Refrigerants and their responsible use

The Next Transition Has Begun

ASHRAE Montréal
13 janvier 2020

David Gauvin, P.Eng. LEED AP BD+C
Strategic Manager – Ice Rinks
TRANE North America
Davidson, NC, USA
Learning Objectives

After viewing the presentation, attendees will be able to:

• Summarize the drivers behind the new regulations & legislation for HVAC refrigerants.

• Discuss the actions being taken both globally (via the Kigali Amendment to the Montreal Protocol) & domestically within North America (via Environment and Climate Change Canada, the U.S. EPA and California +++).

• Discuss the science behind why and how HVAC refrigerants are evolving.

• Compare & contrast current & next-generation refrigerant options, in terms of environmental impact, efficiency & safety.

Understand the facts today; plan for tomorrow
Where were we and where are we going?

Discussions on balancing ozone depletion, global warming, emissions, and energy efficiency as all being equally important.

- As stated in 1991 Article for HPAC Magazine.

Balanced approach minimizes overall environmental impact, now includes Atmospheric Life.
Global Consumption of HFCs

Source: UNEP Ozone Secretariat Fact Sheet 2
“Overview of HFC Market Sectors” (Oct 2015)

Markets Using HFCs

Percent of Tons of CO₂

- RACHP: 86%
- Foam: 4%
- Aerosols: 3%
- Fire Protection: 0.0%
- Solvents: 7%

Source: UNEP Ozone Secretariat Fact Sheet 2
“Overview of HFC Market Sectors” (Oct 2015)

<table>
<thead>
<tr>
<th>Market</th>
<th>Key HFCs</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RACHP</td>
<td>R-404A, R-410A,</td>
<td>3922</td>
</tr>
<tr>
<td></td>
<td>R-407C, HFC-134a</td>
<td>1774</td>
</tr>
<tr>
<td>Foam</td>
<td>HFC-134a, HFC-152a, HFC-227ea</td>
<td>1430</td>
</tr>
<tr>
<td>Aerosols</td>
<td>HFC-134a, HFC-152a, HFC-227ea</td>
<td>124</td>
</tr>
<tr>
<td>Foams</td>
<td>HFC-134a, HFC-245fa, HFC-365mfc / HFC-227ea</td>
<td>1430</td>
</tr>
<tr>
<td>Fire protection</td>
<td>HFC-227ea, HFC-125, HFC-23</td>
<td>3220</td>
</tr>
<tr>
<td>Solvents</td>
<td>HFC-431mee</td>
<td>1640</td>
</tr>
</tbody>
</table>

FACT SHEET 2
Overview of HFC Market Sectors

1. Introduction
This Fact Sheet provides a brief overview of the market sectors that use HFCs. Each market sector is discussed in more detail in Fact Sheets 3 to 14.

- R-134a
- R-125
- R-32
- R-143a
- R-152a
- Other HFCs

Total Metric Tons

- R-134a: 40%
- R-125: 25%
- R-32: 13%
- R-143a: 9%
- R-152a: 6%
- Other HFCs: 7%

Other

- R-410A

Total Metric Tons

79%

12%

7%

2%

0.3%

Other HFCs

- RACHP
- Foam
- Aerosols
- Fire Protection
- Solvents
Global HFC Use of Refrigerants in RACHP

Refrigeration, Air-Conditioning, Heat Pump

Source: UNEP Ozone Secretariat Fact Sheet 2
“Overview of HFC Market Sectors” (Oct 2015)
The Next Refrigerant Transition Begins

The Kigali Amendment provides a global template to phase down the use of HFCs in an orderly fashion.
United Nations Environment Programme (UNEP)

Climate Change Regulations
- Kyoto Protocol (1997)
- Paris Accord (2016)

Ozone Depletion Regulations
- Kigali Agreement (2016)

HFC management moved from Climate to Ozone

Focuses on reduction of waste byproduct emissions of chemicals such as CO₂ and methane

Focuses on reduction of engineered fluorocarbons such as CFCs, HCFCs and HFCs

Understanding the differences helps clarify roles of each
Kigali Amendment to the Montreal Protocol

Key Dates
2024 – A2 40% (69% in EU) and A5 freeze (not ME/India)
2029 – A2 70% (76% in EU) and A5 10% (not ME/India)
2035 – A2 80% and A5 30% (not ME/India)

Globally ratified - begins 2019
As of Oct, 2019, ratified by 87 countries (Includes Australia, Canada, Germany and UK)
~85% reduction by 2036 / 2047
U.S. provides ~20% of funding

Cap-and-phase-down of HFCs starting in 2019 for developed nations
United States Future
Direction not clear; plans evolving

• Compliance with Kigali is expected.
  - International trade regulations dictate compliance

• HFCs will be phased-DOWN.
  - Timing is clear; process is not

• A federal standard is desirable.
  - State-by-state is the alternative
  - California (CARB*) passed HFC legislation
  - Other states (NY, NJ, VT, CT, MD, DE, WA + others) have followed or looking to follow California

• Federal action in the works.
  - Legislation that directs EPA to regulate in accordance with Kigali
  - Kigali ratification being considered

*California Air Resources Board

The future is known... the how and when is unclear

“The United States believes the Kigali Amendment represents a pragmatic and balanced approach to phasing down the production and consumption of HFCs, and therefore we support the goals and approach of the Amendment.

There are a number of steps in our domestic process that we would need to complete before reaching a final decision on transmittal of the Kigali Amendment to the U.S. Senate for its advice and consent.

There is no timeline currently determined for these steps, but we have initiated the process to consider U.S. ratification of the Amendment.

We have enjoyed working with all of you for the past 30 years and look forward to continuing our cooperation. We have much work ahead of us, but we can rely on a strong foundation built by decades of Ozone Heroes. We can, and will, continue that incredible legacy”

Industry Support for Accelerated Phase-DOWN
NRDC & Industry Letter to CARB – September 2018

We support policies to limit use of HFCs in air conditioning technologies provided they include the following. CARB should:

- Implement California Senate Bill 1013 limits on HFCs in air conditioning technologies, namely the bans on certain refrigerants in building chillers in 2024.
- Adopt an additional regulation prohibiting refrigerants with a global warming potential (GWP) in excess of 750 in all new air conditioners of all other types and capacities, excluding those covered by SB 1013, starting January 1, 2023. Implement this prohibition based on the date of manufacture, with a sell-through period of six (6) months.
- Allow the distribution of products from California to other states in which they are legal for sale in cases in which California’s regulations differ from those of other states.

Industry Support Continues to Gain Momentum in HFC Phase-down

750
California Air Resources Board (CARB)

CARB takes the lead on transitioning away from high GWP HFCs

October 2019

California votes to restrict HFC use

• CA adopted U.S. EPA SNAP 20 and 21 rules
  - Chillers transition from R134a/R407A/R410A by January 1, 2024

• CA proposing additional regulations:
  - Proposed < 750 GWP limit for new chillers in 2024
  - Proposed < 750 GWP limit for new unitary/VRF/residential in 2023

Other states are following California:
New York, New Jersey, Washington, Maryland, Delaware, Connecticut, Vermont...
Other Countries Taking Action

Canada

Restrictions:
- Industrial Refrigeration:
  \textit{Phase-out of GWP > 2200 by 2020}
- Transport Refrigeration:
  \textit{Phase-out of GWP > 2200 by 2025}
- HVAC Chillers:
  \textit{Phase-out of GWP > 750 by 2025}

Japan

Restrictions:
- Mini-Splits:
  \textit{Phase-out of GWP >750 by 2018}
- Commercial Split (not VRF):
  \textit{Phase-out of GWP >750 by 2020}

European Union

- Few product bans in place
  \textit{Phase-out of GWP > 750 by 2025 (mini-splits)}
- Aggressive allocation restrictions for HFCs
- Refrigerant price driving transition rather than product bans
## Canada Taking Action

<table>
<thead>
<tr>
<th>Product</th>
<th>GWP of refrigerant in product</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand-alone medium-temperature refrigeration system</td>
<td>1,400</td>
<td>Jan. 1, 2020</td>
</tr>
<tr>
<td>Stand-alone low-temperature refrigeration system</td>
<td>1,500</td>
<td>Jan. 1, 2020</td>
</tr>
<tr>
<td>Centralized refrigeration system</td>
<td>2,200</td>
<td>Jan. 1, 2020</td>
</tr>
<tr>
<td>Condensing unit</td>
<td>2,200</td>
<td>Jan. 1, 2020</td>
</tr>
<tr>
<td>Chillers</td>
<td>750</td>
<td>Jan. 1, 2025</td>
</tr>
<tr>
<td>Mobile refrigeration system</td>
<td>2,200</td>
<td>Jan. 1, 2025</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Reduction from Baseline (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>10</td>
</tr>
<tr>
<td>2024</td>
<td>40</td>
</tr>
<tr>
<td>2030</td>
<td>70</td>
</tr>
<tr>
<td>2034</td>
<td>80</td>
</tr>
<tr>
<td>2036</td>
<td>85</td>
</tr>
</tbody>
</table>
HVAC Industry Investigation & Action

Next-generation refrigerants bring more variables

Some next-generation refrigerants offer new challenges

2010 ASHRAE 34
new class “2L,” defined as:
“Difficult to Ignite & Sustain”

http://www.ahrinet.org/arep.aspx
High Pressure Option Evolution

HCFC → HFC → Low GWP

R-22 → R-410A → R-407C → R-410A → R-407C → R-410A

Glide/Eff

Flammable

Driving Factors
- Performance
- Safety
- Cost

Next transition with high pressure refrigerants offers challenges & trade-offs
### Next-Generation Comparative

#### Low Pressure

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-11</td>
<td>9.10</td>
</tr>
<tr>
<td>R-123</td>
<td>8.95</td>
</tr>
<tr>
<td>R-1233zd</td>
<td>8.85</td>
</tr>
<tr>
<td>R-514A</td>
<td>8.91</td>
</tr>
</tbody>
</table>

#### Medium Pressure

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-12</td>
<td>8.58</td>
</tr>
<tr>
<td>R-134a</td>
<td>8.47</td>
</tr>
<tr>
<td>R-513A</td>
<td>8.28</td>
</tr>
</tbody>
</table>

#### High Pressure

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>BV 3.0</th>
<th>BV 3.3</th>
<th>BV 6.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-22</td>
<td>8.14</td>
<td>8.14</td>
<td>8.15</td>
</tr>
<tr>
<td>R-410A</td>
<td>8.14</td>
<td>8.14</td>
<td>8.22</td>
</tr>
<tr>
<td>R-466A</td>
<td>8.14</td>
<td>8.14</td>
<td>8.15</td>
</tr>
<tr>
<td>R-452B</td>
<td></td>
<td>8.15</td>
<td>8.15</td>
</tr>
<tr>
<td>R-454B</td>
<td></td>
<td>8.15</td>
<td>8.15</td>
</tr>
<tr>
<td>R-32</td>
<td></td>
<td></td>
<td>8.22</td>
</tr>
</tbody>
</table>

---

**Industry choices offer options & trade-offs; New options evolving**
Industry choices offer options & trade-offs; New options evolving

Next-Generation Comparative

Low Pressure
- R-11: 9.10
- R-123: 8.95
- R-123zd: 8.85
- R-514A: 8.91

Medium Pressure
- R-12: 8.58
- R-134a: 8.47
- R-513A: 8.28

High Pressure
- R-22: 8.48
- R-410A: 7.99
- R-466A: 8.14
- R-452B: 8.14
- R-454B: 8.15
- R-32: 8.22

Refrigerant Efficiency (COP)
- All variables held constant for comparison

Global Warming Potential (GWP: CO₂ = 1.0)
- Low Pressure: 4,660, 79, 1, 1.75
- Medium Pressure: 10,200, 1430, 573
- High Pressure: 1,810, 1,924, 703, 675, 461, 677

Global Warming Potential (GWP)
- Past: 500, 1000, 1500, 2000, 2500
- Transitional: 2L, 3.3, 6.7
- Lower GWP: 2L, 2L, 2L
## Choices & Comparison

Screw & Centrifugal Technology Options

<table>
<thead>
<tr>
<th></th>
<th>Low Pressure</th>
<th>Medium Pressure</th>
<th>Ice Rinks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refrigerant</strong></td>
<td>R-123</td>
<td>R-1233zd</td>
<td>R-513A</td>
</tr>
<tr>
<td><strong>Flammability</strong></td>
<td>Non (1)</td>
<td>Non (1)</td>
<td>Non (1)</td>
</tr>
<tr>
<td><strong>Toxicity</strong></td>
<td>Higher (B)</td>
<td>Lower (A)</td>
<td>Lower (A)</td>
</tr>
<tr>
<td><strong>Fluid Efficiency</strong></td>
<td>9.4 COP</td>
<td>9.3 COP</td>
<td>8.5 COP</td>
</tr>
<tr>
<td><strong>Capacity Change</strong></td>
<td>1</td>
<td>35% Gain</td>
<td>1</td>
</tr>
<tr>
<td><strong>GWP</strong></td>
<td>79</td>
<td>1</td>
<td>1300</td>
</tr>
</tbody>
</table>

*Chiller efficiency impacted by refrigerant choice – growing customer options*
Availability of Phased-DOWN Refrigerants?

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.

Adequate quantities of HCFC refrigerants can be supplied for the economic life of equipment by recycling and stockpiling.

From the EPA website:

May I use recovered HCFC refrigerants?

Yes, technicians have a few options when using recovered refrigerants. First, a technician may recover material from an owner's equipment and recharge equipment belonging to that same owner, with the recovered material. The technician can also recycle the recovered refrigerant, which involves extracting it and cleaning it for reuse without meeting the requirements for reclamation. This recovered, recycled refrigerant may only be recharged into equipment belonging to the owner of the equipment from which the refrigerant was recovered. Lastly, the technician may send the recovered material to an EPA certified reclaimer; once the refrigerant is reclaimed, it may be sold and used for servicing any existing equipment.
How Can I Protect My Investment?

*Total cost of ownership encompasses total carbon footprint*

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>“First Cost” (chiller + refrigerant)</td>
<td>4.92%</td>
</tr>
<tr>
<td>Lifetime Service Costs*</td>
<td>6.53%</td>
</tr>
<tr>
<td>Lifetime Refrigerant Supply*</td>
<td>0.04%</td>
</tr>
<tr>
<td>Lifetime Electrical Costs</td>
<td>88.51%</td>
</tr>
</tbody>
</table>

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

Focus on reliable, efficient designs!

And let the manufacturer worry about the refrigerant!

30 Year Investment

*Based on low-pressure, hermetic design*

A balanced approach, with a focus on efficiency
What Actions Should I Take?

- There are no perfect refrigerants.
- Take a balanced approach: *Safety, Efficiency, Environmental Impact*
- Leak tightness and low-charge, closed circuit(s) are key!
- Next-generation alternatives are available today for some products (larger applied products, ice rink refrigeration…)
- Only non-flammable refrigerants offer immediate chiller solutions.
- Unitary and residential applications must wait to transition until the updated standards and codes are adopted by authorities

Use the facts to plan for tomorrow
Thank you for your time and attention!