Performance of R410A and R22 Low GWP Alternative Refrigerants at Elevated Ambient Temperatures

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Overview

- Background.
- Overview of our test program.
- Summary of our test results.
  - Nominal design condition.
  - Elevated ambient temperatures.
- Summary of important factors in the selection of next-generation refrigerants.
- Conclusions
The Transition Away from R22

- Came down to three alternatives globally...
  - Early adoption in Europe = R404A
  - Near drop-in replacement = R407C
  - Higher pressure/capacity = R410A

And the winner is ... R410A.
Transition Away from R410A?

What’s in the toolbox?

- **Primary constituents in blends**
  - R32: GWP = 675, class = A2L
  - R1234yf: 4, A2L
  - R1234ze: 6, A2L

- **Secondary constituents in blends**
  - R125, R134a, R152a, CO₂

The new “HFO’s”. “Mildly” flammable.

- **Lacking non-flammable low GWP blend materials (R125-like).**
  - Are there any more high pressure chemistries? (Will McLinden and Domanski find something?)

- **NO** very low GWP (<150) refrigerant molecules with pressures comparable to R410A or R22 (that aren’t A3’s).

- R32 needed to keep pressures (ie, capacities) in the range of R410A or R22.
AHRI Low GWP AREP

- Industry response to environmental concerns related to high GWP refrigerants.
  - Program was announced 23-Mar-2011.

- Designed to help the industry:
  - Select the most promising refrigerants,
  - Understand technical challenges,
  - Identify the research needed to eventually use these refrigerants.

- Testing be done at participating companies’ laboratories at their own expense.
  - First round results presented at Conference in New York, Jan 2014.

- Second round of testing underway. Reports due by Apr 2015.

See Paper 2250 (X Wang) from previous session R-01 for more information on the AHRI Low GWP AREP.
Equipment Tested

- **Air-Cooled Water Chiller / Heat Pump, ~4.4 RT**
  - Uses R22 or R407C
  - Scroll compressor
  - Brazed plate evaporator
  - Fin-and-tube condenser

- **Configuration #1 – R410A**
  - Engineering prototype compressor with liquid injection (Didn’t use injection)
  - TXV for R410A
  - Tests run with R410A and R410A-like alternatives

- **Configuration #2 – R22**
  - Original equipment compressor for R22
    - Changed oil to POE used above
  - OEM TXV for R22
  - Tests runs with R22 and R22-like alternatives

- **“Outdoor” conditions**
  - Maintained by environmental chamber (dry-bulb only)
R410A/R22 Alternatives Tested by Us

- **R410A-like blends** have GWPs of ~500.
- **R22-like blends** have GWPs as low as 200-250.

A range of options, each with trade-offs.

15 fluids tested (a couple twice)
Best R410A Alt’s – Capacity & COP

- **R32** (GWP = 675)
  - CAP and COP increased, but not as much as predicted. High discharge temperatures.

- **DR5** (GWP = 490)
  - Very similar performance to R410A; potential near drop-in.

- **L41’s** (GWP = 494)
  - Small reductions in capacity; maybe okay?

- **DR4 (296), ARM70a (482)**
  - Performed better than expected – interesting?

Need also to consider discharge temp’s, glide, HXer performance, ...
Best R22 Alt’s – Capacity & COP

- **L20** (A2L, GWP = 330)
  - Matched R22 capacity, but had 5% lower efficiency.

- **LTR4X** (A1, GWP = 1300)
  - Matched R22 capacity, but efficiency was down 10%. A1, but “high” GWP.

- **DR7** (A2L, 245), **ARM32a** (A1, 1575)
  - A little extra capacity, but efficiency is down ~10%.

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Need also to consider discharge temp’s, glide, HXer performance, ...
Did we give away performance at high ambient temperatures?

In many locations, the design cooling loads occur at temperatures well above our typical AHRI rating condition (95°F/35°C).
Normalized to capacity @ 35°C.

Normalized to curve for R410A.

Loss in capacity with R410A is ~8% relative to R22 @ 50°C.
Our Test Results – R410A Alternatives

- Normalized to capacity @ 35°C.
- Normalized to R410A results.

Both graphs show the normalized capacity factor of various refrigerants over a range of air temperatures. The curves are compared against R410A, and it is observed that all the alternatives look similar to R410A.
Normalized to capacity @ 35°C.

- Normalized to capacity @ 35°C.

- Normalized to R22 results.

Range limited by Pmax of R22 compressor.

Only L-20 kept up with R22.
Our Test Results – Efficiency

- Normalized to R410A results.
  - All look like R410A.

- Normalized to R22 results.
  - Only L-20 kept up with R22.
Our Test Results – Discharge Temps

- **Results for R410A alternatives.**
  - R32 is highest; will need mitigation methods.

- **Results for R22 alternatives.**
  - Tmax for the compressors

- **R22 adm’s less of a concern.**
Glide generally increases as move from R410A-like blends toward R22-like blends.
- Capacity is generally decreasing in this direction.
- GWP is generally decreasing in this direction.
- Potential efficiency tends to increase in this direction.

An ideal candidate has <1°Cd of glide.

Large glides because these blends contain CO₂.
## Comparison of Lower GWP Alternatives

<table>
<thead>
<tr>
<th></th>
<th>R410A</th>
<th>R32</th>
<th>DR5</th>
<th>L41’s</th>
<th>....</th>
<th>DR7</th>
<th>L20</th>
<th>LTR4X</th>
<th>R22</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAP</strong></td>
<td>1.00†</td>
<td>+9%</td>
<td>+2%</td>
<td>-5%</td>
<td>?</td>
<td>-25%</td>
<td>-29%</td>
<td>-28%</td>
<td>-29%</td>
</tr>
<tr>
<td><strong>COP</strong></td>
<td>1.00†</td>
<td>+1%</td>
<td>-1%</td>
<td>+2%</td>
<td>?</td>
<td>+2%</td>
<td>+6%</td>
<td>+4%</td>
<td>+11%</td>
</tr>
<tr>
<td><strong>ΔTdchrg (°Cd)</strong></td>
<td>0†</td>
<td>+20</td>
<td>+8</td>
<td>+10</td>
<td>?</td>
<td>-4</td>
<td>+7</td>
<td>-3</td>
<td>+5</td>
</tr>
<tr>
<td><strong>Glide (°Cd)</strong></td>
<td>~0</td>
<td>0</td>
<td>1</td>
<td>~2.5</td>
<td>?</td>
<td>~5</td>
<td>~7</td>
<td>~6</td>
<td>0</td>
</tr>
<tr>
<td><strong>Hi Tamb (50°C)</strong></td>
<td>1.00</td>
<td>1.00</td>
<td>+7%</td>
<td>+6%</td>
<td>+4%</td>
<td>+1%</td>
<td>+7%</td>
<td>+3%</td>
<td>+8%</td>
</tr>
<tr>
<td><strong>CAP/COP</strong></td>
<td>2088</td>
<td>675</td>
<td>490</td>
<td>494</td>
<td>?</td>
<td>246</td>
<td>331</td>
<td>1295</td>
<td>1810</td>
</tr>
<tr>
<td><strong>Flam BV (cm/s)</strong></td>
<td>A1</td>
<td>A2L</td>
<td>A2L</td>
<td>A2L</td>
<td>?</td>
<td>A2L</td>
<td>A2L</td>
<td>A1</td>
<td>A1</td>
</tr>
</tbody>
</table>

There are no ideal replacements for R410A or R22. Which will make the best compromise?
Conclusions

- **“Toolbox” for R410A/R22 replacements is limited:**
  - Blends of R32, R1234yf, and R1234ze with a sprinkling of others.
  - R410A-like alternates are at best “2L”.
  - R22-like alternates can be lowest GWP (330 .. 250), but are “2L”.
  - R22-like alternates can be “1”, but are not (ultra) low GWP.

- **Large number of competing/opposing factors:**
  - thermodynamics
    - operating pressure = capacity
    - inherent efficiency
    - blends = temperature glide
  - range of operation ⇔ reliability
    - high ambient temperatures
    - compressor discharge temperatures
  - safety and environment ⇔ flammability and GWP

Lower GWP R410A & R22 alternatives are possible, however, with more compromises than today.