Preliminary Results of the World Bank Low GWP Alternative Demonstration Project in Saudi Arabia

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Saudi Arabia: Demonstration project at air conditioning manufacturers to develop window and packaged air conditioners using lower GWP refrigerants (World Bank). The Executive Committee considered the proposed demonstration project as described in document UNEP/OzL.Pro/ExCom/76/46.
PETRA KSA Facility

Petra’s KSA facilities are in the King Abdullah Economic City in Rabigh - Saudi Arabia, with a total area of 45,000 m² (485,000 ft²), employing more than 450 persons in the fields of manufacturing, research and development, management, design, technical support, sales, marketing and after sales services.
Scope of Work

- Petra asked to design, develop, and test air-cooled packaged chillers
  - Alternative Refrigerants
    - HFC-32, GWP= 675, safety classification A2L
    - HC-290 (propane), GWP<4, safety classification A3
  - Baseline refrigerant: R410A, GWP=2088, safety classification A1
  - 3 cooling capacities: 40kW, 70kW, and 100kW
  - Total number of chillers built: 6
  - Total number of chillers tested: 9 (R410A as a drop in)
Refrigerant Safety Classification

A2L safety group classification used by several refrigerant designation standards:

- ASHRAE Standard 34
- ISO 817

Figure 1  Refrigerant safety group classification.

from: ASHRAE Standard 34-2010
Project Design – Charge Limitation

- Followed procedures outlined in ISO 5149-2014
  - Authorized occupancy “C” (i.e. manufacturing facility)
  - Location classification “III” – Refrigerant containing parts are located outdoor
- Conclusion: No charge restriction for A2L and A3 refrigerants
Project Software Development

- New software was developed to simulate the performance of the units using the R290 and R32
Prototype Unit
Safety Considerations

- Eliminate all junction boxes inside the unit
- R290 leak detector beside refrigeration pipes
- Installing electrical enclosure in location far from welding pipes.
- Unit Marking – Compliance with IEC 60335-2-40
Safety Considerations

- Wire mesh added to the condenser coil for hot surfaces protection
- Increased number of isolation valves
- NEMA 4X electrical panel
- Airflow switch installed to ensure panel is always at positive pressure
Performance Comparison at Standard Ambient Condition

Relative Cooling Performance to R410A at 35C
PSC 100

COP (%) vs Capacity (%) graph showing relative performance of R32 and R290 compared to R410A at 35C.
Performance Comparison at High Ambient Condition

Relative Cooling Performance to R410A at 46C
PSC 100

COP (%) vs Capacity (%)

- R32
- R290
## Cost Analysis - Refrigerants

### Comparing R290 and R410A

<table>
<thead>
<tr>
<th>Unit</th>
<th>Refrigerant Charge R410A (KG)</th>
<th>Refrigerant Charge R290 (KG)</th>
<th>Charge Ratio</th>
<th>Cost of refrigerant R410A ($)</th>
<th>Cost of refrigerant R290 ($)</th>
<th>Cost increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSC2H-100</td>
<td>16</td>
<td>11</td>
<td>1.45</td>
<td>104.8</td>
<td>134.75</td>
<td>28.6%</td>
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<tr>
<td>PSC2H-70</td>
<td>12</td>
<td>8</td>
<td>1.5</td>
<td>78.6</td>
<td>98</td>
<td>24.7%</td>
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<tr>
<td>PSC2H-40</td>
<td>6.5</td>
<td>5</td>
<td>1.3</td>
<td>42.575</td>
<td>61.25</td>
<td>43.9%</td>
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</tbody>
</table>

### Comparing R32 and R410A

<table>
<thead>
<tr>
<th>Unit</th>
<th>Refrigerant Charge R410A (KG)</th>
<th>Refrigerant Charge R32 (KG)</th>
<th>Charge Ratio</th>
<th>Cost of refrigerant R410A ($)</th>
<th>Cost of refrigerant R32 ($)</th>
<th>Cost increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSC3H-100</td>
<td>16</td>
<td>12</td>
<td>1.33</td>
<td>104.8</td>
<td>225.36</td>
<td>143.66%</td>
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<tr>
<td>PSC3H-70</td>
<td>12</td>
<td>9</td>
<td>1.33</td>
<td>78.6</td>
<td>169.02</td>
<td>115%</td>
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<tr>
<td>PSC3H-40</td>
<td>6.5</td>
<td>5.5</td>
<td>1.18</td>
<td>42.575</td>
<td>103.29</td>
<td>142.6%</td>
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</tbody>
</table>
# Cost Analysis – Major Components

<table>
<thead>
<tr>
<th>PSC 100 Major Components Cost</th>
<th>R410A</th>
<th>R32</th>
<th>R290</th>
<th>R290 Unit with ATEX components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor (2)</td>
<td>1821</td>
<td>1821</td>
<td>6286</td>
<td>10686</td>
</tr>
<tr>
<td>Condenser Coil</td>
<td>2560</td>
<td>2560</td>
<td>2560</td>
<td>2560</td>
</tr>
<tr>
<td>Evaporator Heat Exchanger</td>
<td>1829</td>
<td>1829</td>
<td>1829</td>
<td>1829</td>
</tr>
<tr>
<td>Expansion valves</td>
<td>123</td>
<td>123</td>
<td>196</td>
<td>196</td>
</tr>
<tr>
<td>Electrical Panel and cables</td>
<td>2054</td>
<td>4414</td>
<td>4414</td>
<td>13242</td>
</tr>
<tr>
<td>Piping</td>
<td>693</td>
<td>640</td>
<td>693</td>
<td>693</td>
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<tr>
<td>Pressure Relief Valve</td>
<td>275</td>
<td>275</td>
<td>246</td>
<td>246</td>
</tr>
<tr>
<td>Filter Drier</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td>Solenoid valve</td>
<td>156</td>
<td>156</td>
<td>156</td>
<td>467</td>
</tr>
<tr>
<td><strong>TOTAL ($)</strong></td>
<td><strong>9786</strong></td>
<td><strong>12093</strong></td>
<td><strong>16655</strong></td>
<td><strong>30194</strong></td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td>0%</td>
<td>23.6%</td>
<td>70.2%</td>
<td>208.5%</td>
</tr>
</tbody>
</table>
Summary

- Air-cooled chillers were successfully built and tested with low GWP refrigerants R32 and R290.
- International safety standards were followed and equipment was designed to reduce risk of using flammable refrigerants.
- Performance is comparable or better than baseline refrigerant R410A at standard and high ambient testing conditions.
- Cost of equipment slightly higher for R32 but significantly higher for R290.
- Cost of components are expected to decrease as production increases.
Thank you for your attention!