Effectively Managing the Transition to Lower GWP Refrigerants

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Big Changes Are Coming

- **High GWP Refrigerants will be phased down on a global scale**

- **Drivers:**
  - Montreal Protocol Amendment
  - U.S. EPA SNAP Program / Climate Action Plan
  - F-gas regulations in Europe
  - California HFC proposals

- **The good news:**
  
  Our industry will be prepared
## Refrigerant Transition

<table>
<thead>
<tr>
<th></th>
<th>CFCs (1930s-1990s)</th>
<th>HCFCs (1950s-2010s)</th>
<th>HFCs (1990s +)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SO₂·NH₃</strong></td>
<td>1920s</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>high chlorine</strong></td>
<td>strong ozone depletion</td>
<td>lower chlorine</td>
<td>no chlorine</td>
</tr>
<tr>
<td><strong>1974 – Molina-Rowland theory</strong></td>
<td></td>
<td><strong>2010 - phase-out of HCFC-22 from new equipment</strong></td>
<td></td>
</tr>
<tr>
<td><strong>1987 – Montreal Protocol</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1990 – CAA amendments</strong></td>
<td>1996 – total phase-out of CFCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1996 – total phase-out of CFCs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2010 – F-Gas Europe</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2015 – EPA SNAP</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>2016 – Montreal Protocol</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>2016 – CARB</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2016 – ECCC Canada</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
European F-Gas Regulations: Phase-down steps

<table>
<thead>
<tr>
<th>Year</th>
<th>Reduction by</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>100% (Freeze)</td>
</tr>
<tr>
<td>2016-17</td>
<td>93%</td>
</tr>
<tr>
<td>2018-20</td>
<td>63%</td>
</tr>
<tr>
<td>2021-23</td>
<td>45%</td>
</tr>
<tr>
<td>2024-26</td>
<td>31%</td>
</tr>
<tr>
<td>2027-29</td>
<td>24%</td>
</tr>
<tr>
<td>2030</td>
<td>21%</td>
</tr>
</tbody>
</table>
## F-Gas Regulations - GWP limits

<table>
<thead>
<tr>
<th>Year</th>
<th>GWP Limit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>2500</td>
<td>Hermetically sealed systems (Refrigerators and Freezers)</td>
</tr>
<tr>
<td>2020/2022</td>
<td>2500 and 150</td>
<td>Stationary refrigeration equipment</td>
</tr>
<tr>
<td>2022</td>
<td>150 and 1500</td>
<td>Large commercial refrigeration systems</td>
</tr>
<tr>
<td>2020</td>
<td>150</td>
<td>Movable room a/c appliances</td>
</tr>
<tr>
<td>2025</td>
<td>750</td>
<td>Small split a/c systems</td>
</tr>
</tbody>
</table>

### 11. Refrigerators and freezers for commercial use (hermetically sealed systems)
- That contain HFCs with GWP of 2500 or more
  - 1 January 2020
- That contain HFCs with GWP of 150 or more
  - 1 January 2022

### 11a. Stationary refrigeration equipment, that contains, or that relies upon for its functioning HFCs with GWP of 2500 or more except equipment intended for application designed to cool products to temperatures below -50°C
- 1 January 2020

### 11b. Multipack centralised refrigeration systems for commercial use with a capacity of 40kW or more that contain, or that rely upon for their functioning, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1500 may be used
- 1 January 2022

### 12. Movable room air-conditioning appliances (hermetically sealed equipment which is movable between rooms by the end user) that contain HFCs with GWP of 150 or more
- 1 January 2020

### 12a. Single split air-conditioning systems containing less than 3kg of fluorinated greenhouse gases, that contain, or that rely upon for their functioning, fluorinated greenhouse gases with GWP of 750 or more
- 1 January 2025
U.S. Regulatory Activities on HFCs – EPA SNAP

- **President Obama’s Climate Action Plan**
  - EPA to use SNAP program to encourage use of climate friendly alternatives

- **Several rules finalized in 2015 and 2016**

- **New refrigerants were added as “acceptable” substitutes**
  - Highly flammable refrigerants (i.e. propane) subject to use conditions

- **Listing status of several high GWP refrigerants was changed to “unacceptable”**
## EPA SNAP 2015 Final Rule – Commercial Refrigeration
### Phase-Out Candidates and Dates

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MT &lt;2,200 BTU/hr. and not contain flooded evap. New</td>
</tr>
<tr>
<td>R-410A</td>
<td>OK</td>
<td>-</td>
<td>OK</td>
<td>-</td>
<td>Jan 1, 2019</td>
</tr>
<tr>
<td>R-407A/C/F</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Jan 1, 2019</td>
</tr>
<tr>
<td>HFC-134a</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Jan 1, 2019</td>
</tr>
</tbody>
</table>

- Refer to Tables 4, 5 and 6 of Final Rule for complete details
- Source: Rajan Rajendran Emerson

**EPA HFC Restrictions – September 2016**

<table>
<thead>
<tr>
<th>Phase out Refrigerant</th>
<th>Chillers (new)</th>
<th>Cold Storage Warehouse (new)</th>
<th>Retail Food Refrigeration – Food Processing &amp; Dispensing (new)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-134a</td>
<td>Jan 1, 2024</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>R-404A</td>
<td>Jan 1, 2024</td>
<td>Jan 1, 2023</td>
<td>Jan 1, 2021</td>
</tr>
<tr>
<td>R-407 A&amp;B</td>
<td>-</td>
<td>Jan 1, 2023</td>
<td>Jan 1, 2021</td>
</tr>
<tr>
<td>R-407C</td>
<td>Jan 1, 2024</td>
<td>-</td>
<td>Jan 1, 2021</td>
</tr>
<tr>
<td>R-410A</td>
<td>Jan 1, 2024</td>
<td>Jan 1, 2023</td>
<td>Jan 1, 2021</td>
</tr>
<tr>
<td>R-507A</td>
<td>Jan 1, 2024</td>
<td>Jan 1, 2023</td>
<td>Jan 1, 2021</td>
</tr>
</tbody>
</table>
Regulatory Outlook - California Short-Lived Climate Reduction Strategy

- **Proposed to reduce HFC emissions by 40% by 2030**
  - First published in April 2016
  - Approved in March 2017

- **Strategy:**
  - Includes incentive programs to defray cost of low-GWP technologies
  - Stresses importance of energy efficiency for low-GWP refrigerants
  - Proposes ban on sale of high GWP refrigerants ≥ 2,500 and

<table>
<thead>
<tr>
<th>Stationary Refrigeration or Stationary Air-Conditioning Sector</th>
<th>Refrigerants Prohibited in New Equipment with a 100-year GWP Value:</th>
<th>Proposed Start Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-residential refrigeration</td>
<td>150 or greater</td>
<td>CARB to further evaluate</td>
</tr>
<tr>
<td>Air-conditioning (non-residential and residential)</td>
<td>750 or greater</td>
<td>CARB to further evaluate</td>
</tr>
</tbody>
</table>

- **California-specific HFC phasedown not necessary**
- **Regulation expected to start in late 2017/early 2018**
Agreement on HFC phase down reached in Kigali, Rwanda

- Reduces greenhouse gas emissions by 70 Gigatons CO$_2$e by 2050
- Separate baselines and reduction schedules for A2 and A5 countries
- Will be guided by a technology and economic review process every 5 years
- Provides financial assistance to developing countries
- Will go into effect in 2019
- Needs ratification by U.S. Congress
## Phase Down Schedule

<table>
<thead>
<tr>
<th></th>
<th>A5 Group 1</th>
<th>A5 Group 2</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>2020-2022</td>
<td>2024-2026</td>
<td>2011-2013</td>
</tr>
<tr>
<td><strong>Formula</strong></td>
<td>Average HFC consumption</td>
<td>Average HFC consumption</td>
<td>Average HFC consumption</td>
</tr>
<tr>
<td><strong>HCFC</strong></td>
<td>65% baseline</td>
<td>65% baseline</td>
<td>15% baseline*</td>
</tr>
<tr>
<td><strong>Freeze</strong></td>
<td>2024</td>
<td>2028</td>
<td>-</td>
</tr>
<tr>
<td><strong>1st step</strong></td>
<td>2029 – 10%</td>
<td>2032 – 10%</td>
<td>2019 – 10%</td>
</tr>
<tr>
<td><strong>2nd step</strong></td>
<td>2035 – 30%</td>
<td>2037 – 20%</td>
<td>2024 – 40%</td>
</tr>
<tr>
<td><strong>3rd step</strong></td>
<td>2040 – 50%</td>
<td>2042 – 30%</td>
<td>2029 – 70%</td>
</tr>
<tr>
<td><strong>4th step</strong></td>
<td></td>
<td>2034 – 80%</td>
<td></td>
</tr>
<tr>
<td><strong>Plateau</strong></td>
<td>2045 – 80%</td>
<td>2047 – 85%</td>
<td>2036 – 85%</td>
</tr>
</tbody>
</table>

* For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025

**Notes:**

1. Group 1: Article 5 parties not part of Group 2
2. Group 2: GCC, India, Iran, Iraq, Pakistan
3. Technology review in 2022 and every 5 years
4. Technology review 4-5 years before 2028 to consider the compliance deferral of 2 years from the freeze of 2028 of Article 5 Group 2 to address growth in relevant sectors above certain threshold.
Low-GWP AREP

- Cooperative research & testing program to identify suitable alternatives to high GWP refrigerants
- Evaluation of candidates strongly desired by OEMs
- The program is NOT to prioritize refrigerants, rather test and present objective results in a consistent manner
- Phase I was completed at the end of 2013.
  - 38 refrigerants were evaluated in Phase I
  - AHRI published 40 test reports
- Phase II started in 2014, testing concluded in Dec.2015
  - 17 new refrigerants, high ambient testing
  - 34 additional reports were published
- Final reports available to the public
Low-GWP AREP

- Viable low GWP alternatives exist
- Many promising refrigerants are classified 2L under ASHRAE 34 (mildly flammable)
- ASHRAE 15 does not currently differentiate between 2 and 2L refrigerants
- IEC 60335-2-40 does not currently have requirements for 2L refrigerants
### Refrigerant Safety Classification

<table>
<thead>
<tr>
<th>Flammability</th>
<th>Increasing Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher</td>
<td>A3</td>
</tr>
<tr>
<td>Lower</td>
<td>A2L*</td>
</tr>
<tr>
<td>No Flame Propagation</td>
<td>A1</td>
</tr>
<tr>
<td>Lower Flammability</td>
<td>B2</td>
</tr>
<tr>
<td></td>
<td>B2L*</td>
</tr>
<tr>
<td></td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td>B1</td>
</tr>
<tr>
<td></td>
<td>Lower Toxicity</td>
</tr>
<tr>
<td></td>
<td>Higher Toxicity</td>
</tr>
</tbody>
</table>

* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤10 cm/s (3.9 in./s).

A2L safety group classification used by several refrigerant designation standards:
- ASHRAE Standard 34
- ISO 817

**Figure 1** Refrigerant safety group classification. from: ASHRAE Standard 34-2010
Industry is Moving Forward

- **OEMs starting to select alternatives**
  - Commercial refrigeration: HCs, CO₂, Cascade systems
  - Chillers: HFO 1233zd(E), HFO-1234ze(E)
  - Unitary: R32, R-452B (DR55)

- **OEMs are developing components and equipment**

- **However, regulatory and safety barriers must be adapted to allow the safe use of equipment using 2L and 3 refrigerants**
ASHRAE Standard 15 Recent Activities

- Proposed requirements on equipment using 2L refrigerants
  - Addendum d
    - Addresses “high-probability systems” in applications for human comfort
    - 2nd Public Review completed
  - Addendum h
    - Addresses machinery room applications
    - 1st Public Review completed
  - More addenda are expected later
    - Will address applications for “industrial occupancies and refrigerated rooms”

- Re-write – Change in document structure and organization
- Completion expected early in 2018
ASHRAE 15.2: Safety Standard for Air conditioning and Heat Pump Systems in Residential Applications

- Proposed equipment coverage:
  - split system AC&HPs and single package AC&HPs
  - whole house dehumidifiers, whole house dehumidifiers/ventilators, and
  - permanently connected heat pump water heaters

- Advisory Publication Review (APR) - June 2017
- Plan Two Publication Public Reviews (PPR) in 2017
- Standard to be approved in early 2018
### State of Standards and Codes – Global View

- Increasing charge limits for flammables is global trend
- Expect safety standards in 2017/2018; codes follow standards

#### Refrigerant Classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Usage Restriction</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigerant Designation &amp; Safety Classification UL2182</td>
<td></td>
<td>UL471 Commercial Refrigerators and Freezers 2015-2019</td>
</tr>
<tr>
<td>ISO850-24</td>
<td></td>
<td>IEC60335-2-24 Refrigerating appliances Ice and Ice Cream Makers 2015-2019</td>
</tr>
</tbody>
</table>

**Source:** Rajan Rajendran - Emerson
Code Adoption Process of New Refrigerants

- Code adoption process is slow
  - Proper safety classification (ASHRAE 34)
  - EPA SNAP approval
  - Meet relevant safety standards
  - Meet relevant building codes

Safety Codes must be modified to ease restrictions on use of 2L and 3 refrigerants

ASHRAE Standard 34
Designation and Safety Classification

EPA SNAP Approval
Significant New Alternatives Policy Program

Safety Standards
- Refrigeration Systems: ASHRAE Standard 15
- Equipment: relevant UL/EN/ISO Standards

In compliance with

Adopted by

Model Building Codes
State and Local Codes

2016
2018
2021
2022+
AHRI Flammable Refrigerants Subcommittee (FRS)

- Surveyed relevant codes and standards committees and organizations on:
  - The main knowledge gaps for the use of flammable refrigerants
  - Any standing issues and gaps that require additional research
  - Current and past research activities on flammable refrigerants

- Seven high priority projects and one long term project were identified

- Objective:
  - Produce publicly available technical results to support code and standard activities related to the use of flammable refrigerants
  - Ensure a timely update of relevant safety standards and building codes
Responsibility for high priority projects

- **AHRI Conducting ($1.0 million) – (CARB $0.3 million):**
  - AHRTI-9007: Benchmarking Risk by Real Life Leaks and Ignitions Testing
  - AHRTI-9008: Investigation of Hot surface Ignition Temperature (HSIT) for A2L Refrigerants
  - AHRTI-9009: Leak Detection of A2L Refrigerants in HVACR Equipment

- **ASHRAE conducting ($1.2 million):**
  - ASHRAE-1806: Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update
  - ASHRAE-1807: Guidelines for Flammable Refrigerant Handling, Transporting, Storing and Equipment Servicing, Installation and Dismantling
  - ASHRAE-1808: Servicing and Installing Equipment using Flammable Refrigerants: Assessment of Field-made Mechanical Joints

- **DOE funding ($3.0 million):**
  - ORNL: Investigate the proper basis for setting charge limits of A2L, A2, and A3 for various types of products
  - NIST: Modeling tools for low-GWP refrigerant blends flammability
Future Work on Flammable Refrigerants

- A3 Refrigerants - $0.3 Million funding from CARB
- Characterize refrigerant leak scenarios with actual equipment in “on” and “off” states
- Real world ignition sources
  - Ignition energy
  - Quantity
  - Spatial location throughout the room
  - Activation frequency
Education and Training

- Education and training is critically important
  - Most lower-GWP alternatives are either flammable or mildly flammable

- There are serious potential safety and efficiency issues with improper installation and maintenance

- The whole purpose of phasing down HFCs is environmental protection

- But, in addition to direct emission of the refrigerants, improper installation and lack of maintenance can result in a

30 percent loss of efficiency
Education and Training

- **Global Refrigerant Management Initiative**
  - Launched in September 2014 by AHRI, the Alliance for Responsible Atmospheric Policy, and ABRAVA (Brazil)
  - Promotes recycling, recovery, reclaiming and end of life destruction of refrigerants

- **Participation by Trade associations in Australia, Canada, China, Colombia, the EU, Japan, Mexico, and Korea**

- **UNEP-AHRI Refrigerant Driver’s License**
  - Aims to ensure safe management of refrigerants, especially in Article 5 nations
  - Creates a global network to support safe handling
  - Develop best practices
  - Develop training and certification for technicians on proper management, servicing, and end-of-life practices
Thank you for your attention!