Progress Reports, Future Plans
October 2014

WP3.4: Gas-fired heat pump
WP4.2: Thermal transformer
WP3.5: Domestic heat emitter study
WP3.4 Next generation gas/heat powered heat pump

A reminder of the background:

Rationale

- Up to 50% reduction in CO\textsubscript{2} 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

Previous research was on a 4-bed, high efficiency system:
Efficiency increases with 4 beds and heat recovery

1. Gas Burner
   - Hot Gases
   - Inlet Air
   - Ambient Air to Evaporator

2. Air-to-Pressurised Water Heat Exchanger
   - Warm Exhaust Gases
   - Cool Exhaust Gases
   - Return water from house

3. Final Exhaust Heat Exchanger
   - Heated water to house
   - Cooled Air from Evaporator

4. Adsorbent Bed 1
   - Heated

5. Adsorbent Bed 2
   - Cooled

6. Adsorbent Bed 3

7. Adsorbent Bed 4

8. Condenser
   - Ammonia

9. Evaporator
   - Cooled Air from Evaporator
Concept:

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

Adsorbent Beds (Generators)
Original version, tested May 2011
Initial testing:

- Initial testing successfully produced output water at 60°C.
- The machine functioned as per design but excessive heat losses and internal leakage from water valve assemblies lead to a re-design before further tests.
- Gas burner control difficulties upset the operation of the adsorption system.
• 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

Performance Envelope

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

• After repeated evacuating, heating and recharging the ammonium salt reduced in quantity such that the check valves no longer became blocked.
• 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.
• Cooling pump replaced to increase water flow rate.
• Re-tested in September 2014
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The graph shows the temperature variations over time for different systems:

- **Inlet water [°C]**: Blue line
- **Condenser Out [°C]**: Red line
- **Outlet water [°C]**: Green line

The x-axis represents time in seconds (s), ranging from 0 to 3000 seconds. The y-axis represents temperature in °C, ranging from 30°C to 70°C. The graph illustrates periodic temperature fluctuations with distinct peaks and valleys for each system over the specified time period.
Initial conclusions:

• New system is free of most of the previous problems encountered and has run for many hours without issues.

• Performance (COP) is roughly 0.1 down on predictions. Further analysis will reveal reasons but thermal mass of water and steel in pipes etc. is suspected.

• Achieving a target GUE of 1.2 with a modest re-design seems feasible.
Immediate plans:
• Complete detailed analysis of results
• Design new system with
  ➢ Compact packaging
  ➢ Reduced thermal mass of water and steel
  ➢ Investigate possible improvements in heat transfer, choice of carbon, etc.
Goals:

• Design, build, test compact system with existing generators.

• In parallel, explore ways of improving heat transfer and manufacturability of generators.

• Demonstrate a thermal compressor package with acceptable size and COP to potential manufacturers.
WP4.2 Thermal transformers [2nd Wave, Prof. Critoph, UW]

Rationale: Industrial processes commonly reject heat at temperatures of 90ºC or higher that cannot be utilised close to their source. A thermal transformer can transform some of this heat to higher useful temperatures, rejecting the remainder at close to ambient. There are strong links to WP4.1, 4.3.

Challenges: Identifying suitable economically viable major processes that would benefit. Identifying physical or chemical reactions best suited to the major needs.

Objectives/Deliverables: Identification of process needs and matching reactions with potentially high efficiency. Construction of laboratory PoC to investigate heat and mass transfer limitations.

Other applications of fundamental technology: High temperature heat pumps
Pathway to Impact: Via SIRACH and industrial links (Spirax Sarco)
Previous plans:

- Link to EPSRC Grid scale energy storage capital award (LU and UW) – commissioning in 6-9 months
- New PhD student at Warwick will probably concentrate on chemical adsorption
- Good links with Japanese and Russian laboratories with physical chemistry expertise in this area
What happened:

- Link to EPSRC Grid scale energy storage capital award (LU and UW) – commissioning in 6-9 months
- All equipment ordered and will be in place in December
- Commissioned and functioning by end February
- Consists of 4 sources/sinks of heat + pumps, valves, instrumentation

Subject of successful Working with EUED Centres bid.
1-salt thermal transformer

**Phase 1:** Storage of heat at 90°C

**Phase 2:** Discharge of heat at 120°C

- **Heat in at 90°C**
- **Heat out at 120°C**
- **Heat out at 30°C**
- **Adsorption at high pressure**
- **Desorption at low pressure**
2-salt thermal transformer

Phase 1: Storage of heat at 90°C
- Heat in at 90°C
- Desorption at low pressure

Phase 2: Discharge of heat at 120°C
- Heat out at 120°C
- Adsorption at high pressure

Salt 1
Salt 2

Heat in at 90°C
Heat out at 30°C
What happened:

- New PhD student at Warwick will probably concentrate on chemical adsorption.

New student is working on chemical reactions but concentrate on multiple effect heat pumps with very high COPs.
What happened:

• Good links with Japanese and Russian laboratories with physical chemistry expertise in this area

Bid in to British Council to fund a Russian visitor from Boreskov Institute of Catalysis

Bid in to EU Marie Curie to fund a Dutch visitor from Energy Centre of the Netherlands
Low temperature heat emitters are important to both gas and electric heat pump systems.
Underfloor heating problematic in retrofit situations.
Some fan-assisted radiators on the market, but expensive.
Issues of fan noise, wiring and cost.
WP3.5 Domestic heat emitter study

- Vicky Haynes and Claire Lawson at LU have an initial report on noise of available products
- Focus on domestic heat pumps with thermal storage
- They will carry out a qualitative survey of existing domestic heat pump users to establish experiences of auxiliary equipment, in particular heat emitters, to determine how well these meet the users’ requirements or where they need improvement or supplementation, and whether they deliver in terms of comfort.
Thank you for your attention

• Any questions?