Refrigerant Update
THE NEXT TRANSITION HAS BEGUN

Thomas J. Gorman
Applied Chiller Systems
Product Manager
Understanding the Timeline

Past (CFCs)
R-12, R-11, R-113 more...
⇒ ODP

Low-ODP or no ODP

Present (HCFCs & HFCs)
R-22, R-134a, R-410A, R-407C
R-123, R-404A R-245fa more...
⇒ GWP

Reduced GWP

Future (HFO & Blends)
R-1234yf, R-1234ze, R-1233zd,
R-513A, R-1336mzz, more...

Short Atmospheric Life Reduces Impacts

There's more to refrigerant selection than just ODP & GWP
White House statement: “These industry associations and companies are making significant commitments to phase out or phase down their use of HFCs and transition to climate-friendly alternatives, good for the environment and good for business,”

AHRI president and CEO Stephen Yurek stated: 'Close to $2bn has been spent by the industry since 2009 researching energy-efficient equipment and the utilization of low-GWP refrigerants,” Yurek stated, “and over the next 10 years, the HVACR industry will invest an additional $5bn for r&d and capital expenditures to develop and commercialize low-GWP technologies.”

**22 companies have committed to cutting HFC emissions by 2020**

<table>
<thead>
<tr>
<th>Company</th>
<th>Commitment</th>
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<tr>
<td><strong>Carrier</strong></td>
<td>announced that its commitment to pursue the commercialization of HFC-free refrigerants in road transportation refrigeration by 2020.</td>
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<td><strong>Danfoss</strong></td>
<td>announced that it’s championing a stakeholder task force to accelerate adoption of standards and building codes for next generation, low-GWP refrigerants.</td>
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<td><strong>Johnson Controls</strong></td>
<td>announced that it commits to using the lowest GWP option for each application that best fits the needs of its customers. It also committed to spend an additional $50 million over the next three years to develop new products and improve and expand its existing portfolio.</td>
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<tr>
<td><strong>Goodman Manufacturing Company</strong></td>
<td>commitment to help slash greenhouse gas emissions by developing low-global warming potential (GWP) air conditioners and/or heat pumps. Daikin aims to reduce its greenhouse gas emissions in 2020 to one-quarter of its 2005 emissions.</td>
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<tr>
<td><strong>Ingersoll Rand</strong></td>
<td>commitment to slashing greenhouse gas emissions at their operations by 35%, reduce GHG associated with our products by 50% (increased unit efficiency and the transition to lower GWP refrigerants) and will invest $500M in research and development… all by 2020</td>
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Under this final rule, various HFCs and HFC-containing blends that were previously listed as acceptable alternatives will be listed as unacceptable in various end-uses in the aerosols, foam blowing, and refrigeration and air conditioning sectors where other alternatives are available or potentially available that pose lower overall risk to human health and the environment.

Final Rule - Protection of Stratospheric Ozone:
Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy Program

What?
- Changes the status of certain HFCs now that safer alternatives are available

Which industrial sectors are included?
- Aerosols
- Refrigeration & Air Conditioning
- Foam Blowing

Who is affected?
- Chemical producers and some manufacturers of equipment and products using aerosol propellants, refrigerants, and foam blowing agents

When?
- Starting in January 2016; see table for dates for all affected end-uses

Signature Final Rule put into place on July 2, 2015
U.S. Environmental Protection Agency (EPA) that sets forth the timeframes for the phaseout of certain hydrofluorocarbons (HFCs) in specific applications...

...the EPA is using the SNAP program to help transition the industry away from high-GWP products used in refrigeration and air conditioning, aerosols, and foam-blowing sectors where lower-GWP products are available.

Refrigerants: R-404A, R-507A & R-134a

...as of Jan. 1, 2017, in supermarket systems, and Jan. 1, 2018, in remote condensing units, R-404A, R-507A, and several other high-GWP refrigerants cannot be used in new installations.

Phase-Out is already underway ... using existing laws
EPA Looking at Further Ban on HFCs
Next round of HFC listings as “unacceptable”
September 23, 2015

“…the EPA announced that it is considering listing as unacceptable a number of refrigerants in several end-uses in the future. **This includes R134a, R407C and R410A in chillers**; R134a, R404A and R507A in refrigerated food processing and dispensing; and R134a, R407C, R404A and R507A in cold storage warehouses. It is also considering delisting R134a from use in domestic refrigerators.”
What is happening in the Industry...

Just looking at Air Cooled Chillers that are using something other then R-134a & R-410A

... These are just a few of the screw or scroll chillers available now with new HFO refrigerants.

New equipment offered in the market, using Low-GWP fluids
What is happening in the **Industry**…

Also available for the Water Cooled markets as well…

...both Screw and Centrifugal units.

New equipment offered in the market, using Low-GWP fluids
Industry Consensus and Agreement with NRDC
AHRI Support of Phase-out of HFCs
February 1, 2016

AHRI and NRDC have engaged in discussions on the importance of responsibly moving beyond high-GWP refrigerants used in chillers. Considerations have included the safety of alternatives, the continued improvement of system energy efficiency, reasonable product development timelines, and the avoidance of market migration. With these factors in mind, AHRI and NRDC support EPA finalizing the following changes of status:

- Remove R-134a, R-410A, and R-407C from the list of acceptable substitutes in all new air-cooled and water-cooled chillers using centrifugal, screw, scroll, and all other compressor types effective January 1, 2025

This proposal allows eight years from the publication of the final rule for industry to finish designing and altering existing products. Elected members will engage in the transition period. In addition, this conversion is

Industry Support of Phase-out by January 1st 2025
### Proposed Rule

**What is EPA proposing?**
- List as acceptable subject to use conditions, list as unacceptable, and change the status of several substances
- Exempt propane from the CAA’s section 608 venting prohibition
- Clarify status of acceptable fire suppression alternative

**Which industrial sectors are included?**
- Refrigeration & Air Conditioning
- Fire Suppression & Explosion Protection
- Foam Blowing

**Who is affected?**
- Chemical producers, some manufacturers, and some end-users of equipment and products using refrigerants, fire suppressants, and foam blowing agents

**When?**
- Starting 30 days after publication of a final rule; see table for dates

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FOR IMMEDIATE RELEASE:
March 29, 2016

FACT SHEET

### PROPOSED CHANGE OF LISTING STATUS

<table>
<thead>
<tr>
<th>End-Uses</th>
<th>Substitutes</th>
<th>Proposed Effective Date</th>
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</thead>
<tbody>
<tr>
<td><strong>Air Conditioning</strong></td>
<td></td>
<td></td>
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</tbody>
</table>
HFC Regulations in US and Canada
Ban on Shipment of New Equipment with HFCs

North America HFC Phase-Out dates on High GWP Refrigerants
Next-Generation Refrigerants

AHRI Low-GWP Alternative Refrigerant Evaluation Program

In 2010 ASHRAE 34 Development a new class 2L “Difficult to Ignite & Sustain” Not all 2L refrigerants are equal

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New refrigerants raise new questions…

State Law “enforceable”
High Pressure Refrigerant Replacements

HCFC → HFC → Low GWP

R-22 → R-410A → R-407C → R-452B → R-454B

- Flammable: R-32

Driving Factors:
- Performance
- Safety

Next transition with High Pressure Refrigerants
Completing a drop-in comparison test with Chemours made no system or lubricant changes to the unit to document performance. The DR-55 delivered nearly 5% improvement in energy efficiency at equivalent cooling capacity and discharge temperatures were similar to R410A.

5% Improvement on efficiency
10% Reduction on unit charge

http://www.coolingpost.com/world-news/is-dr-55-best-option-to-replace-r410a/

R-452B provides better performance then current generation R-410A
Tests are said to have shown that R-452B also exhibits a slower burning velocity and higher minimum ignition energy requirement when compared to R32.

Although R-452B has the same A2L “mildly flammable” classification as R32, Chemours maintains that some global OEMs have indicated that the lower flammability properties of XL55 are compelling and are likely to be an important consideration in product selection, especially for larger charge size equipment.

Almost 70% reduction in GWP over R-410A

Not all 2L refrigerants are the same...
Past
Future
Present
High Pressure
Medium Pressure
Low Pressure

Efficiency (COP)

Efficiency (COP)

Efficiency (COP)

9.10 8.95 8.78 8.85 8.91
8.58 8.47 8.28 8.45 8.17
8.48 7.99 8.39 8.22 7.83

R-11 R-123 R-245fa R-1233zd R-514A
R-12 R-134a R-513A R-1234ze R-1234yf
R-22 R-410A R-452B R-32

Global Warming Potential (CO₂=1.0)

Global Warming Potential (CO₂=1.0)

Global Warming Potential (CO₂=1.0)

4,660 858 1 1.75
10,200 1,300 573 1 1
1,810 1,924 675 677

More choices emerging...

More choices emerging...

More choices emerging...

GWP Values are per AR5 of the 2013 UN climate report
BV represents “Burning Velocity” of 2L refrigerants
range from 0-10 cm/sec.

Industry commitments and available options are increasing
## Centrifugal Refrigerant Choices & Comparison

Next round of HFC listings as “unacceptable”

<table>
<thead>
<tr>
<th></th>
<th>Low Pressure</th>
<th>Medium Pressure</th>
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<tbody>
<tr>
<td></td>
<td>R-123</td>
<td>R-134a</td>
</tr>
<tr>
<td>Flammability</td>
<td>Non (1)</td>
<td>Non (1)</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Higher (B)</td>
<td>Lower (A)</td>
</tr>
<tr>
<td>Fluid Efficiency</td>
<td>9.4 COP</td>
<td>9.3 COP</td>
</tr>
<tr>
<td>Capacity Change</td>
<td>1</td>
<td>35% Gain</td>
</tr>
<tr>
<td>GWP</td>
<td>79</td>
<td>&lt; 2</td>
</tr>
<tr>
<td></td>
<td>In Current Trane Product Offering</td>
<td>In Current Trane Screw Product Offering</td>
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**Low Pressure**

- **R-123**: 1,000 ton
- **R-1233zd**: 1,350 ton (35% gain over R-123)
- **R-514A**: 1,000 ton

**Medium Pressure**

- **R-134a**: 1,000 ton
- **R-513A**: 1,051 ton
- **R-1234zf**: 950 ton (5% loss over R-134a)
- **R-1234ze**: 775 ton (25% loss over R-134a)

**Replacement refrigerant impact on Efficiency, Capacity & Flammability**

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How Can I Protect My Investment?

- There are **no** perfect refrigerants
- Take a balanced approach
  Safety, Environmental Impact, Efficiency
- R-123, R-134a, R-410A, R-404A, R-407C are all responsible HVAC refrigerant choices...
  Today
- Leak tightness is key!
  Means lower emissions, higher efficiencies, lower cost
Original Calais chiller plant went on line in 1994 supporting the temperatures needed for the tunnel. It was determined due to service history and the need reduce energy consumption, to replace the chillers on the French side. These chillers perform a mission critical job because the ambient tunnel temperature would reach 55°C (130°F). This would make the trains unbearably warm for passengers, but it would probably cause equipment to malfunction and the tracks to buckle eventually.

- **Three Centrifugal Chillers**  
  - Using R-1233zd “HFO”  
  - 2 x 9 MW (2,560 ton)  
  - 1 x 11 MW (3,130 ton)

- **Total Capacity 30 MW (8,523 tons)**
How Can I Protect My Investment?

**All** refrigerants use today are and will be – available for the life of the equipment.

Focus on reliable, efficient designs

<table>
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<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Lifetime of Electricity</td>
<td>88.51%</td>
</tr>
<tr>
<td>Lifetime of Service</td>
<td>6.53%</td>
</tr>
<tr>
<td>Lifetime Refrigerant Supply</td>
<td>0.04%</td>
</tr>
<tr>
<td>“First Cost” Chiller/Refrigerant</td>
<td>4.92%</td>
</tr>
</tbody>
</table>

Let us worry about the refrigerant!

A Balanced Approach, with a Focus on Efficiency