Drop-in Testing of Next-Generation R134a Alternates in a Commercial Bottle Cooler/Freezer

January 16th, 2014
AREP Conference
Tony Lee
Background

- Test completed in 2010-2011, at a time when these new refrigerants were being introduced

- Information was first presented at 2012 Purdue Engineering Conference.

- Evaluations were completed prior to AREP’s defined test standards
Objective

• Compare bottle cooler/freezer’s performance using different refrigerants in the following categories:
  – Steady State:
    • COP (W/W)
    • Average cooling capacity (assumes saturated liquid at inlet of expansion device)
    • Compressor power (W)
    • Condenser temperatures (average of dew and bubble temperatures)
    • Evaporator temperatures (average of dew and bubble temperatures)
    • Refrigerant Flow Rate (kg/hr)
    • Compressor run time (%)
  – Pull down time:
    • Amount of time from test start to first compressor cycle off
Test Set Up – Bottle Cooler

• Single door, approximately 1.8 meters (6 feet) tall.
• Set points are controlled by SafeNet (Hussmann electronic controller)
• Evaporator and evaporator fan are located in the top-back of these coolers
• Compressor, condenser, and condenser fan are located in the bottom compartment
• Compressor is a fractional horsepower, hermetic, and reciprocating type

Figure 1: Hussmann Bottle Cooler Model #: ARV570
Test Set Up – Bottle Cooler (Continued)

- Aluminum fin/copper tube evaporator and condenser
- Expansion device: Capillary tube 244cm length with 1.24mm ID, piped through the suction tube
- Normal refrigerant charge 266 g of R-134a. With flow meter installed, the total charge is 322 g for all tests.

Figure 2: Flow diagram of refrigerant circuit
# Test Set Up – Test Conditions

<table>
<thead>
<tr>
<th>Refrigerants</th>
<th>R-134a (Baseline)</th>
<th>HFO1234yf</th>
<th>XP10</th>
<th>HFO1234ze(E)</th>
<th>N13a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test type:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full pull-down</td>
<td>23.9 (75)</td>
<td>23.9 (75)</td>
<td>26.7 (80)</td>
<td>26.7 (80)</td>
<td>32.2 (90)</td>
</tr>
<tr>
<td>Half pull-down</td>
<td>32.2 (90)</td>
<td>32.2 (90)</td>
<td>32.2 (90)</td>
<td>32.2 (90)</td>
<td>32.2 (90)</td>
</tr>
<tr>
<td><strong>Test cell temperature °C (°F)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASHRAE 72-2005</td>
<td>23.9 (75)</td>
<td>23.9 (75)</td>
<td>26.7 (80)</td>
<td>26.7 (80)</td>
<td>32.2 (90)</td>
</tr>
<tr>
<td>Bottle cooler set point, °C (°F)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>3.3 (38)</td>
<td>-5.6 (22)</td>
<td>3.3 (38)</td>
<td>-5.6 (22)</td>
<td>3.3 (38)</td>
<td>3.3 (38)</td>
</tr>
<tr>
<td>3.3 (38)</td>
<td>-5.6 (22)</td>
<td>3.3 (38)</td>
<td>-5.6 (22)</td>
<td>3.3 (38)</td>
<td>3.3 (38)</td>
</tr>
</tbody>
</table>
Example of Steady State Results
23.9°C (75°F)/55% RH - 3.3°C (38°F) bottle cooler set point

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>R-134a</th>
<th>R-1234yf</th>
<th>XP 10</th>
<th>R-1234ze</th>
<th>N13a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average COP (W/W)</td>
<td>2.72</td>
<td>2.43</td>
<td>2.46</td>
<td>2.57</td>
<td>2.57</td>
</tr>
<tr>
<td>Average cooling capacity (W)</td>
<td>317</td>
<td>290</td>
<td>292</td>
<td>292</td>
<td>301</td>
</tr>
<tr>
<td>Compressor Power (W)</td>
<td>116</td>
<td>120</td>
<td>119</td>
<td>114</td>
<td>117</td>
</tr>
<tr>
<td>Condensing temperature (°C)</td>
<td>26.8</td>
<td>27.9</td>
<td>27.8</td>
<td>28.8</td>
<td>27.2</td>
</tr>
<tr>
<td>Evaporating temperature (°C)</td>
<td>-0.8</td>
<td>-0.9</td>
<td>-1.5</td>
<td>-1.3</td>
<td>-1.8</td>
</tr>
<tr>
<td>Refrigerant flow rate (kg/hr)</td>
<td>6.37</td>
<td>7.26</td>
<td>6.58</td>
<td>6.5</td>
<td>6.53</td>
</tr>
<tr>
<td>Compressor run time (%)</td>
<td>35.1</td>
<td>35</td>
<td>35</td>
<td>42.6</td>
<td>37</td>
</tr>
</tbody>
</table>
Executive Summary of Trends in Test Results

ASHRAE 72-2005 Tests:

• COP values of the alternative refrigerants are marginally lower than baseline
  – With optimally charged systems and designed components, some of these alternative refrigerants may have had better COP values

• Average cooling capacity is lower than baseline
  – Except for XP10 at 26.7°C with set point at 3.3 °C.

• Compressor power varies with refrigerant and set point
  – It ranges between 6.1% to 7.9% higher for R-1234yf and XP10 at -5.6 °C set point
  – It ranges between 1.7% to 5% lower for R-1234ze

• Condensing temperatures ranges between 7% to 7.5% higher for R-1234ze with 3.3 °C set point and no change when set point is at -5.6 °C
Executive Summary of Trends in Test Results

ASHRAE 72-2005 Tests:

- Evaporating temperatures are generally lower than baseline with the exception of R-1234yf which is comparable to R-134a
- Refrigerant flow rate of R-1234yf ranges between 14% to 22.2% higher than baseline
- Compressor run time is comparable to baseline with the exception of R-1234ze which ranges between 18.1% to 21.4% higher than baseline
Executive Summary of Results

Full Pull-Down

• The amount of time until compressor started cycling is within ±5.2%
  – Except for R-1234ze, which took 31.3% longer

Partial Pull-Down

• The amount of time until compressor started cycling is
  – 10% and 3.8% shorter for R-1234yf and XP 10
  – 40.8% and 50.8% longer for R-1234ze and N13a
  – Result for N13a is inconsistent to the full pull-down situation.
Appendix A - Instrumentation

- Compressor suction and discharge pressures
- Refrigerant mass flow rate
- Refriger. $\Delta p$’s through evaporator, condenser, and flow meter
- Compressor suction and discharge temperatures
- Evaporator refrigerant outlet temperature
- Condenser air inlet and outlet temperatures
- Condenser refrigerant inlet and outlet temperatures
- Discharge and return air temperatures
- Test cell ambient dry and wet bulb temperatures
- Test unit and compressor voltage, current, and power
- Evaporator fan power (checked once, not recorded continuously)
- PC-based Data Acquisition System used to record measurements.