Carrier Engineering Newsletter Volume 3, Issue 2

# New Refrigerants Impact Standards and Codes

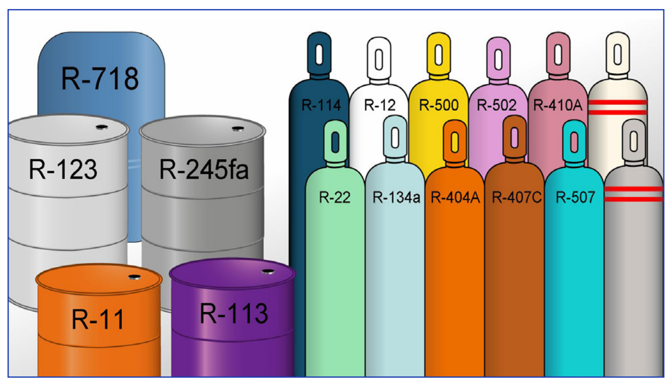
The function of refrigerant as a fluid used for heat transfer has not changed since the development of the first refrigerating system. Today, as in that first system, the refrigerant absorbs heat and transfers it at a higher temperature and a higher pressure, usually with a phase change. However, as the heating, ventilating, and air-conditioning (HVAC) industry has evolved and expanded, refrigerants also have changed over the years, mainly in response to safety and environmental concerns. Now the industry is moving to a new set of refrigerants developed in the last five years to address climate change issues. This newsletter will describe the benefits and challenges presented by these new refrigerants and discuss the current state as well as changes in the standards and codes that guide the application of refrigerants in HVAC equipment.

## Historical Perspective

In the early days of the industry, the refrigerants used were toxic and/or flammable (e.g. methyl chloride, sulfur dioxide). The search for a new refrigerant with the appropriate chemical properties led to the development in 1930 of a new refrigerant, dichlorodifluoromethane (CFC), which would later become known as R-12.

With R-12, the industry now had a chemical that was low in toxicity, non-flammable, compatible with mineral oil and very stable. Use of this refrigerant eventually led to the development of additional fluorocarbons for specific applications. Eventually, R-11 (trichlorofluoromethane) became the primary refrigerant in large water-cooled chillers, R-12 in household refrigerators and mobile air conditioning, and R-22 (chlorodifluoromethane) in unitary equipment for residential and commercial applications. Blends of fluorochemicals were also developed for commercial refrigeration (e.g. R-500, which is a mixture of R-12 and R-152a).

In the 1970s, it was found that the chlorofluorocarbons (CFCs) were remaining in the atmosphere much longer than anyone expected. The CFCs would eventually be carried up to the lower levels of the stratosphere where they would react with the ozone found there and break down the protective ozone layer that shields the earth from harmful ultraviolet radiation from the sun. As a result of this discovery, the members of the United Nations developed the Montreal Protocol on Substances that Deplete the Ozone Layer, which called for the phase-out of ozone-depleting substances. The halogenated refrigerants (those compounds that include fluorine or chlorine) were divided into three categories based on their ozone depletion potential. The chlorofluorocarbons




(e.g. CFC-11 and CFC-12) with the longest atmospheric lifetime and highest ozone depletion potential were phased out first, followed by the hydrochlorofluorocarbons, or HCFCs (e.g. HCFC-22, HCFC-123). In developed countries, production and consumption of HCFCs would be reduced 90% from the base level on January 1, 2015. Production and consumption of HCFCs for use in new equipment will be prohibited on January 1, 2020 with 0.5% of the baseline being allowed for servicing of existing refrigeration and air-conditioning equipment until January 1, 2030. On January 1, 2030 production and consumption of HCFCs will be prohibited. Some nations accelerated this schedule. Developing countries, as defined in Article 5 of the Montreal Protocol, have an additional 10 years to phase out the HCFCs. Actions taken under the Montreal Protocol have led to decreases in the atmospheric abundance of controlled ozone-depleting substances (ODSs), and are enabling the return of the ozone layer toward 1980 levels.[1]

[1]Executive Summary of the Assessment for Policy Makers of the 2014 Scientific Assessment of Ozone Depletion.

The HVAC industry transitioned to hydrofluorocarbons, or HFCs (e.g. HFC-134a, HFC-410A), which do not deplete the ozone layer and thus are not part of the phase-out under the Montreal Protocol.

While non-ozone depleting, HFCs, like the CFCs they replaced, are greenhouse gases (so-called because they trap heat in the atmosphere). The Kyoto Protocol, an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCC), specifically identified these refrigerants and called for reductions in emissions of greenhouse gases, including HFCs. Although the Kyoto Protocol has expired, negotiations are underway for a new international agreement to limit greenhouse gases under the UNFCC. In addition, several proposals have been introduced to amend the existing Montreal Protocol for a global HFC phase-down agreement. In the meantime, some countries and regions are passing regulations limiting the use of HFCs in order to reduce their emissions of greenhouse gases. Although their use in the future may be limited, HFCs (e.g. HFC-134a, HFC-410A) are not being phased out. The HFCs are the best energy-efficient refrigerants for some applications and there will continue to be a requirement for HFCs in order to meet the demand for air conditioning and refrigeration.

The chart in Figure 1 shows the transition in refrigerants since 1930. The fourth generation of refrigerants consists of hydrocarbons, carbon dioxide, and hydrofluoroolefins (HFOs), which were developed in the last five years. They all present the industry with new challenges.

## HFOs and Natural Refrigerants

The move to refrigerants with low global warming potential (GWP)[2] has forced the industry to re-evaluate refrigerants previously considered unacceptable due to high pressure or flammability concerns. In order to reduce the atmospheric lifetime of the refrigerants, the industry has developed a new class of compounds called hydrofluoroolefins or HFOs. These are new chemicals that have very short atmospheric lifetimes and therefore very low GWP. They were developed to replace HFCs that have higher GWP values.

New air conditioning and refrigeration products are being developed to use either the new HFOs or natural refrigerants like hydrocarbons (e.g. propane, R-290, and isobutane, R-600a) or carbon dioxide ($CO_2$). Some of these low GWP refrigerants are flammable and proper safety precautions must be taken to ensure the refrigerant will not ignite in the event of a leak. Safety standards and model codes will have to consider the lower flammable limit of the refrigerant, amount of charge, risk of refrigerant leak, the area where a leaked refrigerant could occur and the presence of ignition sources as they develop requirements for the safe use of these flammable refrigerants.

*Figure 1 – Transition in Refrigerants from 1930s to Present*

| CFCs 1930s-1990s | HCFCs 1930s-2010s | HFCs 1990s+ | New/Natural Compounds* 2010s+ |
|---|---|---|---|
| Long atmospheric lifetime | Shorter atmospheric lifetime | Shorter atmospheric lifetime | Very short atmospheric lifetime |
| Strong ozone depletion | Lower ozone depletion | Non-ozone depleting | Non-ozone depleting |
| Strong global warming | Lower global warming | Lower global warming | Very low global warming |
| | | | *HFOs<br>$CO_2$<br>Hydrocarbons |

[2]Global-warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. All GWP values in this document were obtained from either the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) or the U.S. Environmental Protection Agency (EPA).

## Standards and Codes

Industry standards play an important part in worldwide refrigerant regulation and application. Although ASHRAE Standard 34, which defines refrigerant safety classifications, has been updated, ASHRAE Standard 15, the equipment safety standard that relies on and refers to these classifications, has not yet been revised. Revisions to ASHRAE Standard 15 are in progress. The equipment safety standard must be revised before any updates to the model codes can be made.

Following is a discussion of some of the changes to these standards and how they will affect the use of refrigerants in the HVAC industry.

### ASHRAE Standard 34, Designation and Safety Classification of Refrigerants

ASHRAE Standard 34 assigns the refrigerant numbers and determines the proper safety classification based on toxicity and flammability data.

ASHRAE defines two safety classifications for toxicity: Class A signifies refrigerants that are of lower toxicity and Class B signifies refrigerants that are of higher toxicity. For flammability, there are three classifications and one sub-classification. The three main flammability classifications are: Class 1, for refrigerants that do not propagate a flame when tested as per the standard; Class 2, for refrigerants that are of lower flammability; and Class 3, for highly flammable refrigerants, like the hydrocarbons. The safety classification matrix (Figure 2) was recently updated to include a new flammability Subclass 2L, for flammability Class 2 refrigerants that burn very slowly. Some HFOs, which have very low global warming potential, are mildly flammable and are classified as A2L. This indicates they are of lower toxicity and have a low burning velocity of ≤10 cm/sec.

Following is a description of some of the low GWP refrigerants and other alternative refrigerants being considered by the industry, along with their ASHRAE Standard 34 classifications and direct GWP values:

*Figure 2 – Safety Classification of Refrigerants in ASHRAE Standard 34*

| | | | |
|---|---|---|---|
| Flammability | Higher Flammability | **A3**<br>R-290 Propane<br>R-600a Isobutane | **B3** |
| | Lower Flammability | **A2**<br>R-152a | **B2** |
| | | **A2L***<br>R-32<br>R-1234yf<br>R-1234ze(E) | **B2L***<br>R-717<br>Ammonia |
| | No Flame Propagation | **A1**<br>R-22<br>R-134a<br>R-410A<br>R-1233zd(E)<br>R-404A<br>R-407C<br>R-507A<br>R-744 Carbon Dioxide | **B1**<br>R-123 |
| | | Lower Toxicity | Higher Toxicity |
| | | **Toxicity** | |

*A2L and B2L are lower flammability refrigerants with a minimum burning velocity of ≤10 cm/s.

**HFC-32** (Safety Class A2L) is a component of R-410A and is being considered as an interim substitute for R-410A in unitary equipment. This mildly flammable refrigerant has a higher vapor pressure than R-410A. With a GWP value of 675, the global warming potential of HFC-32 is lower than that of R-410A (GWP of 2088) but still too high for long term use under current regulatory proposals.

**HFO-1234yf** (Safety Class A2L) was first commercialized as a replacement for HFC-134a in automobile air conditioning. This refrigerant is of lower toxicity and mildly flammable, with a GWP value of 0.31.

**HFO-1234ze(E)** (Safety Class A2L) is being evaluated for use in new chiller applications to replace HFC-134a and is planned for introduction in Europe in 2015. Due to the mildly flammable classification, it is suitable for new chiller applications but cannot be used in existing equipment. This refrigerant has a low GWP value of 0.97.

**HFO-1233zd(E)** (Safety Class A1) is of lower toxicity and non-flammable. This refrigerant was developed for and is being used as a blowing agent for polymer foams. This refrigerant has a GWP value of 1.34 and is also being evaluated for use in new chiller applications as a low pressure refrigerant that can operate in a vacuum under normal air conditioning conditions. This application would require the use of a purge to remove noncondensables from the closed cycle.

**Hydrocarbons**, like propane (R-290) with a GWP value of 3.3, and isobutane (R-600a) with a GWP value of 3.0, have very good thermodynamic properties, but are highly flammable and are listed as Safety Class A3. Other than in industrial applications, their use is restricted to hermetically sealed systems with very small charge sizes.

**Carbon dioxide** (R-744 or $CO_2$) works well in some applications, particularly refrigeration, but its high pressures limit its use elsewhere. Listed as Safety Class A1, carbon dioxide is currently being used in commercial refrigeration systems in northern Europe and in marine container units. The GWP value of carbon dioxide is 1.0.

**Ammonia** (R-717 or $NH_3$) works well in some applications, but its mild flammability and toxicity require mitigation controls and limit its application. It is listed in ASHRAE Standard 34 as Safety Class B2L. Ammonia has historically been used in large refrigeration systems and other industrial applications. Ammonia is not a greenhouse gas and therefore has no GWP value.

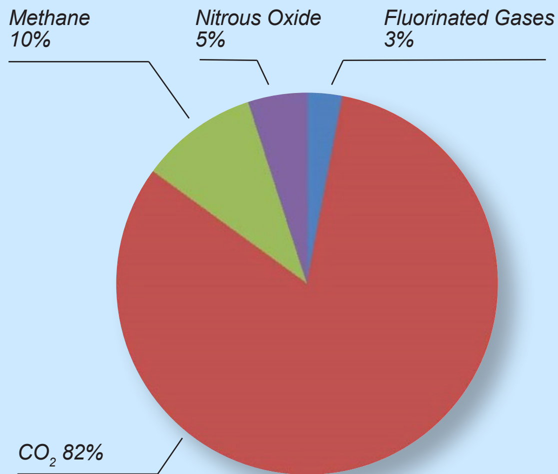
## *DIRECT VS INDIRECT GREENHOUSE GAS EMISSIONS: THE IMPACT OF ENERGY EFFICIENT OPERATION ON CLIMATE CHANGE*

*When evaluating the effect of greenhouse gases on climate change, keep in mind that refrigerants are only part of the story. In 2013, fluorinated gases, which include HFCs, accounted for ~3% of U.S. greenhouse gas emissions (direct effect), while carbon dioxide, which is emitted from fossil fuel burning power plants (indirect effect), accounted for 82% of U.S emissions, as shown in the pie chart.*

*In order to reduce emissions of greenhouse gases we must not only find new low GWP refrigerants but also design equipment that is more energy efficient to reduce consumption of electricity, most of which is generated by burning fossil fuels, leading to emissions of carbon dioxide. The total electricity consumption of the equipment must be considered, including the compressor, fans, and pumps. Appropriate sizing of equipment is important to closely match capacity to load and avoid excessive compressor cycling. Any factor that increases energy usage contributes to the indirect effect that equipment operation has on climate change.*

*Choosing low GWP refrigerants that result in higher energy consumption does not help reduce climate change. In addition, the U.S. Department of Energy is increasing minimum energy efficiency requirements for air conditioning and refrigeration systems.*

***U.S. Greenhouse Gas Emissions (2013)***




The introduction of the flammability classification of A2L in ASHRAE Standard 34 will require related changes to equipment safety standards and building codes. These changes are still in progress, as described below.

## ASHRAE Standard 15, Safety Standard for Refrigeration Systems

This standard specifies safe design, construction, installation, and operation of refrigeration systems. This standard references the safety classifications in ASHRAE Standard 34. The committee responsible for maintaining ASHRAE Standard 15 has established an ad hoc working group to develop revisions to the standard to address the use of mildly flammable refrigerants listed in ASHRAE Standard 34 as A2L. The first draft was circulated for an advisory public review in 2011 in order to obtain comments from industry representatives outside the committee. The committee is now preparing a revised document, taking into consideration the comments received along with recently completed risk assessments, potential ignition sources, ventilation requirements and leak detector reliability.

Currently, ASHRAE Standard 15-2013 prohibits the use of flammable refrigerants in systems for human comfort where leaked refrigerant will enter the occupied space (see sections 7.5.2 and 7.5.3 and excerpts below) and has no provisions for refrigerants with a flammability classification of 2L, therefore refrigerants in this class must be treated as Class 2.

**7.5.2 Applications for Human Comfort.** Group A2, A3, B1, B2, and B3 refrigerants shall not be used in high-probability systems for human comfort.

**7.5.3 Higher Flammability Refrigerants.** Group A3 and B3 refrigerants shall not be used except where approved by the AHJ (authority having jurisdiction).

## UL 1995 Heating and Cooling Equipment

The UL Standard for Heating and Cooling Equipment (UL 1995) is being replaced by IEC 60335-2-40, with U.S. deviations, and will include restrictions for the use of flammable refrigerants in stationary air-conditioning and refrigerating equipment. Standard IEC 60335-2-40 is under revision and a public review document will likely be released later this year for global review. Once completed it will be reviewed and modified as needed for implementation in the U.S., Canada and Mexico.

## Model Codes

Once ASHRAE has published the requirements for application of the new mildly flammable refrigerants in Standard 15, ASHRAE will submit a code change proposal to the model codes in the United States. The codes currently include some of the new refrigerants that are classified as A2L or B2L in ASHRAE Standard 34 but they are classified as flammability Class 2 in the codes until requirements for their safe use have been established.

## International Mechanical Code (IMC)

The 2015 International Mechanical Code (IMC), used in most jurisdictions in the US, handles the safety classification as shown below in an excerpt from Table 1103.1 of the Refrigerant System Classification Section (Figure 3). Refrigerants listed as A2L in ASHRAE standard 34 are listed as Class 2 in the IMC because requirements for the use of Class A2L refrigerants are still in development. A footnote on these refrigerants lets the users of the IMC know that the safety classification in ASHRAE Standard 34 is A2L. ASHRAE will submit a proposal to change the classification in Table 1103.1 to A2L once ASHRAE Standard 15 has been updated with requirements for use of the refrigerants. The code is on a 3-year revision cycle and the deadline for submitting code change proposals for the 2018 IMC has already passed, therefore, the earliest this change would come into effect would be in the 2021 IMC.

Section 1104, System Application Requirements restricts the amount of a refrigerant allowed in a building outside of a machine room based on the amount of refrigerant per occupied space listed in Table 1103.1. For flammable refrigerants, the amount of refrigerant per occupied space is based on preventing the refrigerant concentration from reaching 25% of the lower flammable limit (LFL) if the entire charge were released into the room. Since the LFL of Class A2L refrigerants is higher than the LFL of Class A2 refrigerants, the amount of refrigerant allowed per occupied space will increase.

## Uniform Mechanical Code (UMC)

The Uniform Mechanical Code (UMC), published by the International Association of Plumbing and Mechanical Officials (IAPMO), also includes a table of refrigerants in Chapter 11. The UMC is also on a 3-year revision cycle and ASHRAE routinely submits code change proposal to add refrigerants to Table 11-1 that have been added to the ASHRAE Standard since the last code revision. Refrigerants listed as A2L in Standard 34 are listed as Class A2 in the UMC Chapter 11 with a footnote indicating that the safety classification in Standard 34 is A2L.

## State and Local Code Adoption

Once provisions for use of mildly flammable refrigerants are in the model codes they must be adopted by states and local jurisdictions. The model codes are updated on a 3-year cycle and the deadline for submitting code change proposals for the 2018 IMC has already passed, so the earliest that requirements for the use of A2L refrigerants could appear in the IMC is 2021. The deadline for submitting code change proposals for the 2018 Uniform Mechanical Code (UMC) is in January of 2016 so there is still a possibility of changing that code although it is unlikely that ASHRAE will have an amendment to Standard 15 ready in that timeframe.

*Figure 3 – Excerpt from the International Mechanical Code*

## Section 1103 Refrigeration System Classification

**1103.1 Refrigerant classification.** Refrigerants shall be classified in accordance with ASHRAE 34 as listed in Table 1103.1

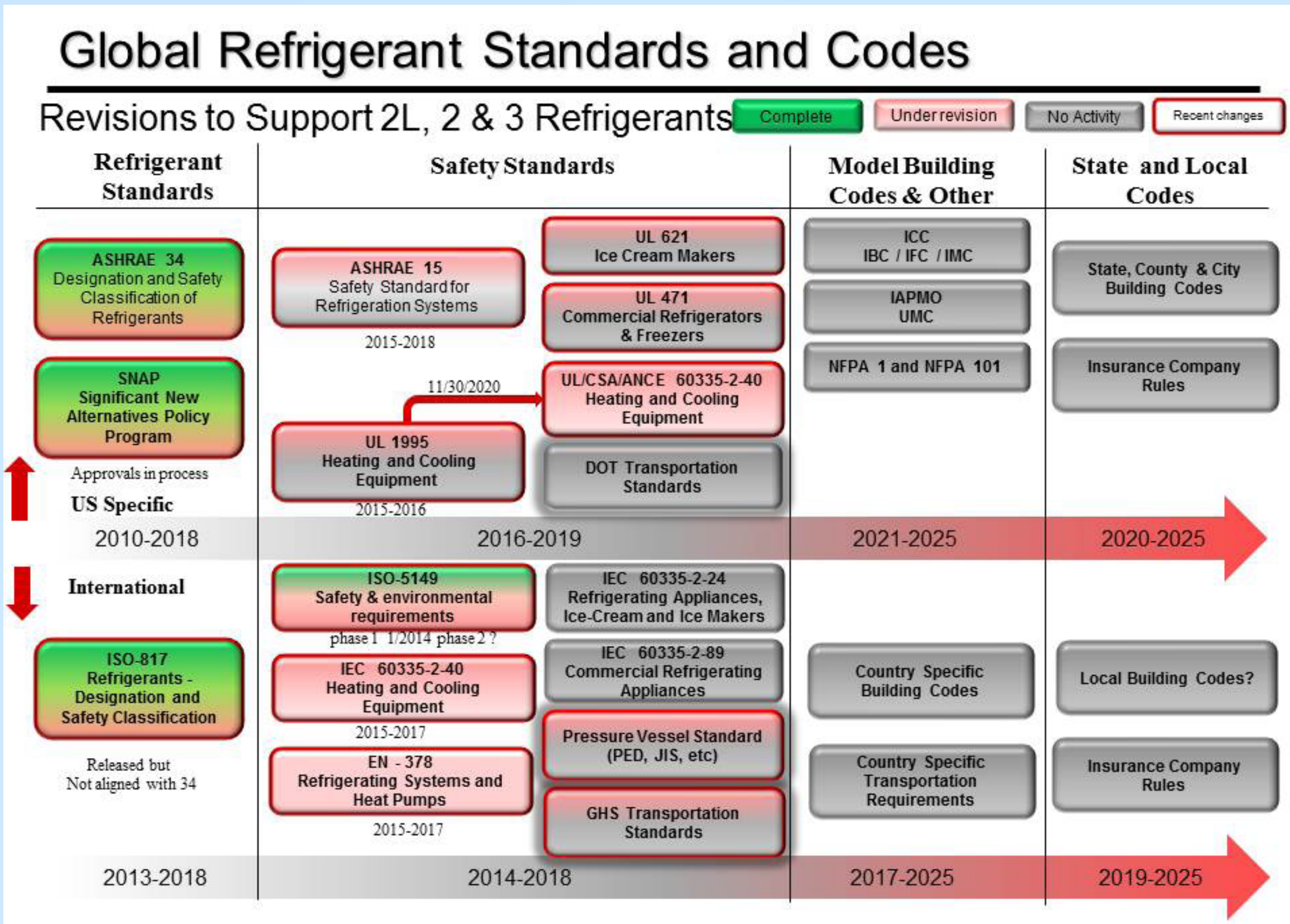
### [F] TABLE 1103.1 REFRIGERANT CLASSIFICATION, AMOUNT AND OEL

| CHEMICAL REFRIGERANT | FORMULA | CHEMICAL NAME OF BLEND | REFRIGERANT CLASSIFICATION | DEGREES OF HAZARD | [M] AMOUNT OF REFRIGERANT PER OCCUPIED SPACE | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pounds per 1,000 cubic feet | ppm | g/m | OEL |
| R-32 | $CH_2F_2$ | Difluoromethane (methylene fluoride) | A2[f] | — | 4.8 | 36,000 | 77 | 1,000 |
| R-143a | $CH_3CF_3$ | 1,1,1-trifluoroethane | A2[f] | 2-0-0 | 4.5 | 21,000 | 70 | 1,000 |
| R-717 | $NH_3$ | Ammonia | B2[f] | 3-3-0 | 0.014 | 320 | 0.22 | 25 |
| R-1234yf | $CF_3CF = CH_2$ | 2,3,3,3-tetrafluoro-1 propene | A2[f] | — | 4.7 | 16,000 | 75 | 500 |
| R-1234ze(E) | $CF_3CH = CHF$ | Trans-1,3,3,3-tetrafluoro-1-propene | A2[f] | — | 4.7 | 16,000 | 75 | 800 |

f. The ASHRAE Standard 34 flammability classification for this refrigerant is 2L, which is a subclass of Class 2. OEL — Occupational Exposure Limit

*MAPPING THE CODE REVISION PROCESS*

*There is a significant amount of work underway to modify standards and codes globally to allow the use of the new refrigerants, but progress takes time as all interested parties must reach consensus on the changes. The chart below provides an example of the complexity of the process.*




## Regulations

In addition to changes in safety standard and codes, governmental regulations must also be considered.

### U.S. Environmental Protection Agency (EPA) Significant New Alternatives Policy (SNAP) Program

In the U.S., the EPA must approve the refrigerant for use in each application. Recently the EPA published a rule that adds low GWP refrigerants to the approved list for some applications as shown in Figure 4. All of the refrigerants are flammable. Most, with the exception of HFC-32, are highly flammable, Class A3 refrigerants. HFC-32 is listed in ASHRAE Standard 34 as a Class A2L refrigerant. Approval is only for the application shown. Details of the rule can be found on the EPA web site: http://www.epa.gov/ozone/snap/index.html

The EPA also has a proposed rule that would remove some high GWP refrigerants from the list of acceptable substitutes used as aerosol propellants, and as refrigerant in motor vehicle air-conditioning and some food refrigeration equipment. This does not impact the use of these refrigerants in HVAC equipment.

*Figure 4 – EPA-Approved Applications for some Low GWP Refrigerants*

| Refrigerant | GWP | Household Refrigeration | Retail Refrigeration Stand-Alone | Vending | Very Low Temp Ref | Heat Transfer | Home AC Self-Contained |
|---|---|---|---|---|---|---|---|
| Ethane | 6 | | | | √ | √ | |
| Isobutane | 3 | | √ | √ | | | |
| Propane | 3 | √ | | √ | | | √ |
| R-441A | <5 | | √ | √ | | | √ |
| HFC-32 | 675 | | | | | | √ |

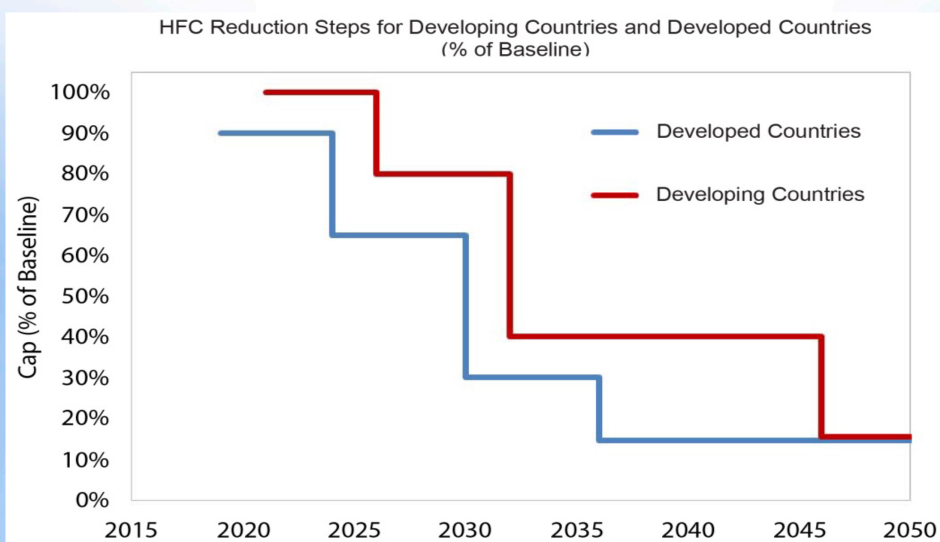
## HFC Control Measures

The European Union has passed regulations requiring a phase-down of HFCs beginning January 1, 2015 with a cap on the quantity of HFCs that can be placed on the market. The first step-down occurs in 2016 with a 7% reduction from the cap, leading ultimately to a reduction of 79% by 2030. In addition there are bans on some high GWP HFCs in specific applications that take effect between now and 2025.

The U.S., Canada and Mexico have submitted a proposal to the parties to the Montreal Protocol on Substances that Deplete the Ozone Layer that would require a stepped phase-down of HFC production and consumption over the next 20 years resulting in an eventual reduction of HFC production of ~85% over baseline levels (see Figure 5). The proposal has not yet overcome objections from several nations, but seems to be gaining momentum.

This year, HFC phase-down proposals have also been submitted by India, the European Union, Senegal and the Pacific Island States. In addition, the African Group has called for formation of a contact group to discuss a program under the Montreal Protocol to phase down HFCs. All these proposals will be considered in the negotiations among the parties to the Montreal Protocol.

*Figure 5 – Proposal for Amendment to the Montreal Protocol Stepped Phase-Down of HFC Production and Consumption*



### *RESEARCH PROJECTS ASSIST WITH STANDARDS DEVELOPMENT*

*ASHRAE and AHRI have research programs underway to assist with standards development process. The eight projects below are either underway or have been completed recently:*

- *AHRI 8004 -- Risk Assessment of Residential Heat Pump Systems Using 2L Flammable Refrigerants, T. A. Lewandowski, 2012.*
- *AHRI 8006 -- Low Global Warming Potential (GWP) Refrigerants, Phase II: Defining the Configurations of Residential Air-Conditioning and Heat Pump Systems Using Hydrocarbons, Ammonia, Carbon Dioxide, and HFO-1234yf as Refrigerants and Meeting Previously Defined Safety Requirements, W. Goetzler, D. Westphalen, and J. Burgos.*
- *AHRI 8009, Risk Assessment of Refrigeration Equipment Using A2L Refrigerants.*
- *AHRI 8016, Risk Assessment of Rooftop Units Using A2L Refrigerants.*
- *ASHRAE RP-1448 -- Ventilation Requirements for Refrigerating Machinery Rooms.*
- *ASHRAE RP-1580 -- Study of Input Parameters for Risk Assessment of 2L Flammable Refrigerants in Residential Air Conditioning and Commercial Refrigeration Applications.*
- *ASHRAE RP-1584, Developing Alternative Approaches to Predicting the Laminar Burning Speed of Refrigerants Using the Minimum Ignition Energy.*
- *ASHRAE 1717-RP, Improve Accuracy and Reproducibility of ASTM E-681, Test Method for Flammability Limit Measurement of 2L Flammable Refrigerants.*

## Summary

Regulations related to climate change will have an impact on several aspects of the HVAC industry. The industry will be faced with another refrigerant transition as it moves to new low GWP refrigerants and, in some cases, will have to prepare for the use of flammable refrigerants in commercial, industrial, and residential buildings. Changes to industry safety standards and the model building codes will be required before these new refrigerants can be implemented. The use of flammable refrigerants also will require changes in service practices to prevent ignition of the refrigerant.

Refrigerants with very high GWP, like R-404A, will be the first to be replaced with lower GWP options. Other HFCs will be in use longer as the industry investigates the various low GWP options that are available. The industry will also work to reduce refrigerant charge size in equipment as much as possible to minimize the amount of refrigerant used that could ultimately be released to the atmosphere. In addition to developing new equipment, the industry must address how to retrofit existing equipment to use lower GWP refrigerants.

At the same time, the industry will be working to increase energy efficiency of all air-conditioning and refrigeration equipment systems in an effort to minimize the greenhouse gases produced by generating electricity to run the equipment. In many cases, these changes will be required by energy efficiency standards imposed by the U.S. Department of Energy.

As requirements evolve, the industry will look to innovative manufacturers to provide solutions that can meet the challenges of efficiency, safety, and environmental concerns.

Carrier continuously invests in research and development and is committed to deploying products and technologies that minimize environmental impact while serving customer needs. This is equally true for refrigerants. While not every application may have the same refrigerant solution, Carrier will have the right refrigerant solution for every application.