Sorption Heat Pump and Energy Storage Research at Warwick

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Next generation gas/heat powered heat pump

Background:

Rationale

- Up to 50% reduction in CO₂ emissions compared with domestic condensing boilers
- Inability of electricity supply system to cope with an ‘all electric’ future with all homes heated by electric heat pumps – gas (inc. biogas) still has a role to play

Technical options

- Engine driven heat pumps
  - Small sizes have maintenance and noise issues
- Sorption cycles [Absorption and Adsorption]
  - Very few moving parts
  - Potentially low cost
Efficiency increases with 4 beds and heat recovery.
Higher calorific value of natural gas used in all cases
Burner efficiency: 84%
Burner exhaust gas recovery: 5% of gas input
Condensing boiler efficiency (assumed constant for simplicity): 91% (SEDBUK)
Water flow rate: 20 l/min
Heating power: 6-7 kW
Burner water temperature: 120-200°C

Note that the COP should never drop below 1.0 (10% better than condensing boiler), within the heat pump operating range.
Change in product concept over time of project:

Where has the rest of the hardware gone?
Fits into standard wall-mounted casing

Box-for-box exchange for old boiler

Key competitive advantage
• other gas-fired heat pumps too large for wall mount

Retrofit market >90% of annual sales
Original version, tested May 2011

Top valve assembly

Generators

Bottom valve assembly

Evaporators

Gas heat exchanger

Burner
Initial testing:

Initial running successfully produced output water at 60°C.

The machine functioned but excessive heat losses and internal leakage from valve assemblies lead us to a re-design.

Problems to be solved:

- ‘Production water valve’ [4-pole, 4-way] needed that did not suffer from internal heat and flow leakage.
- Ammonia check valves unreliable.
- Generator heat transfer less than predicted.
So what happened since 2011???

Many development problems
Decision made to revert to a two-bed system.

Lower efficiency, but simpler and lower cost.

Power density of a two-bed system is higher which reduces the overall size of the generators.

Predicted gas saving of 15-20% compared to a condensing boiler.
System COP: \((1.26 \times 0.8) + 0.1 = 1.1\) gross
Condensing boiler 90%
Gas saving 18%
Heating Power: 5.5 kW

System COP: \((1.228 \times 0.8) + 0.1 = 1.08\) gross
Condensing boiler 90%
Gas saving 16%
Heating Power: 9.9 kW
TWO-BED SYSTEM

• Two-bed system installed in environmental chamber.
• Less tightly packaged system to enable easier fault diagnosis and rectification.
• Uses air source evaporator from previous system.
• Electrically heated.
TEST RESULTS AND ACTIONS

• Heat output was between 7 and 12 kW and in line with model predictions.
• New water distributors increased pressure drop in the generators and reduced water flow rate, particularly during the cooling phase.
• Investigated mass transfer which limited output and efficiency
• Investigated possible ammonia mass transfer problem
• Investigated possible check valve leakage
• Now think that (maybe!) water leak into ammonia circuit may be the problem
Next steps:

1. Test water leak hypothesis
2. Figure out how to fix leak
3. Try to generate two bed performance envelope

Watch this space…
Thermal Storage, Thermal transformers

- Link to EPSRC Grid scale energy storage capital award (LU and UW) – commissioning in 6-9 months
- Solid gas reactions suitable for both heat storage and thermal transformers
• Probably complete by September
• Consists of 4 sources/sinks of heat + pumps, valves, instrumentation

Some understandable examples to give an idea of the new sorts of toy we could play with…
1-salt thermal store
(c. 2 MJ/litre)

Phase 1: Storage of heat at 200°C

Heat in at 200°C

Desorption

Condenser

Heat out at 30°C

Adsorption at high pressure

Evaporator

Heat out at 200°C

Phase 2: Discharge of heat at 200°C

Salt 1

Salt 1
Condenser
Desorption at low pressure

Salt 1 → Condenser

Heat out at 120°C

1-salt thermal transformer

Heat in at 90°C

Desorption at high pressure

AdSORption at high pressure

Phase 1: Storage of heat at 90°C

Heat out (120°C)/Heat in (90°C) = 0.35 ?

Phase 2: Discharge of heat at 120°C

Evaporator

Salt 1

Heat out at 120°C
2-salt thermal transformer

Phase 1: Storage of heat at 90°C

Desorption at low pressure

Heat in at 90°C

Heat out at 30°C

Adsorption at high pressure

Heat in at 90°C

Heat out at 120°C

Phase 2: Discharge of heat at 120°C
PROGRESS

• Laboratory refurbished
• Thermal baths delivered
• Design of fluid loops, controls etc finished
• Out to tender
• Installed in October?
Thank you for your attention

• Any questions?