The Path to Greener HVAC Refrigerants

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Northeast Sustainable Energy Association (NESEA)
September 15, 2022
The Path to Greener HVAC Refrigerants

- Ozone Depletion Potential
- Global Warming Potential
- Energy Efficiency
Industry Standard Refrigerants
1902 - 1928

Ammonia

Sulfur Dioxide

Methyl Chloride
1928

"FREON"

By

Doctor Thomas Midgley, Jr.
Chlorofluorocarbon (CFC)

Chlorine

Fluorine

Carbon
Chlorofluorocarbon (CFC)

CCl₂F₂
Dichlorodifluoromethane
R-12
Chlorofluorocarbon (CFC)

CCl₃F
Trichlorofluoromethane
R-11
Chlorofluorocarbons (CFCs)
1928 - 1996

R-12

R-11
1984

The Ozone Hole

Joseph Farman  Brian Gardiner  Jonathan Shanklin
CFCs Destroy Ozone

R-11

Ozone

Cl
Cl
C
F
Cl

O
O
O
CFCs Destroy Ozone
1987

Montreal Protocol
Chlorofluorocarbon (CFC)

R-11

ODP: 1

No New Production: 1996
Chlorofluorocarbon (CFC)

- C
- Cl
- F
- R-12
- ODP: 1
- No New Production: 1996
HydroChlorofluorocarbon (HCFC)

R-22
ODP: 0.05
No New Equipment: 2010
No New Production: 2020
HydroChlorofluorocarbon (HCFC)

- **R-123**
  - ODP: 0.02
  - No New Equipment: 2020
  - No New Production: 2030
Hydrofluorocarbon (HFC)

R-134a
ODP: 0
GWP: 1,300
Hydrofluorocarbon (HFC) Blend

R-410A

ODP: 0

GWP: 1,924

50% R-32

50% R-125
The Kigali Amendment to the Montreal Protocol

Global HFC Phase-down

- European Union
- A2 Developed Countries
- A5 Developing Countries – Group 1
- A5 Developing Countries – Group 2
AIM Act to phase down HFC production 85% over 15 years
Low Pressure Refrigerants – Easy to replace

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Type</th>
<th>Refrigerant</th>
<th>Toxicity</th>
<th>Flammability</th>
<th>ODP</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>CFC</td>
<td>R-11</td>
<td>A</td>
<td>1</td>
<td>1</td>
<td>4,660</td>
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<tr>
<td></td>
<td>HCFC</td>
<td>R-123</td>
<td>B</td>
<td>1</td>
<td>0.01</td>
<td>79</td>
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<tr>
<td></td>
<td>HFO</td>
<td>R-514A</td>
<td>B</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HCFO</td>
<td>R-1233zd</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Hydrochlorofluoroolefin (HCFO)

R-1233zd
ODP: 0
GWP: 1
Hydrofluoro-olefin (HFO) Blend

R-514A
ODP: 0
GWP: 1.5

74.7% R-1336mzz(Z)

25.3% R-1130(E)
Medium Pressure Refrigerants – Easy to replace

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Type</th>
<th>Refrigerant</th>
<th>Toxicity</th>
<th>Flammability</th>
<th>ODP</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>CFC</td>
<td>R-12</td>
<td>A</td>
<td>1</td>
<td>1</td>
<td>10,200</td>
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<tr>
<td></td>
<td>HFC</td>
<td>R-134a</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>1,300</td>
</tr>
<tr>
<td></td>
<td>HFO</td>
<td>R-513A</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>573</td>
</tr>
<tr>
<td></td>
<td>HFO</td>
<td>R-1234ze</td>
<td>A</td>
<td>2L – BV 0.0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>HFO</td>
<td>R-1234yf</td>
<td>A</td>
<td>2L – BV 1.5</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Hydrofluoro-olefin (HFO)

R-1234yf
ODP: 0
GWP: 1
# High Pressure Refrigerants – Challenging to replace

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Type</th>
<th>Refrigerant</th>
<th>Toxicity</th>
<th>Flammability</th>
<th>ODP</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>HCFC</td>
<td>R-22</td>
<td>A</td>
<td>1</td>
<td>0.05</td>
<td>1,810</td>
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<tr>
<td></td>
<td>HFC</td>
<td>R-410A</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>1,924</td>
</tr>
<tr>
<td></td>
<td>HFC</td>
<td>R-32</td>
<td>A</td>
<td>2L – BV 6.7</td>
<td>0</td>
<td>677</td>
</tr>
<tr>
<td></td>
<td>HFC</td>
<td>R-454B</td>
<td>A</td>
<td>2L – BV 5.2</td>
<td>0</td>
<td>467</td>
</tr>
<tr>
<td></td>
<td>HFC</td>
<td>R-152a</td>
<td>A</td>
<td>2 – BV 23</td>
<td>0</td>
<td>138</td>
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<tr>
<td></td>
<td></td>
<td>R-290 (Propane)</td>
<td>A</td>
<td>3 – BV 40</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>
Flammability

Burn Velocity (cm/s)

R-1234ze  R-1234yf  R-454B  R-32  Ammonia  R-152a  Methane  Propane

Class 1  Non Flammable

Class 2  Lesser Flammable

Sub Class 2L  Slightly Flammable

Class 3  Highly Flammable
Toxicity Classes A&B - Long Term Exposure

Occupational Exposure Limit (OEL)
The time-weighted average concentration for a normal eight-hour work day and a 40-hour work week to which nearly all workers can be repeatedly exposed without adverse effect.

Class A: ≥ 400 ppm
Class B: < 400 ppm
“Concerns with refrigerant safety have been heightened by negative marketing by competing equipment and refrigerant vendors. Frequent overstatement (to influence customer perceptions) coupled with contradictions have fueled discomfort in refrigerant choices for some alternative refrigerants.”
Replacing R-410A

**R-410A**
- 1,924 GWP

**R-32**
- 677 GWP

**R-454B**
- 467 GWP

**R-32**
- 50% R-32
- 50% R-125

**R-32**
- 100% R-32

**R-32**
- 31.1% R-1234yf
- 68.9% R-32
“Energy efficiency is, by far, the biggest impact to the environment, especially if you are able to contain the refrigerant inside the machine.”

“Efficiency is essential to a chiller’s environmental impact. About 95% of a chiller’s lifetime carbon footprint comes from indirect emissions.”

“For chillers, the vast majority of impact on climate change will come from generating electricity to run the equipment, versus refrigerant emissions.”

“Energy efficiency is the main environmental consideration in the selection of a chiller as long as the equipment is carefully maintained and refrigerant emissions are kept near zero.”
The Path to Greener HVAC Refrigerants

- Ozone Depletion Potential
- Global Warming Potential
- Energy Efficiency
AGENDA

• Products & Applications
• Regulatory Overview
• Safety Considerations
• Tools in the Trades
• Summary - Recap
R-32 has achieved a global installed base of over 190 million units in over 120 countries by more than 50 OEMs (*Daikin’s estimate)
Daikin Global R32 Product Offering

Products will be ready when the codes, standards and market is ready

R32 Mini/Multi/Commercial Splits (Globally)

R32 VRV (Japan)
- 6-10 tons

R32 VRVS (Europe)
- 2-5 tons 1ph
- 6-24 tons 3ph

R32 Compact Inverter Chillers (5-25 tons)

R-32 technology at its best

R-32 Altherma
- Heat/Cool/Hot Water
- Residential/ Multi-Family
Daikin has chosen R32 as the next refrigerant in NA based on global experience and superior ease of use.
Over 68% reduction in GWP (Global Warming Potential) from R410a and approx. 6-10% more efficient.

- Daikin has taken the lead in North America by launching the first systems with next generation low GWP R32 refrigerant.
- Installation in Florida residential 2021.
In 2020, Daikin converted the heating system in a nearly 100-year-old, 10-unit, multifamily Manhattan building from an oil-burning steam boiler to Daikin Aurora multi-split heat pumps. These 20 century buildings are common throughout the U.S. Northeast region. Daikin’s demonstration project shows how its products can reduce fossil fuel heating and, in the process, bring 20 century buildings into the 21 century.

Measurements were taken throughout a period of over 18 months, using more than 100 sensors in the building to validate the heat pumps’ performance and measure comfort:

- The Daikin system reduced direct heating system emissions by 58 percent and building wide greenhouse gas emission (GHG) emissions by 49 percent.
- Switching to air-source heat pumps for heating reduced building energy costs by more than 16 percent.
- The cold-climate air source heat pumps provided 100 percent of the space heating in the building for two full winters without ever needing to use the building’s oil-fired boiler.

- More than 40% of U.S. energy consumption comes from heating and cooling houses, buildings, and water.
- 10 million + homes in the Northeast U.S. still rely on gas-fired furnaces.
- Heat pumps are proven to be 3x more efficient than fossil-fuel-burning furnaces.
- That accounts for 20% of U.S. greenhouse gas emissions.
While older heat pumps may have underperformed in cold climates, Daikin is proud to partner with the U.S. Department of Energy’s Cold Climate Heat Pump Challenge to develop new variable speed inverter heat pump solutions utilizing lower GWP refrigerant R-32, which will deliver effective heating performance and efficiency in ambient temperatures of 5°F Fahrenheit and below.

**Performance Requirements**

**Seasonal Heating**
- 8.5 HSPF2 (Region V)
- Heating at 5°F [15°C]
- Minimum COP of 2.12.4 at 5°F
- Capacity ratio of 100% for 5°F capacity to 47°F capacity
- Minimum turndown ratio at 47°F
- Compressor cut-in and cut-out temperatures
- Heating at -15°F [-26°C] (optional)
- HP operation at -15°F as measured by compressor cut-in and cut-out temperatures

**Auxiliary heat**
- Staged auxiliary heating

**Low GWP Requirement**
- Employ refrigerant with a global warming potential (GWP) value of no more than 750 (AR4,100 year)
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AIM Act passed in 2020 will address hydrofluorocarbon (HFC) use in three ways:

1. Phasing down the production and consumption
2. Maximizing reclamation and minimizing release from equipment
3. Facilitating the transformation to next-generation technologies.

**AIM Act HFC Phasedown Schedule**

The AIM Act gives authority to the EPA to phase down HFC refrigerants in the US

- **CO, FL, IN, ME, MO, NC, NJ, OR, TN, UT, VT, WA, and WV** already allow A2L refrigerants
- **AZ, CT, NY, OH, SC, and TX** are complete, just waiting for the effective dates

Source: AHRI - Daikin Environmental Committee, extracted AHRI database

- EPA finalized rules to phase down production and consumption of bulk HFCs in 2022 and 2023
- Set the baseline
- 2024 allocations not in rule. 40% reduction guaranteed
- HFC allowance allocation and trading program. Can’t carry forward unused allocations
- Imported Products Containing not included
- QR Codes on cylinders (tracking). Compliance is extended to 2025
- Disposable cylinders (heel). Compliance is extended to 2025
- Sector-based petitions not covered -- but EPA has ruled in favor of 11 petitions
  - Align with CARB 750 limit and dates
  - Petitions can’t delay the phasedown schedule
  - Increase reclamation

- High probability USA will transition Chillers on Jan '24 and residential HVAC on Jan '25, same as CA. VRV/F will follow in ‘26.

- Early California Position: 750 GWP limit
  - Jan ‘23 for PTAC and Window AC
  - Jan ‘24 for Chillers
  - Jan ‘25 for Direct HVAC other than VRF
  - Jan ‘26 for VRF
THE CODE ADOPTION PROCESS FOR NEW TECHNOLOGY

New or Revised Product Safety Standard

Updated Application Safety Standard

Updated Model Code (triennial)

Your state code adopts model code*

*Model code is updated triennially.
EPA SNAP Rule 19 (PTAC/RAC)
UL 484 (2015)

EPA SNAP Rule 23 (Most equip)
UL/CSA 60335-2-40 4th edition

State and Local Codes (see CO, FL, IN, ME, MO, NC, NJ, OR, TN, UT, VT, WA, and WV already allow A2L refrigerants)

ASHRAE 15-2022
add. d, add. h

ASHRAE 15.2-2022
addendum c,d,e,g,l,m,p,q,s

UL/CSA 60335-2-40 3rd edition
ASHRAE 15-2019

State and Local Codes


Product Safety Standards

Application Safety Standards

Model Building Codes

State Building Codes

UMC, Uniform Mechanical Code
IMC/IRC, International Mechanical Code/International Residential Code
MECHANICAL CODE ADOPTION

Based on upcodes.com

The law ensures that substances allowed under U.S. EPA’s SNAP (Significant New Alternative Policy) are not prohibited by any building.

NY’s Draft Scoping Plan outlines refrigerant-related strategies the state needs to pursue to achieve long-term climate goals set forth in the Climate Leadership and Community Protection Act (CLCPA):

1. Transition to low-GWP Refrigerants and enhanced management
2. Adopting Ultra-Low GWP Technologies by 2030
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AHRTI-9007: Benchmarking Risk by Whole Room Scale 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
AHRTI-9012/Oak Ridge National Laboratory (ORNL): Real-world Leak Assessments of Alternative Flammable Refrigerants
AHRTI-9015: Assessment of Refrigerant Leakage Mitigation Effectiveness for Air-Conditioning and Refrigeration Equipment
AHRI-8017: Investigation of Energy Produced by Potential Ignition Sources in Residential Application
ASHRAE-1806: Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update
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
ASHRAE-1808: Servicing and Installing Equipment using Flammable Refrigerants: Assessment of Field-made Mechanical Joints
AHRI 8028: A2L Refrigerants and Firefighter Tactical Considerations

New Safety Requirements for Low GWP Refrigerants
Understanding the Updated UL 60335-2-40 Refrigerant Detector Requirements and Future Standard Updates.
Mitigation Strategies – DX Human Comfort (and Refrigeration) Applications

System Design Considerations (select)

- Keep potential refrigerant charge released to a minimum
  - Verify minimum area (Amin) is met.
  - Locate equipment to minimizing piping - and charge.
  - Two smaller systems versus one larger system.
- Circulation
  - Most equipment will have refrigerant sensor to trigger air circulation in the event of detected refrigerant leak.
- Safety Shut-off Valves
  - Factory Installed Refrigerant Sensor, if applicable
  - Minimizes releasable charge, initiated by refrigerant sensor(s).
- Ventilation
  - Remove air/refrigerant mixture from smaller space to either larger space or outdoors, also initiated by refrigerant sensor(s).

Building Owners and Operators

- Stay informed and trained on regulations and building codes for A2Ls
- Understand and only use contractors that are trained to install A2L equipment
- Understand and stay trained on safety procedures associated with leaks
- Know and actively prohibit ignition sources
- First responder training and procedures will need to be updated to incorporate the properties, hazards, and fire-fighting measures associated with Class A2L refrigerants
Product Differences

- New labeling requirements for A2L systems will be used, with new symbols indicating that A2L refrigerants are in use.
- Understand that A2L systems are uniquely designed with different compressor oils, design piping pressures, and specific heat exchangers, so it is prohibited to service existing A1 refrigeration equipment with new A2L refrigerants or vice-versa.
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Per the Environmental Protection Agency’s (EPA) Significant New Alternative Policy Program (SNAP) guidelines, “spark proof tools are recommended”

<table>
<thead>
<tr>
<th>Tooling</th>
<th>R-410A</th>
<th>R-32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge Manifold</td>
<td>Normal</td>
<td>Different Scale</td>
</tr>
<tr>
<td>Vacuum pump</td>
<td>Normal</td>
<td>Equipped with oil backflow prevention function</td>
</tr>
<tr>
<td>Leak detector</td>
<td>Normal</td>
<td>HFC capable. Torch type models cannot be used</td>
</tr>
<tr>
<td>Recovery unit</td>
<td>Normal</td>
<td>Different – must be R-32 certified</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Recommended</td>
<td>Necessary (fan)</td>
</tr>
<tr>
<td>Recovery cylinder</td>
<td>580 psig, right thread</td>
<td>696 psig, possibly left thread</td>
</tr>
</tbody>
</table>
Unique Fittings and Service Ports for Flammable Refrigerant Use

Recommended Fittings for refrigerant cylinders should be of the type described in Table 1

- A2L fittings on units are proposed to be the same as fittings on current A1 (most service fittings are ¼” SAE flare right hand thread), while fittings on cylinders on proposed to be left hand thread.

- This is a big notable item – left hand thread on cylinder, right hand thread on equipment

### Table 1. Recommended Fittings for Refrigerant Cylinders

<table>
<thead>
<tr>
<th>Refrigerant Container Type</th>
<th>Refrigerant Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2 lb</td>
<td>CGA 164</td>
</tr>
<tr>
<td>&gt;2 &amp; &lt;50 lb</td>
<td>CGA 164</td>
</tr>
<tr>
<td>50 – 240 lb</td>
<td>CGA 670</td>
</tr>
<tr>
<td>&gt;240-1000 lb</td>
<td>CGA 670</td>
</tr>
</tbody>
</table>

Note: SAE Flare is 45°, per SAE Standard J513
Tools for R-32

Gauge manifold and hoses

- Supports R-32 (R-410A) pressure
  - If the gauge manifold and hoses support R-410a, it can also be used with R-32 if the temperature is recalculated
  - High-pressure gauge: -14.5 to 753 psig
  - Low-pressure gauge: -14.5 to 536 psig
- Bore of connecting portion uses 5/16” flare screw

Recovery unit for R-32

- Supports R-32 (R-410A) pressure
- Some units have an ambient pressure switch which stops recovery above ambient pressure for leaking systems to prevent pulling air into recovery cylinder.
- Must be approved for A2L refrigerants
Tools for R-32

### Vacuum pump
- Older vacuum pumps **MAY NOT BE** certified for A2L refrigerants.
- Equipped with oil backflow prevention function (In the case of using a vacuum pump without reverse flow preventive function, use only after connecting it to a reverse flow preventive vacuum adapter.)

### Electronic leak tester
- Detectors that can be used with R-410A can also be used for R-32 if approval from tooling manufacturer.
- Must be HFC capable
- Torch type models cannot be used.
A monitor to check for presence of combustible gas should always be used when entering a service area.

No service should begin on the system until the area has been checked for flammable refrigerants.

Monitors that use audible signals are recommended.

The monitor should also remain on for the duration of work.

A Class B dry powder type fire extinguisher shall be kept nearby when working with slightly flammable refrigerants.
Recovery Cylinder

- Only cylinders with pressure resistance to 696 psig or greater can be used.
- Keep in mind that the bottle might have left hand thread. In that case, an adapter piece is necessary.
- Never exceed the maximum allowable liquid fill weight of a cylinder
- Never mix recovered refrigerants.
- Label cylinder with refrigerant recovered

Adapter

- Adapter piece left thread to right thread
- Flammable gas cylinders may have left thread.
- This adapter piece converts left thread to right thread, for use of manifolds.
Wrap-Up

- Our Industry can safely commercialize low GWP refrigerants to reduce the impact of global warming.

- Evolution of refrigerants – we can apply our knowledge to solve climate change by increasing energy efficiency with lower GWP refrigerants.

- Codes and Standards need to rapidly embrace the changes – State and local code officials need to ensure smooth transition.

- Heat Pumps will evolve and replace fossil fuel usage (aided by lower GWP refrigerants) – already proving acceptable – ccHP challenge.

- Tools and Safety awareness training must accelerate in the trades.