R-410A Alternative
Lower GWP
Refrigerants Drop in Testing: System and Components

Omar Abdelaziz, and
Som Shrestha

January 16th, 2014
New York City

AHRI LOW GWP AREP CONFERENCE
Overview

- System Drop-In Testing
- Indoor Heat Exchanger Evaluation
- Compressor Testing
System Drop-In Testing
System Description

• 5-TR heat pump unit
  – Outdoor unit: fixed capacity compressor, single speed fan
  – Single zone air handler: single speed blower, draw-through configuration

• R410A baseline: GWP = 2100†

• R32/R152a (95% R32 - 5% R152a): GWP ~ 687

† UNEP 2010
Heat Exchanger

• A-Coil
  - 8 circuits
  - OD = 3/8” (9.53 mm)
  - Tube thickness = 0.012” (0.305 mm)

• Air flows from bottom to top

• R410A TXV, set at ~ 5°F (3°C) superheat
**System Setup**

TC: Thermocouple  
P: High accuracy pressure sensor ~ 0 to 500 PSia  
T/RH: Temperature and Humidity Sensor
Results – System performance

Air-Side Heat Capacity (kBtu/W·h)

![Graph showing Air-Side Heat Capacity comparison between R410A and R32/R152a across different components A, B, C, H1, H2, H3.]

EER (Btu/W·h)

![Graph showing EER comparison between R410A and R32/R152a across different components A, B, C, H1, H2, H3.]

R410A Alternative Lower GWP Refrigerants Drop in Testing: System and Components
Additional System Performance Indicators

![Graph showing discharge pressure and total power consumption for R410A and R32/R152a refrigerants.](image)

- **Discharge Pressure (psi):**
  - A, B, C, H1, H2, H3
  - R410A and R32/R152a

- **Total Power Consumption (W):**
  - A, B, C, H1, H2, H3
  - R410A and R32/R152a
Compressor Discharge Temperature

![Compressor Discharge Temperature Chart]

- **A**, **B**, **C**, **H1**, **H2**, **H3**
- **R410A** vs. **R32/R152a**

9  R-410A Alternative Lower GWP Refrigerants Drop in Testing: System and Components
Indoor HX Evaluation

Evaporating Mode

- **Overall UA, kW/m²**
  - 1.5
  - 1.6
  - 1.7
  - 1.8
  - 1.9
- **Mass Flux, kg/m².s**
  - 100
  - 125
  - 150
  - 175
  - 200
  - 225

- **R410A**
- **R32/R152a**
Indoor HX Evaluation

Condensing Mode

Overall UA, kW/m²

Condensing Mode

Mass Flux, kg/m².s

R410A

R32/R152a

Oak Ridge National Laboratory
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY
Conclusions

• R32/R152a (95.22/4.78 by mass) was tested as a drop-in replacement to R410A

• R32/R152a has higher volumetric capacity and lower pressure drop through heat exchanger

• R32/R152a exhibited higher or similar system capacity for all test conditions

• In the evaporating mode, R32/R152a had comparable overall heat transfer characteristics to R410A even at much lower mass flux

• In the condensing mode, R32/R152a showed lower overall UA (5 to 21% lower) than R410A
Compressor Calorimeter Testing
# Tested Refrigerants

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Components</th>
<th>Mass Fraction, %</th>
<th>GWP$_{100}$(†)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-410a</td>
<td>R-32/R-125</td>
<td>50/50</td>
<td>2100</td>
</tr>
<tr>
<td>R-32</td>
<td>R-32</td>
<td>100</td>
<td>716</td>
</tr>
<tr>
<td>DR-5</td>
<td>R-32/R-1234yf</td>
<td>72.5/27.5</td>
<td>520*</td>
</tr>
<tr>
<td>L-41a</td>
<td>R-32/R-1234yf/R-1234ze(E)</td>
<td>73/15/12</td>
<td>524*</td>
</tr>
<tr>
<td>R-32/R-134a</td>
<td>R-32/R-134a</td>
<td>94.07/5.93</td>
<td>755*</td>
</tr>
</tbody>
</table>

† GWP100 based on UNEP, 2010

* Calculated based on the GWP values of pure refrigerants and their mass fraction in the blend
Results

Saturation Discharge Temperature (SDT), °F

Saturation Suction Temperature (SST), °F

Capacity Ratio

R-32

DR-5

L-41a
Results
Results
Results – R32/R134a

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>EER</th>
<th>Capacity</th>
<th>Discharge Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evap 45°F/ Cond 130°F</td>
<td>-2.20%</td>
<td>-0.80%</td>
<td>+37°C</td>
</tr>
<tr>
<td>Evap 50°F/ Cond 100°F</td>
<td>-4.30%</td>
<td>-2.8</td>
<td>+22°C</td>
</tr>
<tr>
<td>Over the range</td>
<td>-5.2% to -1.4%</td>
<td>-4.9% to +0.3%</td>
<td>+16 to +50°C</td>
</tr>
</tbody>
</table>
Conclusions

• R-32 resulted in capacity gain at the cost of slight efficiency loss and higher compressor discharge temperature

• DR-5 resulted in moderate capacity loss, less than 5% penalty in EER with increased discharge temperature within 20° R

• L-41a resulted in the most capacity degradation; however it behaved exceptionally well at high saturation discharge temperature (>130°F)

• At all test conditions, the EER with R-32/134a was lower than that with R-410A (by 1.4 to 5.2%). At higher discharge dew point temperatures, the ratio generally increased as the suction dew point temperature increased
Acknowledgements

• The authors would like to acknowledge funding from DOE-BTP and thank Mr. Antonio Bouza for his support.

• The authors would like to thank Dr. Isaac Mahderekal, Mr. Vishaldeep Sharma, Randy Linkous and Brian Goins (ORNL), Kyle Karber (Post Graduate Research Associate), and Evelyn Tio for their technical support.
Bibliography

• Open Source Life Cycle Climate Performance Design Tool: http://locp.umd.edu/ormllocp


Questions?

Omar Abdelaziz
abdelazizzoa@ornl.gov
Appendix
Heat Pump Drop-In Test Instrumentation

• Airflow: Self-averaging Pitot, ±2% of reading

• Refrigerant mass flow rate (liquid line): Coriolis flow and density, bi-direction calibration, ±0.5% of reading

• Refrigerant pressure measurement: ±0.08% Full scale of BSL with ±1% span shift

• Indoor airside temperature and relative humidity measurements: ±0.15°C and ±1.5% RH

• Refrigerant side temperature measurements: in-stream T-type thermocouple ±1°F
Heat Pump Drop-In Test Instrumentation

- Outdoor airside measurement: T-type thermocouple grid ±1°F
- Power measurement:
  - Compressor: 0-20 kW ±0.5% F.S.
  - Outdoor Fan: 0-1 kW ±0.5% F.S.
  - Indoor Blower: 0-500 W ±0.5% F.S.
- Uncertainty propagation for the R410A Cooling Test A based on air side performance is‡:
  - Q=62933 [Btu/hr] ±881 (±1.4%)
  - EER=14.12 [Btu/hr-W] ±0.201 (±1.42%)

‡ Based on averaging 82 data points
Compressor Calorimeter Test Setup

- Test condition:
  - 70°F to 140°F SDT in 10°F increments
  - 10°F to 55°F SST in 5°F increments
The measured cooling capacity and EER were within 2.7% and 1.0%, respectively, of the manufacturer’s data. Intermediate tests confirmed repeatability of cooling capacity within 1.5% and EER within 2% at standard test conditions. Properties of refrigerants were calculated using REFPROP version 9.0 (Lemmon et al., 2010). Interaction parameters and “mixture” files provided by the refrigerant manufacturers were used in REFPROP to calculate properties of the alternative refrigerants (except for R-32 and R-32 + R-134a mixture) tested.