Task 2
Thermal Mass

Typical household of 100 sq.m

Space heating demand of 10kW

Maximum Demand 35kW

Air Source Heat Pump in a retrofit situation

Condenser Mass = 40kg

<table>
<thead>
<tr>
<th>Heat Pump</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant</td>
<td>r407c</td>
</tr>
<tr>
<td>$dt_{\text{Cond}}$</td>
<td>4 K</td>
</tr>
<tr>
<td>$dt_{\text{Evap}}$</td>
<td>7 K</td>
</tr>
<tr>
<td>Ambient T</td>
<td>-2 °C</td>
</tr>
<tr>
<td>Compressor Efficiency $n$</td>
<td>0.8</td>
</tr>
<tr>
<td>Winter mains water temp</td>
<td>10 °C</td>
</tr>
</tbody>
</table>
Task 2
Simplified Heat Pump Cycle Integration – U/F Heating/Cold Start

Bypass for Rapid Heating
Task 2

Simplified Heat Pump Cycle Integration Thermal Mass Response

Time taken to Overcome Thermal Mass (seconds)

Water Temperature °C

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Task 2
Retrofit Operation

Bypass for Rapid Heating
Task 2

60°C Heating from cold…. (Mixer in constant position)
Task 2
Research Challenges (1)

Initial calculations made at 3600 rpm
  - How quickly can the compressor come to 7200 rpm?
  - Different information from the same manufacturer

Overcoming thermal mass
  - PCM or other form of heating
  - As part of the condenser insulation?
  - Integrated with as part of the internal heat exchanger?

Compressor lubrication and the boost cycle
  - How to make best use of this
Task 2
Research Challenges (2)

There is a relationship between compressor capacity range, household heating demand, hot water demand => Household Characterisation => Target Markets

Maximum Heat Demand and limited Capacity Control
Below this point

Highest Capacity Bath Taps

3Ø Power Supply (UK)
Compressor: Emerson: XP/0302E-4X9
Condenser: Swep: B80Ax-28
EEV: Emerson in package
Receiver: ESK Schultz: SGS-11-CD
Accumulator: ESK: FA22

Discharge line (comp to condenser): EN12 (1/2")
Liquid line (cond to rec): EN22 (7/8") &
(Rec to EEV): EN15 (5/8")
Suction line (Exp to Com): EN 1B (3/4")

EEV flare
Filter flare

Evaporator
EEV
Solenoid valve
Condenser
Filter
Liquid receiver
Compressor
Suction accumulator

4S-DHW
Layouts
4S-DHW Layouts

Compressor: Emerson XPF3002E-4X9
Condenser: Swoop: B604S-28
EEV: Emerson in package
Receiver: ESK Schultz: SGS-11-CD

Circulating Pump (3 speed)
4S-DHW

Layouts

3 Phase & Single-Phase Electric Meter

ED3 3 Phase Inverter for Variable Speed Copeland Scrolls (~6kW at 400 Volts)

Sec Mono (Emerson) Superheat & Envelope Controller
4S-DHW

Layouts
## 4S-DHW

### Initial Challenges

<table>
<thead>
<tr>
<th>Date</th>
<th>Time Start</th>
<th>Time End</th>
<th>Cond Inlet (degC)</th>
<th>Heat Demand SEC (kW)</th>
<th>Cond Flow Rate</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/01/2019</td>
<td>10:43</td>
<td>13:10</td>
<td>30</td>
<td>6</td>
<td>Pump setting 3</td>
<td>Oil return at around 11:45 ramped up to 3500rpm for 120sec (see configuration mod monitoring)</td>
</tr>
<tr>
<td>15/01/2019</td>
<td>13:11</td>
<td>15:45</td>
<td>30</td>
<td>8</td>
<td>Pump setting 3</td>
<td>2:05 switched to go through tank coil, around 2:24 tap through tank to draw of heat also.</td>
</tr>
<tr>
<td>15/01/2019</td>
<td>15:45</td>
<td>16:25</td>
<td>30</td>
<td>10</td>
<td>Pump setting 3</td>
<td>Running through tank, taps slightly on</td>
</tr>
<tr>
<td>15/01/2019</td>
<td>16:25</td>
<td>17:02</td>
<td>30</td>
<td>11</td>
<td>Pump setting 3</td>
<td>Running through tank, taps slightly on</td>
</tr>
<tr>
<td>15/01/2019</td>
<td>17:02</td>
<td>17:26</td>
<td>25</td>
<td>11</td>
<td>Pump setting 3</td>
<td>Running through tank, taps slightly on</td>
</tr>
<tr>
<td>15/01/2019</td>
<td>17:26</td>
<td>18:00</td>
<td>25</td>
<td>12</td>
<td>Pump setting 3</td>
<td>Running through tank, taps slightly on</td>
</tr>
</tbody>
</table>
4S-DHW
Initial Runs

- DLT - Condenser Refrigerant In (degC)
- Condenser Water Out (degC)
- Condenser Refrigerant Out (degC)
- Condenser Water In (degC)
- Compressor Suction (degC)
- Compressor Speed (RPM/100)
- Heating Capacity Request (kW)

RPM up to 3500 for 120 sec for compressor oil return (programmed into SEC controller)

Changed from 30 degC condenser inlet to 25 degC
### 4S-DHW Performance

<table>
<thead>
<tr>
<th>Heating Demand (kW)</th>
<th>Cond Inlet Set Point (degC)</th>
<th>Av_Cond Water Inlet (degC)</th>
<th>Av_Cond Water Outlet (degC)</th>
<th>Av_deltaT (degC)</th>
<th>Av_COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>30</td>
<td>28.7</td>
<td>40.2</td>
<td>11.5</td>
<td>4.61</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>28.6</td>
<td>43.6</td>
<td>15</td>
<td>4.85</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>28.1</td>
<td>50.5</td>
<td>22.4</td>
<td>3.92</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>27.1</td>
<td>53.7</td>
<td>26.6</td>
<td>3.6</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>24.1</td>
<td>54.9</td>
<td>30.8</td>
<td>3.39</td>
</tr>
</tbody>
</table>
4S-DHW
Compressor Challenges at 11 kW
4S-DHW
Compressor Challenges at 11 kW
4S-DHW

Planned Work

The HP will be moved to the environmental chamber for testing at controlled ambient air and humidity conditions. Testing will initially follow a similar procedure to the commissioning tests i.e. maintain the condenser water inlet temperature, maintain the condenser water flow rate, maintain the ambient environmental conditions and vary the heat demand given to the SEC controller to get a corresponding condenser outlet temperature. The condenser water inlet temperature will then be varied and the same tests repeated. Further to this the environmental conditions will be varied e.g. 7°C, 3°C, -1°C etc. (to be specified in more detail). The testing will establish the HP COP for different loads and also at different ambient conditions as well as the maximum heat capacity possible at given environmental conditions.

Further to this, analysis of ramp up rates etc. will be carried out, as well as electrical parameters. The goal will be to establish the HP suitability (or not) for providing instantaneous hot water comparable to a gas combi boiler and the issues which might arise with respect to compressor lifespan etc. Further programming may be required to interface more autonomously with the SEC controller so that the HP can be run like a gas combi boiler i.e. on tap opening so that the impact of frequent draw off patterns on the HP capacity and longevity can be analysed.