Thermo-Chemical Storage for Solar Space Heating in a Single-Family House

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Motivation

- Solar space-heating systems
- State of the art: Solar ASSISTED heating systems
  solar fractions ~ 20 - 30 % of DHW and space-heating load
- Energy has to be stored from summer to winter to be able to reach high solar fractions.
- Goal: 100% solar
- No conventional boiler necessary
- High energy density
- Small heat losses
Closed - Cycle Sorption Heat Store

- Working pair silica gel / water
- Silica gel relatively cheap, mass produced
- Temperatures necessary for desorption can easily be reached with standard flat plate collectors

- Thermo-chemical heat pump
- Heat sink and heat source necessary
First Generation System from EU-Project HYDES
New System Design

- Integration of key components (adsorber and evaporator/condenser) into a single container
- Short distances for vapor diffusion
- Large cross-section available for vapor transport
- Laboratory scale unit (approx. 350 liters)

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The Temperature Lift

Example:
- Desorption
  - Adsorber: 80°C
  - Temperature necessary for condensation: 80°C − 25 K = 55°C
- Adsorption
  - Evaporation at 15°C
  - Reachable adsorber temperature: 15°C + 25 K = 40°C

- Maximum water content approx. 350 g water per kg silica gel
- Temperature lift = (Adsorber temperature – temperature evap/cond)
Desorption – Different Condensing Temperatures

- Final water content (15°C): 2%
- Final water content (38°C): 4%
Desorption – Alternating Operation

Simulation of
- Heating of silica gel during daytime
- Cooling of condenser during nighttime

- 3.0 hours heating phase
- 2.5 hours rest period
- 1.5 hours cooling phase
- 2.5 hours rest period

Temperature [°C]

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Desorptions Cycles

Condensation
Heating
Water content of silica gel decreased from 15% to 2% in 3 days
Adsorption

Constant water level in the evaporator
Heat evaporator when store temperature below set temperature

Constant silica gel temperature for 30 hours
**Adsorption Test**

- **Inlet temperature evaporator**
- **Power evaporator**
- **Return temperature space heating loop**
- **Inlet temperature evaporator**

**Space heating load**

- **Space heating load ~ 400 W**
- **Evaporator power peaks at 200 W**
Influence of Water Level on UA-value of Evaporator
Influence of Water Level on UA-value of Evaporator

Evaporator filled with water
Open valve when water level is ~ 27 kg

Power evaporator

UA-value of evaporator heat exchanger
Influence of Water Level on UA-value of Evaporator

- UA-value of evaporator heat exchanger increases significantly when water level in evaporator is low.
- Evaporation takes place mostly at the heat exchanger surface that is at the water surface.
- Water level should always be just below the upper limit of the heat exchanger.
- The height of the heat exchanger is not so important; more important is a large surface area close to the water surface.
- Evaporator setup like in the HYDES project with a lot of water above the heat exchanger leads to very low UA-values…
Conclusions

- System design has been improved significantly
  - Improved vapor transport
  - Less water in evaporator, improved UA-value
  - Less pressure and heat losses

- Disadvantages compared to standard solar combinystem
  - One more heat exchanger between store and space heating loop
  - Store has to be heated at the beginning of adsorption operation (losses)
  - Conventional storage tank needed in addition to sorption storage (heat losses from tanks and piping)
  - Heat pump instead of store (88% of the energy has to be supplied at low temperature level)
Conclusions

- A sorption storage system cannot efficiently be used for short-term storage.
- The advantage of storage without thermal losses (separation of adsorbent and working fluid) can only make an impact if it is used for longer-term storage.
- But the material pair has to deliver a sufficient temperature lift that compensates for the disadvantages mentioned before.
- The temperature lift of silica gel and water is only sufficient in a range between approx. 2 and 12%. → Low energy density!!
Conclusions

- Different sorption material needed
  - Higher temperature lift over a larger range of water contents
  - Higher binding energy (i.e. more energy actually stored)
  - Higher energy density
  - Better heat conduction to reduce temperature losses across heat exchangers
  - Medium-temperature collectors currently under development

- Sorption material that is adapted to heat storage applications!
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