Trane Refrigerant Update

THE NEXT TRANSITION HAS BEGUN

W. Ryan Geister
Applied Systems Leader, Chillers
Trane, A Division of Ingersoll-Rand
Chairman of AHRI Chiller Section
Member of IR Refrigerant Council
ASHRAE Member since 1996

Trane Refrigerant Message

Trane said ozone depletion, global warming, and energy efficiency as all being equally important.

Balanced approach minimizes overall environmental impact:
- Ozone depletion
- Energy efficiency
- Refrigerant emissions
- Global warming
- Atmospheric life

Trane will offer the right product with the right refrigerant at the right time.
Understanding the Timeline

**Past**  (CFCs)
- R-12, R-11, R-113 more...
- Low-ODP or no ODP

**Present**  (HCFCs & HFCs)
- R-22, R-134a, R-410a, R-407C
- R-123, R-404a R-245fa more...
- Reduced GWP & De Minimis ODP

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

“There’s more to refrigerant selection than just ODP & GWP

Global Pressure on ALL Refrigerants

HFCs Are On Shaky Ground In Europe

The Pressure on HFCs is Not New
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.”

In 2014 22 companies committed to cutting HFC emissions by 2020

| Ingersoll Rand | 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 |
| Carrier | announced that its commitment to pursue the commercialization of HFC-free refrigerants in road transportation refrigeration by 2020. |
| Danfoss | announced that it’s championing a stakeholder task force to accelerate adoption of standards and building codes for next generation, low-GWP refrigerants. |
| Johnson Controls | 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. |
| DAIKIN | Goodman Manufacturing Company, 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. |

Ingersoll-Rand Commitment
Reducing Greenhouse Gas Emissions

**Our Products**
50% reduction in GHG via:
1) increased energy-efficient products; 2) use of next generation refrigerants with lower GWP in refrigerant-based products by 2020

**Our Operations**
35% GHG reductions in our office buildings, manufacturing facilities and fleet by 2020

**Market Leadership and Convening**
$500M in research to promote energy efficiency & solve refrigerant gaps via innovation, research, testing, policy over the next 5 years

**EcoWise™**
Designed to lower environmental impact with next generation, low global warming potential refrigerants and high efficiency operation

Ingersoll-Rand committed & focused, all aspects of the business
EPA Looking at Further Ban on HFCs

Next round of HFC listings

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."

http://www.coolingpost.com/world-news/us-epa-consider-future-ban-on-r134a-chillers/

EPA is considering listing R-134a, R-407C & R-410A as "unacceptable"

World Agrees: HFC Phase-Down to begin in 2016

Latest Montreal Protocol Meetings

November 6, 2015

“Pleased with the progress made, Stephen Yurek, president and CEO of the US Air Conditioning, Heating, and Refrigeration Institute (AHRI), said ‘AHRI’s member companies – including refrigerant producers and original equipment manufacturers – have proactively been researching potential alternative refrigerants to ensure that the world's air conditioning and refrigeration equipment manufacturers will have access to appropriate refrigerants.’


Global agreement to include HFCs in Montreal Protocol
Industry Acceptance of HFC Phase-Down Direction

AHRI support of amendment to Montreal Protocol
November 9, 2015

“AHRI has commended the decision of the Parties of the Montreal Protocol to work toward an amendment in 2016 to include HFCs in the treaty’s purview, with a goal of working toward a schedule to phasedown their use across the globe.

AHRI President and CEO, Stephen Yurek, said: “Even as other MP signatories have debated the original North American Proposal to include HFCs, AHRI’s member companies – including refrigerant producers and original equipment manufacturers have been proactively researching potential alternatives to HFCs…”


Global HFC Phasedown – Montreal Protocol

New chapter in the fight against climate change
November 23, 2015

“The end is near for hydrofluorocarbons (HFCs).

The 197 Parties to the Montreal Protocol agreed to begin work on an amendment that will reduce the global production and consumption of HFCs at the 27th Meeting of the Parties (MOP). The amendment, deemed the “Dubai Pathway,” is expected to be completed in 2016 and puts to rest an ongoing discussion regarding HFC usage that’s persisted among Montreal Protocol members for more than five years.”

Montreal Protocol targets HFC phasedown amendment completion in 2016
**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 selling existing units.

**Industry Support of Phase-out by January 1st 2025**

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**Industry Agrees: HFC Phase-OUT in 2025**

**Latest Montreal Protocol Meetings**  
February 3, 2016

“US Environmental group the Natural Resources Defense Council (NRDC) and the Air Conditioning, Heating, and Refrigeration Institute (AHRI) are said to have agreed on a schedule for eliminating the use of the refrigerants in new chillers of all types and sizes.”

http://www.coolingpost.com/world-news/r134a-faces-chiller-ban-from-2025/

**Industry Alignment with NGO Supports USA Climate Commitment**
Final Rule - Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy Program

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.

EPA-HFC 7-2015

Global HFC Consumption 2010 (MMTCO₂)

- Refrigeration & A/C (75%)
- Mobile A/C & R (42%)
- Stationary Refrigeration (42%)
- Comm A/C (30%)
- Unr/Res A/C (12%)
- Aerosols (16%)
- Foams (11%)
- Fire Extinguishing (4%)
- Solvents (1%)
What the Industry is Doing...

- Initiated in 2011
- Phase I Completed Dec 2013
  - Tested 30+ Refrigerants
- Phase II Began Jan 2014
  - Testing 20+ More Refrigerants
- Results first Release Jan 2015
- 2016 continued the evolution...

Huge opportunity for equipment providers to lead

Next-Generation Refrigerants

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

2L Definition Being Evaluated

What is the Next Refrigerant?

Future of refrigeration and air conditioning in 2032; insights into design and market challenges with lower global warming potential (GWP) refrigerant candidates

Krajik S.¹, Thompson, M.²

¹Climate Solutions Division, Honeywell
²Climate Solutions

Resources Available to Help Better Understand Various Options
HVAC Industry Next Transition Begins...

Industry commitments and available options are increasing

High Pressure Refrigerant Replacements

HCFC → HFC → Low GWP

R-22

R-32

R-407C

R-410A

Blend 50% R-125
50% R-32

Blend 52% R-134a
28% R-125
23% R-32

DR-55
R-452B

Blend 26% R-1234yf
7% R-125
67% R-32

Blend 31% R-1234yf
69% R-32

Driving Factors
- Performance
- Safety

Next transition with High Pressure Refrigerants

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Completing a drop-in comparison test with a 2.5 ton York residential air conditioning heat pump design for R-410A to DR-55.

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.

DR-55 provides better performance than current generation R-410A

5% Improvement on efficiency
10% Reduction on unit charge
**High Pressure Refrigerant Replacements**

**Review of Safety**

Tests are said to have shown that DR-55 also exhibits a slower burning velocity and higher minimum ignition energy requirement when compared to R32.

Although DR-55 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

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**Trane Debuts R410A Replacement**

Showcased at the IIR International Congress on Refrigeration

**Testing done by two independent teams**
- University of California at Davis
- Oak Ridge National Laboratory

**Findings**
- 5% improved efficiency
- 10% lower refrigerant charge
- 70% reduction in direct GWP (over R-410A)

**Trane Announces Demonstration Chiller using DR-55**

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Trane Offers Transition Choices

<table>
<thead>
<tr>
<th>Medium Pressure</th>
<th>R-134a</th>
<th>R-513A</th>
<th>R-1234yf</th>
<th>R-1234ze</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammability</td>
<td>Non (1)</td>
<td>Non (1)</td>
<td>Slight (2L)</td>
<td>Slight (2L)</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
</tr>
<tr>
<td>Fluid Efficiency</td>
<td>8.5 COP</td>
<td>8.3 COP</td>
<td>8.2 COP</td>
<td>8.5 COP</td>
</tr>
<tr>
<td>Capacity Change</td>
<td>Same</td>
<td>Same</td>
<td>5% Loss</td>
<td>25% Loss</td>
</tr>
<tr>
<td>GWP</td>
<td>1300</td>
<td>573</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

In Current Trane Product Offering | Under Evaluation for Trane Products

Portfolio of next-generation helical-rotary chillers by 2020

What is happening in the Industry...

Just looking at air-cooled chillers for R-134a & R-410A alternatives

... Just a few of the screw scroll chillers available now the 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

Trane Centrifugal Chiller Roadmap

Lowest Environmental Impact:
- Efficiency: Full & Part Load
- Sustainability: Reliability & Serviceability
- System Integration & Control
- Balanced environmental approach
  - High efficiency
  - Low leakage
  - GWP
  - ODP
  - Short atmospheric life

Convertible & Compatible Solutions:
Continuing to help Customers Transition

Full line in 2015: Today, limited size & regional availability.
Next-Generation, Low-GWP

Regulations & new refrigerants push new technologies & transitions.
Trane was – and is – ready to deliver tomorrow’s solutions today.
CenTraVac™ Portfolio Refrigerant Comparison

Trane has remained steadfast in its product and refrigerant choices for over 75 years.

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Low Pressure</th>
<th>Medium Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-123</td>
<td>Non (1)</td>
<td>Non (1)</td>
</tr>
<tr>
<td>R-123zd</td>
<td>Non (1)</td>
<td>Non (1)</td>
</tr>
<tr>
<td>R-xxxx</td>
<td>Available in advance of phase-out dates</td>
<td></td>
</tr>
<tr>
<td>R-134a</td>
<td>Slight (21)</td>
<td>Slight (21)</td>
</tr>
<tr>
<td>R-513A</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
</tr>
<tr>
<td>R-1234yf</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
</tr>
<tr>
<td>R-1234ze</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
</tr>
</tbody>
</table>

The current EarthWise™ CenTraVac Portfolio chillers shipping today with R-123 will be convertible in the future for use with next-generation, low-GWP refrigerant: R-123 CenTraVac chillers will become part of the EcoWise portfolio once available with next-generation refrigerant.

Enabling the most efficient chillers in the world – Then. Now. Always!

Design Fundamentals
Evolution of the Trane® CenTraVac™ Chiller

Product Design Commitment:
- Reliability
- Efficiency
- Lowest Emissions

Providing the Performance for the next 30 years

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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

Understand the Facts

New Article Now Available:
**Considerations for Next-Generation HVAC Refrigerants**

Offering customers insights into the next transition
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>
<thead>
<tr>
<th>Metric</th>
<th>Percentage</th>
</tr>
</thead>
<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

Centrifugal Chiller Comparison

Operating Pressure by Refrigerant

Many Customers Enjoy the First Charge as the Last Charge
Proven through 3rd party validation... Products with EPDs contribute toward a LEED point under Material & Resources

Questions?

Thank you for your time and attention!
**How do I Find Out More?**

**THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEplete THE OZONE LAYER**

November 2015 meetings:

...and industry support:

http://www.epa.gov/climatechange/ghgemissions/gases/fgases.html
http://www.coolingpost.com/world-news/us-epa-considers-future-ban-on-r134a-chillers/

Rule 20 (July 2015) – Prohibition on the use of certain high-GWP HFCs as alternatives

AHRI/NRDC petition (February 1, 2016):

AHRI's Low-GWP Alternative Refrigerants Evaluation Program
  
Kujak S., Thompson, M. "Future of refrigeration and air conditioning in 2032; insights into design and market challenges with lower global warming potential (GWP) refrigerant candidates.” Cryogenics and Refrigeration-Proceedings of ICCR2013. Paper ID: B-4-10.

Trane / Ingersoll Rand:

Considerations for Next-Generation HVAC Refrigerants (February 2015)

HVAC Refrigerants: A Balanced Approach (June 2011)

CenTraVac™ Chiller Environmental Product Declaration (EPD) – UL Environment Sustainable Products Guide
Indefinite Use of Reclaimed/Recycled/Stockpiled Refrigerant

Montreal Protocol. The Protocol authorizes HCFC production for use in developed countries in new chillers until 2020 and for service until 2030 and HCFC production for use in developing countries in either new equipment or servicing until 2040. After production phaseout, HCFCs can be supplied from reclaimed and recovered sources.

From the EPA website:

SNAP Ruling Documentation
(Unacceptable Refrigerants & Those Subject to Restrictions)

Title 40 > Chapter I > Subchapter C > Part 82 > Subpart G
http://www.ecfr.gov/cgi-bin/text-idx?SID=1336e126c41c48100eb799e3a21d554&mc=true&node=sp40.18_82.qg&rgn=div6

Find the Appendix with the ruling of interest:
Appendix U -- http://www.ecfr.gov/cgi-bin/text-idx?SID=1336e126c41c48100eb799e3a21d554&mc=true&node=sp40.18_82.qg&rgn=div6#ap40.18.82.u
Older References:

(Nice summary of North American proposal to Montreal Protocol)

(April 2013, quotes from other HVAC companies)

http://www.epa.gov/ozone/intpol/mpagreement.html
(Sept 2013, fact sheets on the right side of page – focuses on refrigeration, but shows next refrigerants)

(Sep 2013, G20 nations sign agreement to curtail HFCs)

(Oct 2013, U.S. and India joint agreement on HFC phasedown)

(Mar 2014, New EU F-gas regulation passed)

http://www.alliancepolicy.org/index.php
(Learn more about The Alliance for Responsible Atmospheric Policy)

http://www.bna.com/epa-proposes-prohibit-n17179892134/
(Jul 2014, Article on proposed EPA bans/reductions on HFC refrigerants through SNAP)

Global Pressure on ALL Refrigerants:


Additional References to Learn More About Impending Transitions

(Nice summary of North American proposal to Montreal Protocol)

(April 2013, quotes from other HVAC companies)

http://www.epa.gov/ozone/intpol/mpagreement.html
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