WP3.3: Advanced Electric Heat Pump

April 2015

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Context

• WP3.3 has a number of roles for advanced air source heat pumps:
  – Demand side management/response
    • Integration with storage
  – Meeting householder thermal needs
    • Operation as a DSM mechanism for non-dispatchable, variable renewable energy
    • Operation as an optimised heat pump (supply heat at the warmest times of the day)
Heat Pump Integration

Shed for heat pump & storage tank installation
Heat Pump Integration

Heat pump outdoor unit installed and indoor unit placed in side the shed

Thermal store integration with heat pump for better DSM

Inside view of tank: possibility to add coil for PCM
Schematic for Heat Pump-Storage set-up
Heat Pump Integration

Heat pump

Temperature sensor for heat pump to charge the tank

To house

De-stat pump

From house
DSM testing

Two stages
1.) Direct mode (heat pump only)
House heating demand met directly by heat pump (26/11/2014 to 10/03/2015)

2.) Combined mode (heat pump and storage mode)
Heat pump stores energy during morning hours and during first call for heat, storage tank meets house heating demand and when storage temperature drops, heat pump takes over and meets house heating demand for rest of the day (02/04/2015 to onwards)
Heat Pump Operation – No storage

**Temperature (deg C)**

**Time (26/11/2014, Wednesday)**

**Temperature (deg C)**

**Time (27/11/2014, Thursday)**
Heat Pump and Storage

Heat demand met by heat pump

Heat demand met by Storage
Future Plans

• Storage control
  – Weather compensated (optimum heat pump)
  – Pricing Tariff – (with WBS)
• End-user satisfaction (with Loughborough)
• Higher temperature heat pump for compact storage?
  – Loughborough
  – New working fluids (R234ze, R1234yf, natural fluids etc)
Outputs

• Applications of Economised Vapour Injection Air source heat pump in residential buildings Ming Jun Huang; Ye Huang and Neil Hewitt, SUSTEM, Newcastle July 2015

• Performance Of Underfloor Heating System With Phase Change Covering Materials M.J. Huang and N.J. Hewitt, ICR2015, Japan

• Considerations For The Use Of Heat Pumps With Combined Thermal Storage As A DSM Tool In A Domestic Retrofit Setting, Christopher WILSON, Nikhilkumar SHAH, Neil HEWITT, Ming HAUNG, ICR2015, Japan
WP4.1: High Temperature Heat Pumps

April 2015

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Context

• Globally the value of waste heat is region of €500billion
• EU is wasting €55bn per year (800 TWh) in recoverable waste heat.
• Only 6.9 TWh of industrial excess heat recycled in the whole EU27
• Typically this heat is 35°C to 60°C
• R245fa – heat to 150°C is possible
• R365mfc – Near 200°C
• Storage will provide Demand Side Response
• Other working fluids available
Progress to Date

• Keeping within the ranges of current equipment i.e. 1 to 30 Bar, fluids are R717, R134a, R290

• Alternative fluids might be:

Thermodynamic assessment of high-temperature heat pumps using Low-GWP HFO refrigerants for heat recovery
Progress to Date – R245fa
Demonstration

Flow Temp °C
Return Temp °C

Distribution Water Temp °C

Ambient Temp °C

Data Source: ISTUTE

Research Councils UK
For a Low Carbon Future
Demonstration – 90kWt
Demonstration
# Demonstration

<table>
<thead>
<tr>
<th></th>
<th>TEMPERATURE</th>
<th>PRESSURE</th>
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<tbody>
<tr>
<td></td>
<td>Suction C</td>
<td>Discharge C</td>
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<tr>
<td>05-Nov</td>
<td>23.22</td>
<td>81.74</td>
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<tr>
<td>01-Dec</td>
<td>21.80</td>
<td>62.12</td>
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<tr>
<td>09-Jan</td>
<td>12.75</td>
<td>70.46</td>
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<td>18-Feb</td>
<td>19.28</td>
<td>58.27</td>
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<tr>
<td>19-Feb</td>
<td>18.84</td>
<td>59.56</td>
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<table>
<thead>
<tr>
<th></th>
<th>ENTHALPY</th>
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<tbody>
<tr>
<td></td>
<td>h evap kJ/kg</td>
<td>h cond kJ/kg</td>
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<tr>
<td>05-Nov</td>
<td>132.37</td>
<td>173.88</td>
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<tr>
<td>01-Dec</td>
<td>158.70</td>
<td>188.83</td>
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<tr>
<td>09-Jan</td>
<td>161.92</td>
<td>208.83</td>
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<tr>
<td>18-Feb</td>
<td>165.68</td>
<td>195.70</td>
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<tr>
<td>19-Feb</td>
<td>165.89</td>
<td>197.70</td>
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## Demonstration

<table>
<thead>
<tr>
<th>Evaporator</th>
<th>Condenser</th>
<th>POWER</th>
<th>Heat Cap.</th>
<th>COP</th>
</tr>
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<tbody>
<tr>
<td>m (kg/s)</td>
<td>ΔT (K)</td>
<td>m (kg/s)</td>
<td>ΔT (K)</td>
<td>Win (kW)</td>
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<tr>
<td>0.8</td>
<td>9.26</td>
<td>1.26</td>
<td>7.16</td>
<td>6.93</td>
</tr>
<tr>
<td>0.96</td>
<td>8.18</td>
<td>1.26</td>
<td>7.52</td>
<td>7.12</td>
</tr>
</tbody>
</table>

### Graph

- **Water Flow Rate (kg/s)**
- **Capacity (kW)**
- **Time (hrs)**

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**m evap**

**m cond**

**Qevap**

**Qcond**
Demonstration

- Test 24 hours (18th-19th February)
- Tamb: Min. 0.1°C Max. 2.4°C
- Building Q: 38kW
- Heat pump Qout: 39.08kW
## Demonstration – 90kWt

<table>
<thead>
<tr>
<th>Date</th>
<th>Heating Capacity</th>
<th>Power IN</th>
<th>COP</th>
<th>η isen</th>
<th>Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-Dec</td>
<td>40.36 kW</td>
<td>7.82 kW</td>
<td>5.16</td>
<td>75.48%</td>
<td>3.63</td>
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<tr>
<td>09-Jan</td>
<td>28.33 kW</td>
<td>6.12 kW</td>
<td>4.63</td>
<td>51.64%</td>
<td>4.13</td>
</tr>
<tr>
<td>18-Feb</td>
<td>38.63 kW</td>
<td>6.97 kW</td>
<td>5.54</td>
<td>70.15%</td>
<td>3.31</td>
</tr>
<tr>
<td>19-Feb</td>
<td>37.84 kW</td>
<td>6.76 kW</td>
<td>5.59</td>
<td>66.67%</td>
<td>3.34</td>
</tr>
</tbody>
</table>
Conclusions

• Evaporator
  – Very low pressure causes higher pressure drop within the distribution device

• Expansion valve & controller
  – Valve never tested with type of fluid
  – Non-existent settings for R245fa

• Compressor
  – Very low suction pressure (compared to R134a!!)
Future Plans

• Break the 200°C barrier
  – Storage improvements (Loughborough)
  – Greater industrial relevance
  – Another demonstration?
  – Alternative fluids
Outputs

• SIRACH Presentation at Artic Circle 23rd April 2015
• High Temperature Heat Pumps For Seasonal Thermal Energy Storage And District Heating Systems Neil HEWITT, Ming HUANG, Miguel RAMIREZ, ICR2015, Japan