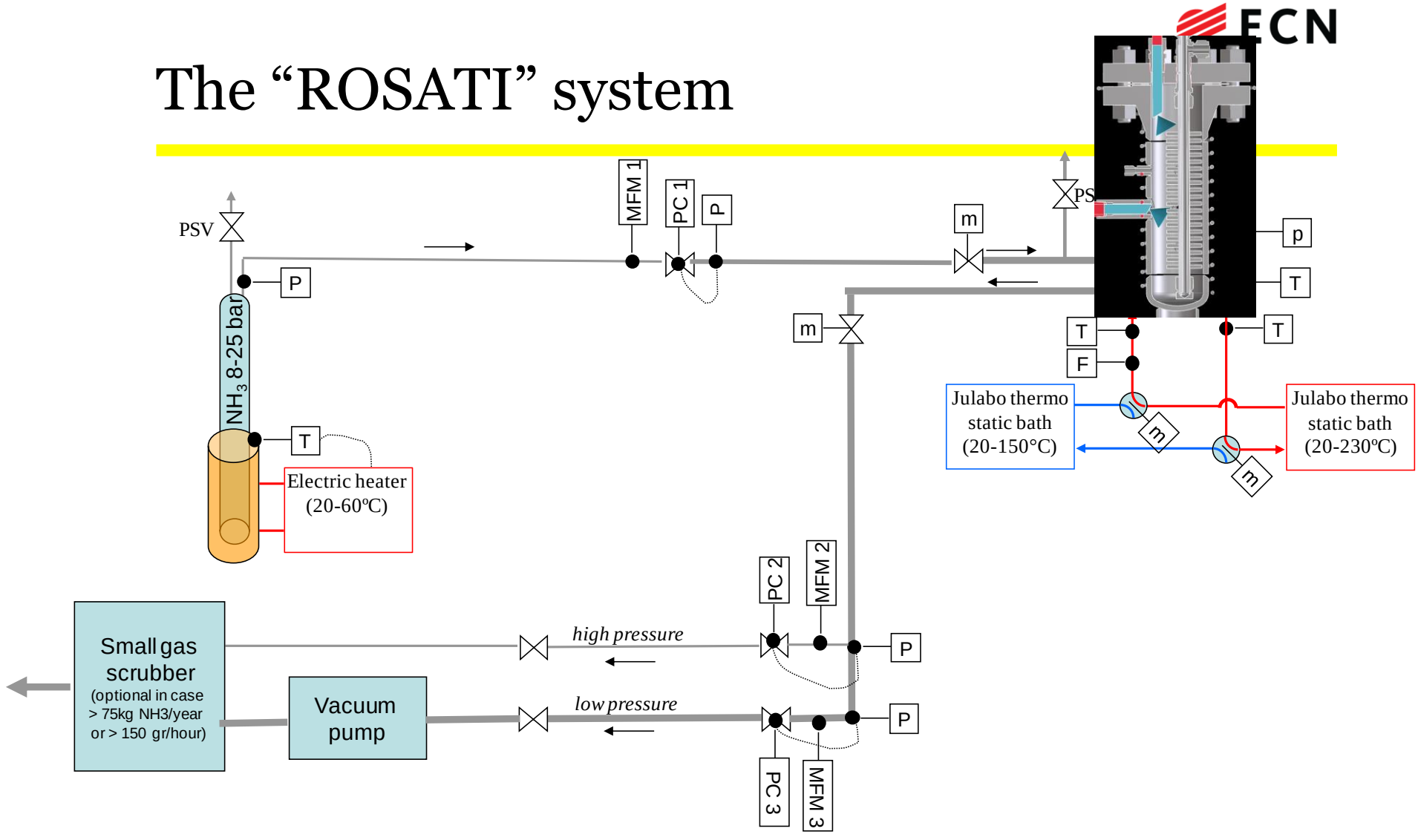
Therefore…

- Development of system for measuring performance of reactor-elements under typical heat pump conditions:
  - Temperature
  - Pressure
  - Ammonia adsorption/desorption amounts
- Also: need for visual inspection

With the objective:

- Understanding the underlying processes to help further development and improvement of adsorption heat pumps

The “ROSATI” system



ROSATI setup and reactor

Specs

- 40 to 100 grams of sorbents
- reactor 16 - 50mm fin diameter,
- 16 mm tube diameter, 200mm length
- Temperature 20 – 220^{o}C
- Pressure 0.1 – 20 bar
- Endoscope for visual inspection

Experiments conducted

- Lithium chloride: $LiCl(1\text{-}3)NH_3$
- Calcium chloride: $CaCl_2(2\text{-}8)NH_3$
- Magnesium chloride: $MgCl_2(2\text{-}6)NH_3$

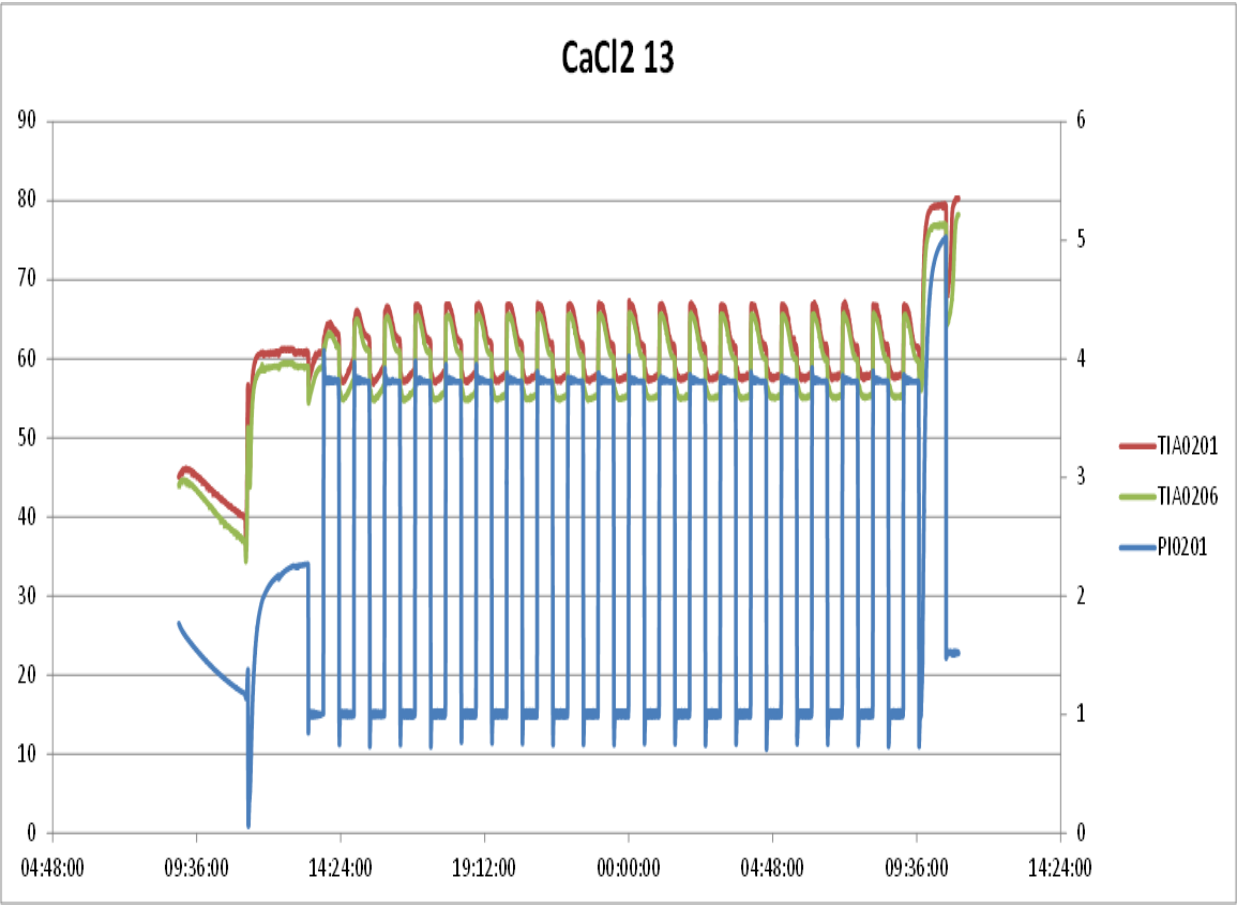
Lithium Chloride

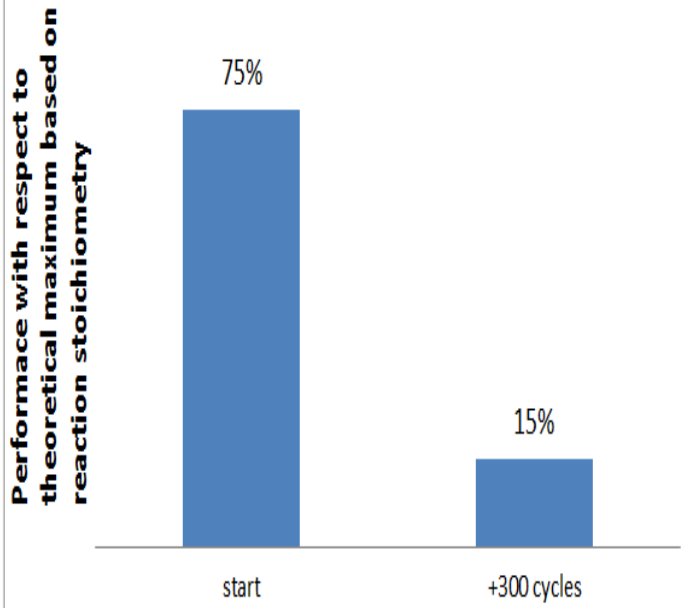
- Test conditions: P = 5 bar, T (t=start)= 60^{o}C, T(t=end) = 120^{o}C
- Goal: to determine whether melting of $LiCl{\cdot}xNH_3$ occurs
- Main parameter: visual inspection
- Result: see next slide
- Interpretation: $LiCl{\cdot}xNH_3$ does melt, that causes it to escape from its matrix, likely to have poor thermal conductivity upon desorption

Calcium Chloride

- Test conditions: T = 60°C, P_{high} = 4 bar, P_{low} = 1 Bar, # of cycles > 300
- Goal: to determine long-term stability of calcium chloride reaction with ammonia: $CaCl_2 \cdot (2 \leftrightarrow 8) NH_3$
- Main parameter: amount adsorbed/desorbed as a function of cycle #
- Result: Graph (see next slide)
- Interpretation: Reactivity of $CaCl_2(2\text{-}8)NH_3$ deteriorates, likely caused by escape of $CaCl_2$ from its matrix

CaCl2 performance



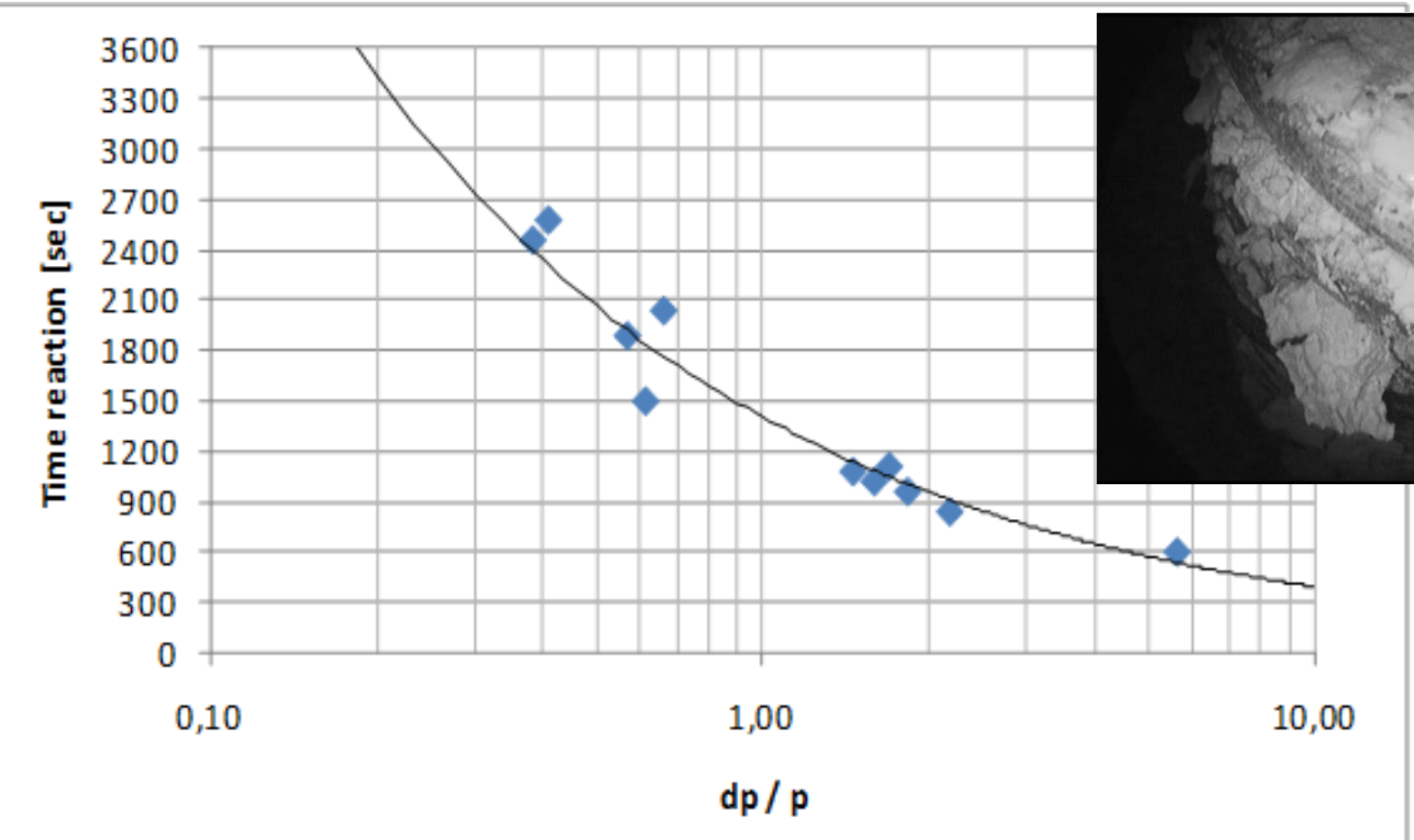


$CaCl_2$ reactor before and after 300+ cycles

Magnesium Chloride

- Test conditions: pressure-step for various temperatures and pressures
- Goal: to determine adsorption (and desorption) rate as a function of relative pressure
- Main parameter: (time for) amount adsorbed/desorbed for various P and T conditions
- Result: Graph
- Interpretation: Good correlation between relative pressure and adsorption rate

MgCl2: relative pressure vs reaction time (90% of sorbent reacted)



Conclusions

- ROSATI- apparatus allows measurements of mass flow and visual inspection under well-controlled conditions (P,T)
- Measurements of mass-flow, temperature, pressure and visual inspection all provide very useful information for interpretation
- ROSATI is a useful tool for investigating behavior of ammonia-salt reactions at reactor-level

Further developments:

- Adjusting reactor to allow for other reactor geometries
- Measuring other sorbents and reactor types

Thank you for your attention

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