Interim And Long-Term Low-GWP Refrigerant Solutions For Air Conditioning

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Outline

- Background
- Interim 750 GWP A2L Solutions
- Compressor Improvements For Interim Solutions
- Potential Long-Term Solution Paths
- Summary
HFC Phase Down Challenge

- Interim Regulations Centered On 750 GWP
- Is A 300 GWP Target Sufficient To Meet The 15% Ultimate Cap?

Source: DOE http://energy.gov/eere/buildings/articles
GWP, Efficiency and Flammability Trade Offs Will Impact System Cost
R32 And R452B/R454B – Interim Solutions

<table>
<thead>
<tr>
<th>Category</th>
<th>R32</th>
<th>R452B</th>
<th>R454B</th>
<th>Vs. R410A</th>
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</thead>
<tbody>
<tr>
<td>GWP / Charge % To R410A</td>
<td>677 / -20%</td>
<td>677 / -10%</td>
<td>464 / -10%</td>
<td>R454B Best GWP</td>
</tr>
<tr>
<td>Compressor Design &amp; Cost</td>
<td>DT*/Oil &amp; Envelope</td>
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<td></td>
<td>R32 DT* Concerns</td>
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<tr>
<td>Efficiency Vs. R410A</td>
<td>+ 1-2%</td>
<td>+ 0%</td>
<td></td>
<td>If Equal Capacity</td>
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<tr>
<td>Flammability/ Burn Velocity</td>
<td>A2L BV = 6.7</td>
<td>A2L BV = 3</td>
<td>A2L BV = 5</td>
<td>Varying BV But All Are A2L</td>
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<tr>
<td>Refrigerant Cost</td>
<td></td>
<td></td>
<td></td>
<td>R1234yf Cost</td>
</tr>
<tr>
<td>Cooling capacity (vs. R410A)</td>
<td>5% Compr. Downsize</td>
<td>Near Drop-In</td>
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</table>

*Compressor Discharge Temperature (DT)
Compressor Improvement For Interim Solutions – Envelope Management

Actual Compressor Discharge Temperature at $T_{e}/T_{c}$ Conditions & 20°F Superheat

**Fig. 6: Operating Envelope R32/R410A**

- **R-410A**
- **R452B**
- **R-32**

<table>
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<tr>
<th>Te/Tc Condition</th>
<th>Discharge Temperature (°F)</th>
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<tr>
<td>55/150</td>
<td>225, 245, 276</td>
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<td>45/130</td>
<td>201, 214, 239</td>
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<tr>
<td>50/115</td>
<td>172, 182, 201</td>
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<tr>
<td>10/90</td>
<td>178, 194, 217</td>
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- **R410**
- **R32**

**Condensing Temperature (°F)**

- Low Amb. H/P
- Max Amb. A/C

**Operating Envelope**

- **Heat Pump**
- **A/C**
Compressor Improvement For Interim Solutions – Capacity/Efficiency

**Fig. 7:** 3-Ton Scroll performance (R32/R410A Capacity)

**Fig. 8:** 3-Ton Scroll performance (R452B/R410A Capacity)

**Fig. 9:** 3-Ton Scroll performance (R32/R410A EER)

**Fig. 10:** 3-Ton Scroll performance (R452B/R410A EER)
Potential Long-Term Solution Paths

- **R410A-Like**
  - R410A
  - Like R407/R22
  - Like R134a

- **R407/R22-Like**
  - R290
  - R32
  - R452B
  - R454B
  - R32/HFO Blends
  - A1 Blends 1100-1300
  - R449B/C

- **R134a Like**
  - HFO 1234yf
  - HFO 1234ze

- **R123-Like (Very Low Pressure)**
  - HFC/HFO Blends

- **GWP Level**
  - <150 (Long Term?)
  - <750 (Interim)
  - <1300 (Retrofit)

Chart notes:
- A1 – Non Flammable
- A3 – Flammable
- A2L – Mildly Flammable
- B2L – Toxic, Mildly Flammable
- 750 gwp interim
- 1
- 3a
- 3b
- 3c
Efficiency Vs. GWP Challenge

Efficiency of R32/R1234yf Blends Vs. R410A

Range Of gwp With Good Efficiency - Good LCCP

Significant Efficiency Penalty With Pure HFO-1234yf

Sources: Papers from Univ. Tokyo, NEDO Symposium 2/17/2010 Japan
Beyond 300 GWP Likely Will Involve System Architecture Change

### Refrigerant Options To Replace R410A In Stationary AC & R Applications

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<tr>
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<th>1</th>
<th>2</th>
<th>3a</th>
<th>3b</th>
<th>3c</th>
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<tr>
<td>GWP</td>
<td>Interim Solutions</td>
<td>HFO Blends</td>
<td>Pure HFO &amp; Blends</td>
<td>HC (R290)</td>
<td>Carbon Dioxide</td>
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<td>460-675</td>
<td>300-400</td>
<td>1-150</td>
<td>&lt;10</td>
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<td>Compressor Design &amp; Cost</td>
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<td>High Press.</td>
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<td>Pump+HX Losses</td>
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<td>Flammability</td>
<td>A2L</td>
<td>A2L</td>
<td>A2L</td>
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<td>Refrigerant Cost</td>
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<td>System Cost</td>
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<td>Sec. Loop Required</td>
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Change System Architecture
Summary

- R32 and R452B/R454B Offer Reasonable Solutions For Interim 750 GWP With Good LCCP And Balanced Trade Offs Among Efficiency, Flammability and Applied Cost

- Both Compressors and Systems Can Be further Optimized For R32 and R452B

- The AHRI AREP Program Has Provided Good Insights To System Performance Including Drop-In, Soft-Optimized and High Ambient Testing, and Provide A Good Basis to Continue With Further Optimization

- Acceleration Of A2L Standards Development Into Building Codes By 2021 Will Enable Commercialization and Market Adoption Learning

- Uncertainty Remains Relative To Required GWP Levels To Meet The 15% Cap So Several Potential Long-Term Paths Are Possible and Will Likely Consider System Architecture
Thank You!

Questions?

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