New Refrigerants Designation and Safety Classifications

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Agenda

• Overview of regulations driving refrigerant changes
• What is a Class 2L “mildly flammable” refrigerant?
• Industry work to better understand flammability and system design implications
• Where do we go from here as an industry?
Environmental Considerations Driving Regulations

**Ozone Depletion**  
“ODP”

**Relevant Regulation:**
- Montreal Protocol — global agreement for **phase-out** of chlorine-containing gases (CFCs and HCFCs)

**Climate Change**  
“GWP”

**Relevant Existing Regulations:**
- Montreal Protocol Amendment (Kigali Agreement) — global agreement for **phase-down** of HFCs
- U.S.: EPA SNAP program
- EU: F gas II
- Japan: METI material conversion GWP limits
- Other countries: in development/TBD based on amendment implementation timing applicable for that country
Selection of Refrigerants for the Future Will Need to Balance Performance (Capacity and Efficiency), Safety and Sustainability, and Total Cost of System Ownership.
How HFOs Work

Weaker double bond in HFOs allows for short atmospheric life, while maintaining stability in systems.
R-1234yf: HFO Molecule

- Same operating conditions as R-134a (similar P/T curve)
- Thermally stable
- Capacity and efficiency similar to R-134a
- **Mildly flammable (A2L)**
- Used as blend component with other refrigerants to lower GWP
  - Depending on the composition and percentage of 2L material, resulting blends are classified as either A1 (non-flammable) or A2L (mildly flammable).

<table>
<thead>
<tr>
<th></th>
<th>R-134a</th>
<th>HFO-1234yf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>CH₂FCF₃</td>
<td>CF₃CF₂CH₂</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>102</td>
<td>114</td>
</tr>
<tr>
<td>ODP</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GWP₁₀₀ (AR5)</td>
<td>1,300</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>T Critical Point</td>
<td>102 °C</td>
<td>95 °C</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>-26 °C</td>
<td>-29 °C</td>
</tr>
</tbody>
</table>

![Graph showing pressure vs. temperature for R-134a and HFO-1234yf](image-url)
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ANSI/ASHRAE Flammability Classifications

Class 2L vs. 2 Flammability classification is based on:

**Burning velocity**
- Maximum velocity at which a flame propagates in a normal direction relative to unburned gas ahead of it
- Lower burning velocity
  - \(<10\ \text{cm/s} = 2L\)
- Higher burning velocity
  - \(>10\ \text{cm/s} = 2 \text{ or } 3\)

Class 2 vs. 3 Flammability classification is based on:

**Heat of combustion and lower flammability limit (LFL)**

- Higher Flammability
  - A3
  - B3
- Lower Flammability
  - A2
  - B2
- No Flame Propagation
  - A1
  - B1
- Lower Toxicity
- Higher Toxicity

*\ A2L and B2L are lower flammability refrigerants with a maximum burning velocity of \(\leq 3.9 \text{ in/s} \ (10 \text{ cm/s})\).*
Perspective: Burning Velocity and Minimum Ignition Energy

- **Class 2L**
  - HFO-1234yf
  - Ammonia
  - HFC-32

- **Class 2**
  - HFC-152a

- **Class 3**
  - Propane
Understanding Pressure Rise on Ignition

Watch the ping pong balls for pressure rise

<table>
<thead>
<tr>
<th>t</th>
<th>63 ms</th>
<th>125 msec</th>
<th>250 msec</th>
<th>500 msec</th>
<th>750 msec</th>
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<tbody>
<tr>
<td>Isobutane</td>
<td>Elect. Arc</td>
<td>4 vol%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-152a</td>
<td>Elect. Arc</td>
<td>8 vol%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFO-1234yf</td>
<td>Elect. Arc – no ign</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Lighter – above 4 vol%, no ign</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Elect. Arc + butane → ign</td>
<td></td>
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<tr>
<td></td>
<td>8 vol%, orange flame is butane</td>
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</tbody>
</table>

HFO-1234yf flames can best be characterized as “lazy and unstable” with low energy release.

Reference: B. Hill, MACS January 21, 2010
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The Global Refrigerant Standards and Codes ‘Process’
Revisions to Support 2L, 2 and 3 Refrigerants

<table>
<thead>
<tr>
<th>Refrigerant Standards/Regulations</th>
<th>Safety Standards</th>
<th>Application</th>
<th>Building &amp; Other Codes</th>
<th>Local Codes</th>
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<tbody>
<tr>
<td>(Developed)</td>
<td>UL 471 Commercial Refrigerators &amp; Freezers</td>
<td>ASHRAE 15.2 Safety for Residential Refrigeration Systems</td>
<td>IRC — International Residential Code</td>
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<tr>
<td><strong>ASHRAE 34</strong></td>
<td>UL 621 Ice Cream Makers</td>
<td>DOT Transportation Standards</td>
<td>IBC/EBC — International Building Codes</td>
<td></td>
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<tr>
<td>Designation and Safety Classification of Refrigerants</td>
<td>ASME Section VIII Pressure Vessels</td>
<td><strong>Source:</strong> Richard Lord, UTC Building &amp; Industrial Systems</td>
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<td><strong>EPA SNAP</strong></td>
<td><strong>Revisions to Support 2L, 2 and 3 Refrigerants</strong></td>
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<tr>
<td>Significant New Alternatives Policy Program</td>
<td>IEC 60335-2-40 6th Heating and Cooling Equipment</td>
<td>BS2 (Canada) Safety for Commercial Refrigeration</td>
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<td><strong>U.S. Specific</strong></td>
<td>IEC 60335-2-89 Commercial Refrigerating Appliances</td>
<td><strong>Jan. 2018</strong></td>
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<td>ongoing</td>
<td>IEC 60335-2-24 Refrigerating Appliances, Ice-Cream and Ice Makers</td>
<td><strong>2018–2021</strong></td>
<td></td>
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<tr>
<td><strong>International</strong></td>
<td>Pressure Vessel Standard (PED, JIS, etc.)</td>
<td><strong>2018–2029</strong></td>
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<tr>
<td><strong>Montreal Protocol (GWP)</strong></td>
<td><strong>Country Regulations (i.e., Switzerland, Australia)</strong></td>
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<tr>
<td>(Developed)</td>
<td><strong>Jan. 2018</strong></td>
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<td><strong>ISO-817</strong></td>
<td><strong>2018–2021</strong></td>
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<td>Refrigerants — Designation and Safety Classification</td>
<td><strong>2018–2029</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Source:** Richard Lord, UTC Building & Industrial Systems
Local Code Adoption: Complex and Time Consuming

**Codes Can Vary State to State, County to County and Town to Town**

- Example: Illinois does not have a statewide adoption.
- Every jurisdiction can adopt a mechanical code.
- Codes can change when you cross the border of a town or city.
- Counties can also adopt a mechanical code.

**Local code implementation may take years to accomplish.**

- Work ongoing at industry and local levels with AHJ’s to try to accelerate process to drive adoption of new technology
Revision Status of Key North American HVAC&R Safety Standards

- **UL60335-2-24** (Commercial Refrigerating Appliances — Ice Makers [Non-commercial] And Ice Cream Appliances)
  - 2nd Edition published April, 28, 2017

- **UL60335-2-40** (*Particular Requirements For Electrical Heat Pumps, AC And Dehumidifiers*)
  - Fast pace implementation of A2L requirements taking place. Will likely meet the Jan 8, 2019 publishing deadline so that A2L’s will be in the 2021 Code cycle. Second edition is published and allows A2L’s, but they must comply with ‘A2’ guidelines

- **UL60335-2-89** (Particular Requirements For Commercial Refrigerating Appliances With An Incorporated Or Remote Refrigerant Unit Or Compressor)
  - 1st Edition to be published shortly (Oct. ‘17), WG4

- **ASHRAE Std. 15** (Safety Standards For Refrigeration Systems), Addendum ‘d’ for comfort cooling & Addendum ‘h’ for Machinery Rooms—If substantive comments received, either addendum is at risk to hit Dec 1, 2017 deadline for inclusion in the 2018 codes.
  - Since Std 15 is already listed in the IMC, its deadline is Jan. 7, 2019 and will likely make the 2021 code cycle

- **ASHRAE Std. 15.2** (Safety Standard For Refrigeration Systems In Residential Applications)—Not a formal standard yet.
  - Future Std. 15.2 is not yet listed in the codes, so would have to have a consensus draft by Jan. 8, 2018, to be referenced in the 2021 IMC or IRC. This date is at risk unless 15.2 becomes ‘part of’ Std. 15. APR to go out ~Oct. 2017

Note: For both UL2-40 and Std. 15/15.2, “elements” of the standards may be implemented into the building codes via code ‘amendments’; So stay tuned...

*See Appendix for international standards under revision.*
**Summary Regarding Charge Limits—Now and Proposed**

### Refrigeration

- **UL250** (household refrigerators and freezers)
  - A2 – 225g (8.0 oz)
  - A3 – 50g (1.7 oz)

- **UL471** (commercial refrigerators and freezers, incorporated or remote)
  - A2/A2L – 500g max. (17.7 oz)
  - A3 – 150 g max. (5.3 oz)

- **UL60335-2-89** (particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compress)
  - A2L: 150g now, 1.2 kg being proposed, A3: 150g now, 500 grams being proposed
  - Now, charges larger than 150g, use ISO5149

- **UL60335-2-24** (commercial refrigerating appliances — ice makers and ice cream appliances)
  - The second edition increased flammable refrigerants from 50g to 150g to harmonize the IEC

- **UL1995** (heating and cooling equipment)
  - Refrigeration condensing units use UL471

### Air Conditioning

- **UL1995** (heating and cooling equipment), UL 1995 merging into UL2-40, 2020 new products, 2022 all products.
  - A2/A2L – not allowed
  - A3 – not allowed

- **UL60335-2-40** (particular requirements for electrical heat pumps, air conditioners and dehumidifiers)
  - A2/A2L/A3 — Based on room size calculations and mitigations used
    - UL: 3 kg for A2Ls, 114 grams for A3s
    - IEC is aiming for: ~60–80kg A2Ls and 1 kg A3s

- **UL484** (room air conditioners), merging into UL2-40, 2020 new products, 2022 all products.
  - Based on room size calculations
    - $A_{min} = (M/(2.5 \times (LFL)^{(5/4)} \times h_0))$

**NOTE:**

Flammable refrigerants are only allowed for new equipment, not retrofits, because OEM design modifications will be needed.
Low-GWP Refrigerant Research

- **AHRI Flammability Research Subcommittee (FRS)**
  - Cross-functional team working on several projects related to flammability of low-GWP refrigerants

- **ASHRAE and DOE** sponsoring several studies

- **Other Research Taking Place Through NFPA, AHAM, Japan, China**

**Goal:** To Use Science-Based Information To Fill Gaps In Safety Standards
Key Research Projects

- AHRTI Project No. 9007-01: Benchmarking Risk by Whole Room Scale Leaks and Ignitions Testing of A2L Refrigerants
- AHRTI Project No. 9007-02: Benchmarking Risk by Whole Room Scale Leaks and Ignitions Testing of A3 Refrigerants (only PTAC’s, Mini-splits and Reach-in)
- ASHRAE-1806: Flammable Refrigerants Post-ignition Risk Assessment with A2L’s
- ASHRAE-1807: Guidelines for flammable refrigerant handling, transporting, storing and equipment servicing and installation
- ASHRAE-1808: Servicing and Installing Equipment Using Flammable Refrigerants: Assessment of Field-made Mechanical Joints
- AHRTI Project No. 9009: Leak Detection Sensors for A2L Refrigerants in HVACR Equipment
- DOE Project: Determination of setting charge limits for various types of equipment employing flammable refrigerants; Phase II (CFD study)
- AHRTI Project No. 9008: Investigation of Hot Surface Ignition Temperature for A2L Refrigerants
- NFPA: A3 Risk Assessment and Ignition Severity study
- ASHRAE-1794: Flammable Refrigerant Odorant study may be funded by the Consumer Products Safety Commission instead of ASHRAE; TBD.

AHRI completed research reports are available to the public on the AHRI website:
http://www.ahrinet.org/site/511/Resources/Research/Public-Sector-Research/Technical-Results
Factors Found That Influence the Safe Use of Flammable Refrigerants

- Minimum room size (concentration in whole room must stay well below LFL)
- Lower Flammability Limit (LFL) of the refrigerant; higher is safer
- Lowest height from the floor of a potential leak (higher, safer → more dilution)
- Use of leak detection sensors/alarms (ventilation must start fast; ~10-30 seconds proposed)
- Use of passive or active ventilation (airflow very influential in preventing ignition)
- Minimum ventilation flow rate (related to charge size and LFL); higher, safer
- Maximum ‘releasable charge’ (proposed concept; limit the amount of charge that can leak by using active isolation valves)
- Minimize or eliminate sources of ignition inside the cabinets
- Use of safety factors in most calculations (accommodates unpredictable circumstances)

The Standards Will Combine Many Of The Above Parameters Into Equations Or Tables For The Users
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Work Across Industry to Prepare for Use of Flammable Refrigerants

**Aftermarket servicing/recovery stds**
- Servicing guidelines (*AHRI project[s]*)
- Hand-held leak detectors (*ASHRAE 173, EN 14624*)
- Refrigerant cylinder disposal (*AHRI Guideline Q*)
- Pumps/recovery machines (*UL 1963 SA*)

Status: **In process**

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**Aftermarket service equipment**
- Refrigerant identifiers
- Pumps/recovery machines
- Hand-held leak detectors
- Recovery cylinders (DOT)

Status: **In development**
Work Across Industry to Prepare for Use of Flammable Refrigerants (cont’d.)

• **Storage/warehousing**
  - NFPA 58
    - Std. is currently available; provides guidance on total flammable product storage based on type of facility
    - Std. can be used, but will probably be upgraded to incorporate flammability hazards associated with A2Ls vs. A2/A3 refrigerants

• **Transportation**
  - DOT Class 2.1 flammable
    - Currently, no distinction in terms of refrigerant flammability class; all flammables transport at flammable compressed gases (markings as shown)
    - Left-hand threading on cylinders industry best practice

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**Cylinder Markings**

- **Non-Flammable Compressed Gas**
- **Flammable Compressed Gas**
Safe Servicing of Flammable Refrigerants

• Notes for servicing systems with flammable refrigerants
  – Look for the RED Pantone-colored service connections
  – Look at the unit’s nameplate for the refrigerant and see if it has a flame symbol
    • If the equipment has the features mentioned above, do the following:
      – Review the manual supplied by the manufacturer prior to repair
      – Evacuate/purge/evacuate/purge the system prior to repairing leaks
        » Purging is to be completed with dry nitrogen

• AHRI Guideline N Committee is proposing cylinder color designations for flammables.
• AHRI Guideline M Committee is discussing appropriate fittings for flammables.
Key Take-Away Messages

- A significant reduction in GWP can be achieved with non-flammable HFO blends, which provide solutions for system retrofits and new equipment with large charge sizes.

- As the industry drives toward the use of ultra-low GWP refrigerants, many solutions will necessitate a transition to Class 2L, 2 or 3 flammable solutions in certain applications.

- Industry organizations are currently studying appropriate charge size limits and safety criteria for Class 2L and Class 3 refrigerants. Updates to relevant codes and standards are expected over the next two years.

- Flammable or mildly flammable refrigerants will only be allowed for new systems; retrofit solutions will need to be non-flammable.

- Standards revision dates and content are still under development, so the information provided herein is a snapshot in time.

- New systems will be safe, but could possibly be more costly and complex due to mitigating equipment (sensors...)

- Across all of the studies, there is significant focus on ensuring the safety of all involved in manufacturing, transporting, servicing and operating HVACR equipment.
Questions?

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Appendix
## Charge Limit Detail — International Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Title</th>
<th>Current Max Charge Limits</th>
<th>Current or Proposed Factors That Will Dictate Allowable Charge Size</th>
<th>Speculated Future Max Charge Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 60335-2-40</td>
<td>Particular requirements for electrical heat pumps, AC and dehumidifiers</td>
<td>A2L: 150 grams A3: 150 grams</td>
<td>Min room size, LFL, lowest release height, max. releasable charge, leak detection sensors, ventilation</td>
<td>A2L: ~80 kg A3: 1 kg (but mitigation will allow smaller rooms)</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>IEC 60335-2-89</td>
<td>Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor</td>
<td>A2L: 150 grams A3: 150 grams</td>
<td>Min. room size, LFL, leak detection sensors, fan circulation</td>
<td>A2L: ~1.2 kg A3: ~0.5 kg</td>
</tr>
<tr>
<td>ISO 5149 and EN378</td>
<td>Refrigerating systems and heat pumps — Safety and environmental req’ts.</td>
<td>A2L: (see next column) A3: (see next column)</td>
<td>Varies by access category and location classification, e.g., indoor with unlimited access (refrigeration uses a different formula than human comfort), maximum: A2L: 39 x LFL (or 195 x LFL for systems with more than four evaporators), A3: 1.5 kg in EN378, ~1 kg in ISO5149</td>
<td>A2L: ~60–80 kg A3: no change</td>
</tr>
</tbody>
</table>
International Safety Standards Under Revision

- **BS EN 378** (refrigerating systems and heat pumps — safety and environmental requirements)
  - BS EN 378 was revised to bring it into alignment with ISO5149, the international safety standard. This included the introduction of an additional flammability class, 2L, to the method of charge calculation based on refrigerant classification and the addition of two new alternative methods of charge calculation. Most of this is detailed in Part 1 of the standard. In Part 2, flowcharts used for determination of protective device requirements have changed. Part 3 includes changes to the requirements for machinery rooms. Changes to Part 4 are less significant. Several informative annexes have been introduced to cover stress corrosion cracking, leak simulation, commissioning and ignition sources (Part 2), and special provisions for handling ammonia vapor during maintenance or decommissioning (Part 4, within the existing Annex C). ISO 5149
  - To be published in the near future

- **IEC 60335-2-89** (particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor)
  - Currently, this standard is under standard continuing maintenance cycle
  - The work Group 4 is working on charge limits for A2/A2L/A3 refrigerants (awaiting results of the NFPA research)
  - All flammable refrigerants 150g (5.3 oz)
  - Charges larger than 150g, use ISO5149