WHITE PAPER

UPDATE — REVISITING FLAMMABLE REFRIGERANTS

JANUARY 2017

Introduction

On January 11, 2011, thirty-five representatives from stakeholder organizations participated in a forum hosted by Underwriters Laboratories Inc. (UL) on the introduction and use of flammable refrigerants in appliances and HVAC/R equipment in the United States. The impetus for the forum and overall marketplace situation at the time was summarized in UL's 2011 white paper, *"Revisiting Flammable Refrigerants."*[1] Additional observations were recorded in the forum meeting Report.[2]

Though anticipated, the introduction of flammable refrigerants in the US market was still considered a bit far-off at the time, outside of a few pilot initiatives. Government regulations, product safety standards and installation codes, servicing, handling and disposal practices were all in need of attention before wide-scale use of such refrigerants could occur. Much has been accomplished since the stakeholder forum. This paper is intended to update the 2011 white paper and identify the challenges and opportunities that remain with these refrigerants.

The Landscape Has Changed

2011 Snapshot

With the exception of industrial process refrigeration, by early 2011 the US EPA Significant New Alternatives Policy (SNAP)[3] had not yet authorized the use of hydrocarbon refrigerants (propane, butane and blends) as substitutes for existing refrigerants. There were a few trial installations in commercial refrigeration, but little consumer and commercial market experience in the US with these refrigerants.

Refrigeration equipment and installation safety standards and codes already had, in some cases, a provision for flammable refrigerants, though they were generally not permitted to be installed except where approved by the authority having jurisdiction (AHJ). However, in the limited case of *"listed portable-unit systems containing no more than 150 g of group A3 refrigerant,"* refrigeration equipment could be installed in accordance with the manufacturer's instructions. Flammable refrigerants for comfort cooling were not permitted.[4]

A new flammability sub-class of refrigerant, known as A2L,[5] became available and one particular A2L refrigerant, R-1234yf a hydrofluoro-olefin (HFO), was being contemplated as an alternative to R-134a, a hydrofluorocarbon (HFC) refrigerant commonly used in automotive air conditioning applications. Sub-class A2L refrigerants exhibit low burning velocities and were generally considered more difficult to ignite and sustain ignition than class A2 (lower flammability) or A3 (higher flammability) refrigerants. However, equipment and installation safety standards and codes did not distinguish between classes A2 and A2L. What advantage, if any, A2Ls should have due to a lower burning velocity was only just being discussed.

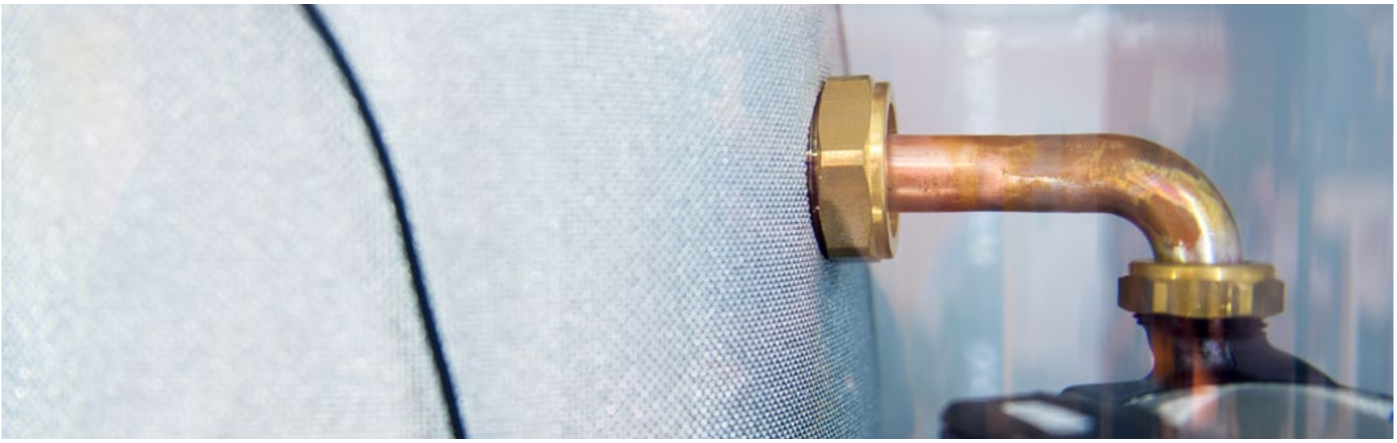
Conversely, the use of flammable refrigerants for refrigerators and freezers with charge limits higher than those permitted in the US standards was growing internationally. Today, there are an estimated one billion hydrocarbon-based (R-600a, refrigerant class A3) domestic refrigerators in operation worldwide with 100 million more being produced annually.[6]
Along with growing global consensus regarding the importance of addressing potential contributing factors to climate change, these international products resulted in serious consideration in the US of refrigerants that would require weighing the benefits of reduced ozone depletion (ODP)/global warming potential (GWP) against the increased risk of fire hazard.

However, more than ten years after it was adopted in 1997 and six years after being put into effect in 2005, the Kyoto protocol[7] had not been ratified by the US Senate, despite the US being a signatory. Regardless, the US had completed its phase out of chlorofluorocarbon (CFC) refrigerants and the phase out of hydrochlorofluorocarbon (HCFC) refrigerants was well underway at the time. Arguably, the US market was poised to accept the introduction and use of flammable refrigerants, but not yet ready to embrace such a change.

The Changes

A lot has happened in the regulatory space since 2011, a year now seen largely as a tipping point toward flammable refrigerants. In particular, EPA SNAP proposed and published a number of rules that facilitate the use of hydrocarbon and other flammable refrigerants while limiting the availability and use of refrigerants with higher ODP/GWP. Notable rules and guidance are as follows:

- **SNAP hydrocarbons rule (Rule 17)** effective Feb 21, 2012.[8] *Subject to use conditions, the hydrocarbons rule permitted the use of:*
  - *propane (R-290) refrigerant for new stand-alone retail food refrigeration, and*
  - *isobutane (R-600a) and the blended refrigerant R-441A for new household refrigerators and freezers*



- **Hydrocarbon exemption from venting prohibition rule** effective June 23, 2014.[9] *Permitted venting of refrigerants covered by the SNAP hydrocarbons rule directly to the atmosphere under servicing and disposal conditions.*
- **Additional flammable refrigerant substitutes and exemption from venting prohibition rule (Rule 19)** effective May 11, 2015.[10] *Extended the SNAP rules as follows:*
  - *Propane in household refrigerators*
  - *Isobutane and R-441A in retail refrigerators*
  - *Ethane (R-170) in very low temperature refrigerators*
  - *Isobutane, propane, and R-441A in vending machines*
  - *HFC R-32, propane, and R-441A in self-contained residential and ligh commercial air conditioners*
  - *Venting exemptions for the above refrigerants, except not for HFC R-32*
- **Update to the Refrigerant Management Requirements under the Clean Air Act** published on November 16, 2016.[11] *Updated existing requirements for persons servicing or disposing of air-conditioning and refrigeration equipment to "observe certain service practices that reduce emissions of ozone-depleting refrigerant as well as extend them, as appropriate, to non-ozone-depleting substitute refrigerants, such as hydrofluorocarbons... (strengthening) leak repair requirements, establishing recordkeeping requirements for the disposal of appliances containing five to 50 pounds of refrigerant, (...and also resulted in) changes to the technician certification program, and changes for improved readability, compliance, and restructuring of the requirements."*
- **Prohibition on the use of certain high-GWP HFCs as alternatives (Rule 20)** published August 19, 2015.[12] *Various HFCs and HFC-containing blends that were previously listed as acceptable alternatives under the SNAP program for refrigeration and air conditioning were listed as unacceptable. The action also changed the status from acceptable to unacceptable for certain hydrochlorofluorocarbons (HCFCs) being phased out of production under the Montreal Protocol.[13] The rule specifically affected retail food refrigeration equipment and vending machines, specifying a timetable for discontinuing use of the indicated refrigerants. See Table 3 for the end-use conditions, affected refrigerants and decision effective date.*
- **New listings/changes of listing status and revision of Clean Air Act propane venting prohibition (Rule 21)** published September 26, 2016.[14] *Within the refrigeration and air conditioning (and several other) sectors, this rule expanded the list of acceptable substitutes - subject to use conditions, listed unacceptable substitutes, and changed the status of a number of substitutes that were previously listed as acceptable, based on information showing that other substitutes are available for the same uses that pose lower risk overall to human health and/or the environment. This rule also lists propane as acceptable, subject to use conditions, as a refrigerant in certain new equipment and exempts it in these end-uses from the venting prohibition. See Table 1.*

Though not directly related to the scope of this paper, it is worth noting that EPA SNAP has not extended the hydrocarbon rule to automotive air conditioning pending additional research and analysis.

Table 1 EPA SNAP Proposed Acceptable Alternatives[15]

End-Uses	Substitutes	Proposed Effective Date
Refrigeration		
Commercial ice machines (new)	Propane	30 days after publication of a final rule

Proposed Unacceptable Alternatives

End-Uses	Substitutes	Proposed Effective Date
Air Conditioning (AC)		
Residential and light commercial AC and heat pumps – unitary split AC systems and heat pumps (retrofit)	All ASHRAE Flammability Class 3 Refrigerants	30 days after publication of a final rule
Residential and light commercial AC and heat pumps (new)	Propylene, R-443A	30 days after publication of a final rule
Centrifugal chillers and positive displacement chillers (new)	Propylene, R-443A	30 days after publication of a final rule
Refrigeration		
Cold storage warehouses (new)	Propylene, R-443A	30 days after publication of a final rule

Proposed Change of Listing Status

End-Uses	Substitutes	Proposed Effective Date
Air Conditioning		
Centrifugal chillers (new)	FOR12A, FOR12B, HFC-134a, HFC-227ea, HFC-236fa, HFC-245fa, R-125/134a/600a (28.1/70/1.9), R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-410A, R-410B, R-417A, R-421A, R-422B, R-422C, R-422D, R-423A, R-424A, R-434A, R-438A, R-507A, RS-44 (2003 composition), and THR-03	Unacceptable, except as otherwise allowed under a narrowed use limit, as of January 1, 2024
Centrifugal chillers (new)	HFC-134a for military marine vessels and for human-rated spacecraft and related support equipment	Acceptable, subject to narrowed use limits, as of January 1, 2024
Centrifugal chillers (new)	R-404A for human-rated spacecraft and related support equipment	Acceptable, subject to narrowed use limits, as of January 1, 2024

End-Uses	Substitutes	Proposed Effective Date
Positive displacement chillers (new)	FOR12A, FOR12B, HFC-134a, HFC-227ea, KDD6, R-125/134a/600a (28.1/70/1.9), R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-410A, R-410B, R-417A, R-421A, R-422B, R-422C, R-422D, R-424A, R-434A, R-437A, R-438A, R-507A, RS-44 (2003 composition), SP34E, and THR-03	Unacceptable, except as otherwise allowed under a narrowed use limit, as of January 1, 2024
Positive displacement chillers (new)	HFC-134a for military marine vessels and for human-rated spacecraft and related support equipment	Acceptable, subject to narrowed use limits, as of January 1, 2024
Positive displacement chillers (new)	R-404A for human-rated spacecraft and related support equipment	Acceptable, subject to narrowed use limits, as of January 1, 2024
Refrigeration		
Cold storage warehouses (new)	HFC-227ea, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-423A, R-424A, R-428A, R-434A, R-438A, R-507A, and RS-44 (2003 composition)	Unacceptable, as of January 1, 2023
Retail food refrigeration – refrigerated food processing and dispensing equipment (new)	HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-44 (2003 formulation	Unacceptable, as of January 1, 2021
Household refrigerators and freezers (new)	FOR12A, FOR12B, HFC-134a, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-426A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), RS-44 (2003 formulation), SP34E, and THR-03	Unacceptable, as of January 1, 2021

Today, the US still has neither ratified the Kyoto Protocol nor is it a signatory to the subsequent Doha Amendment[16] but continues to be actively involved in the process of phasing out HCFC refrigerants. HCFCs may not be produced for new equipment after 2020 and no production or import of any HCFCs will be permitted after 2030. HCFCs R22 and R-142b were previously phased out (2010) for new equipment.[17] See Table 2 for the phaseout schedule.

Table 2 US Action to Meet the Montreal Protocol HCFC Phaseout Schedule[18]

Implementation Date	Details of Phase out	Reduction Date	Percent Reduction in HCFC Consumption and Production From Baseline
2003	No production or import of HCFC-141b	2004	35.0%
2010	No production or import of HCFC-142b and HCFC-22, except for use in equipment manufactured before January 1, 2010	2010	75.0%
2015	No production or import of any other HCFC's, except as refrigerants in equipment manufactured before January 1, 2020	2015	90.0%
2020	No production or import of HCFC-142b and HCFC-22	2020	99.5%
2030	No production or import of any HCFC's	2030	100.0%

One of the significant new alternative refrigerants introduced in response to the CFC and HCFC phaseouts was hydrofluorocarbon (HFC). The HFC R-134a refrigerant, among others, became a widely used substitute. Without the chlorine atom present in CFCs and HCFCs, HFCs are not considered significant ODP substances; however, these refrigerants have high GWP and, therefore, certain HFCs are being targeted for phaseout.

In addition to the implementation of EPA SNAP Rule 20 (see Table 3), and with the recently concluded Kigali Amendment (October 15, 2016), the US *"will freeze the production and consumption of HFCs by 2018, reducing them to about 15 percent of 2012 levels by 2036."*[19]

Potentially complicating matters for planners, on September 19, 2016, California enacted its own law intended to drive reduction in the use of HFCs. *"The science unequivocally underscores the need to immediately reduce emissions of short-lived climate pollutants (SLCPs), which include ... fluorinated gases (F-gases, including hydrofluorocarbons, or HFCs)."*[20] Proposed by the California Air Resources Board (CARB), the law established *"planning targets to reduce emissions of methane and HFCs by 40 percent below current (2013) levels by 2030..."*[21] The particulars include prohibiting the sale or distribution of refrigerants with GWP of 2500 or greater (beginning January 1, 2020) and limiting the use of high-GWP refrigerants for stationary refrigeration and air conditioning as described in Table 4. Additional details were described during a public workshop in May 2016[22] and in a subsequent fact sheet.[23]

Table 3 EPA SNAP Status Changes for High GWP HFCs[24]

Retail Food Refrigeration		
End-Use	**Substitutes**	**Decision**
Supermarket Systems (Retrofit)	R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	Unacceptable as of July 20, 2016
Supermarket Systems (New)	HFC-227ea, R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	Unacceptable as of January 1, 2017
Remote Condensing Units (Retrofit)	R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	Unacceptable as of July 20, 2016
Remote Condensing Units (New)	HFC-227ea, R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	Unacceptable as of January 1, 2018
Stand-Alone Units (Retrofit)	R-404A, R-507A	Unacceptable as of July 20, 2016
Stand-Alone Medium-Temperature Units+ with a compressor capacity below 2,200 Btu/hour and not containing a flooded evaporator (New)	FOR12A, FOR12B, HFC-134a, HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-426A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), RS-44 (2003 formulation), SP34E, THR-03	Unacceptable as of January 1, 2019
Stand-Alone Medium-Temperature Units with a compressor capacity equal to or greater than 2,200 Btu/hour and Stand-Alone Medium-Temperature Units containing a flooded evaporator (New)	FOR12A, FOR12B, HFC-134a, HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-426A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), RS-44 (2003 formulation), SP34E, THR-03.	Unacceptable as of January 1, 2020
Stand-Alone Low-Temperature Units++ (New)	HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-44 (2003 formulation)	Unacceptable as of January 1, 2020
+ *"Medium-temperature" refers to equipment that maintains food or beverages at temperatures above 32°F (0 °C).* ++ *"Low-temperature" refers to equipment that maintains food or beverages at temperatures at or below 32°F (0 °C).*		
Vending Machines		
End-Use	**Substitutes**	**Decision**
Retrofit	R-404A, R-507A	Unacceptable as of July 20, 2016
New	FOR12A, FOR12B, HFC-134a, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-410A, R-410B, R-417A, R-421A, R-422B, R-422C, R-422D, R-426A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), SP34E	Unacceptable as of January 1, 2019

Table 4 High-GWP Refrigerant Prohibitions in New Stationary Systems[25]

Stationary Refrigeration or Stationary Air-Conditioning Sector	Refrigerants Prohibited in New Equipment with a 100-year GWP Value:	Start Date
Non-residential refrigeration	150 or greater	January 1, 2020
Air-conditioning (non-residential and residential)	750 or greater	January 1, 2021
Residential refrigerator-freezers	150 or greater	January 1, 2021

In Canada, Environment and Climate Change Canada (ECCC) is in the process of proposing product-specific requirements that will set global warming potential limits. See Table 5.

Mexico's Climate Change General Law similarly recognizes the goal of reducing greenhouse gases, but no mandatory product-specific reductions are currently specified.[27]

Table 5 Proposed Product-Specific Controls – Canadian Refrigeration and Air Conditioning Sector (March 2016)[26]

Product	GWP Limit	Proposed Timeline
Mobile air-conditioning	150	2021 model year
Stand-alone medium temp commercial refrigeration	650	2020
Stand-alone low temp commercial refrigeration	1500	2020
Centralized refrigeration	1500	2020
Chillers (air conditioning only)	700	2025
Domestic refrigeration	150	2025
Mobile refrigeration	2200	2025

Appliance Industry Phaseout of HFCs

While the aforementioned drivers for change have been regulatory, industry and other stakeholders have also contributed to the changing landscape. One notable ongoing stakeholder partnership is the research program funded by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and the U.S. Department of Energy (DOE), *"…part of an ongoing global effort to phase down the use of high global warming potential (GWP) refrigerants and identify appropriate climate-friendly alternatives."*[28]

In addition, *"the Association of Home Appliance Manufacturers (AHAM) announced on February 9, 2016 a goal — for which it is seeking the support of government and safety authorities — to voluntarily phase down the use of hydrofluorocarbon (HFC) refrigerants used in household refrigerators and freezers after 2024."*[29] AHAM indicated that the goal enables safety, energy efficiency, component compatibility and other considerations to be adequately addressed. They also indicated the *"timetable is longer for room air conditioning products given the added work needed to address viable alternatives and building codes for multi-housing units."* Note that EPA SNAP Rule 21 subsequently set the phase-out to be by January 2, 2021 (see Table 3).

Emergence of A2L Alternatives

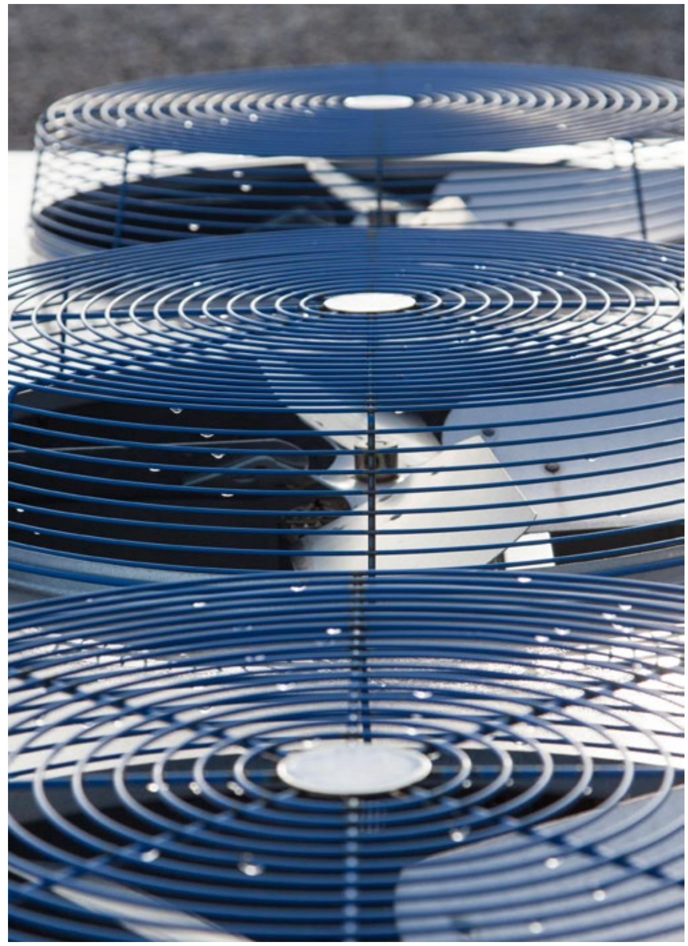
The ANSI/ASHRAE 34 *(Designation and Safety Classification of Refrigerants)* and ISO 817 *(Refrigerants - Designation and safety classification)* standards each have a safety group classification system for refrigerants. The letter prefix "A" is used to designate "lower toxicity" while the "B" prefix refers to "higher toxicity." The number (1, 2 or 3) indicates flammability with 3 being the most flammable. For decades, the only safety classes of refrigerant used for household/commercial refrigeration and air-conditioning equipment were A1 types and, for certain refrigeration applications, one B2 type (R-717, ammonia). More recently, the safety classification system was expanded to include the option of an "L" suffix which for class 2 refrigerants exhibiting a "low burning velocity."[30]

Although the door was always open to the potential for use of flammable refrigerants (within limitations), the EPA rulemaking opened it more widely such that class A2 and A3 refrigerants are increasingly being developed and appearing in the market. Due to continuing concerns about using the more flammable refrigerants in equipment requiring larger charge sizes (most notably, air-conditioning equipment), the A2L refrigerant class has received increased attention.

An example of a class A2L refrigerant is R-1234yf, an HFO used as a replacement for R-134a in automotive air conditioning. Another is R-32, used for air conditioning in markets outside the US. To facilitate the use of R-32 in the US market, a significant amount of research on its properties has been and will continue to be done. More information on this research will come later in the document.

Summary

To summarize developments to date, in 2011 it was reasonable to assume flammable refrigerants would be introduced into the US market, and by 2016 this was already accomplished in part and the market was poised for a significantly greater expansion of their use. That being said, there remains market uncertainty due to the political change that is underway in the US, potentially compounded by state regulations that may not align with federal regulations and are already or may be emerging. Regardless, one thing is certain: The arcane landscape observed by the UL Flammable Refrigerant Stakeholder Forum in 2011 is now abuzz with interest and activity.



Installation Code/Standard Making Bodies Respond

As the environmental and energy efficiency regulatory framework and commitments — both domestic and international — are increasingly driving the US market toward flammable refrigerants, how have product safety and installation safety standards and codes kept up?

Standards and code making bodies have been carefully attending to the details necessary for successful and safe implementation of the regulations. In the US, there are a variety of installation codes and standards addressing refrigeration and air-conditioning equipment. These typically depend upon such equipment complying with product safety standards. All of the nationally significant standards and codes are developed via voluntary, consensus processes,[31] each on its own timetable. Stakeholders often participate on multiple consensus standards development committees and seek to coordinate requirements development so that technical requirements are implemented in a consistent manner and timing across the many inter-related documents.

Technical requirements are published by AHRI, ASHRAE, The International Association of Plumbing and Mechanical Officials (IAPMO), International Code Council (ICC), The International Electrotechnical Commission (IEC), International Organization for Standardization (ISO), The National Fire Protection Association (NFPA), and UL, among others. The following section highlights relevant standards/requirements having an impact on the safety of flammable refrigerants.

ANSI/ASHRAE 15 – Safety Standard for Refrigeration Systems

ANSI/ASHRAE 15 is a standard *"directed toward the safety of persons and property on or near the premises where refrigeration facilities are located. It includes specifications for fabrication of tight systems but does not address the effects of refrigerant emissions on the environment."*[32] Depending upon the refrigerating system classification and the refrigerant safety classification (including any restrictions on refrigerant use), the standard specifies installation restrictions, design and construction criteria for equipment and systems, and additional requirements relevant to the safe installation of such equipment.

With exceptions, the standard permits installation of equipment with a flammable refrigerant charge provided that a leak in the occupancy cannot result in concentration limits (in g/m^3) greater that that specified for the refrigerant used as cited in ANSI/ASHRAE 34 (Tables 4.1 and 4.2).[33] Instead of applying the concentration limit requirement, self-contained systems can have a flammable refrigerant charge of up to 3 kg in residential occupancies and 10 kg in commercial occupancies,[34] but not for flammability class A3 refrigerants unless approved by the AHJ and generally the AHJ will require the equipment to be listed. Applications for comfort cooling (air conditioning) are similarly limited to a charge up to 3 kg in residential occupancies and 10 kg in commercial occupancies for flammability sub-class A2L refrigerant.[36]

AHJ approval is required for any installation of equipment employing flammability class A3 refrigerant except for listed portable units with a 150 g or less charge of flammability class A3 refrigerant.[37]

Industrial occupancies, institutional occupancies, refrigeration machinery rooms and, in some cases, corridors / lobbies are subject to additional requirements for the particular application. They include cumulative charge limits for all installed equipment, gravity and mechanical ventilation and charge limits. Note that there are some additional exceptions to these requirements for sealed ammonia/water absorption systems. As has been the case for decades, ammonia is a special case.[38]

In 2014, the standard was updated to provide additional details on the safe outdoor venting of refrigerants.

The Standing Standard Project Committee responsible for ANSI/ASHRAE 15 (SSPC15) has been continuously maintaining the standard and formed an ad hoc working group for 2L refrigerants. It is currently considering proposed addenda to ANSI/ASHRAE 15 that address high probability systems[39] for human comfort and machinery rooms. High probability systems include comfort cooling equipment as described in Table 6.

Table 6 High Probability Systems *(as contemplated by SSPC 15, June 2016)*

Indoor	Indoor and Outdoor		Outdoor (entire system)
	Packaged	Field Assembly	
Water-cooled Self-contained Water Source Heat Pump Portable equipment	Room Air Conditioners[a] Packaged Terminal Air Conditioners[a] Rooftop Units[b]	Mini/Multi-splits[a] VRF[a] Split Chiller[a] Residential/Commercial Split Air Conditioner/Heat Pump[b]	n/a
a Ductless b Ducted			

The SSPC 15 technical committee is also actively pursuing development of proposed SPC 15.2P (Safety Standard for Air-conditioning and Heat Pump Systems in Residential Applications). According to the currently proposed scope, the *"standard applies to Listed residential refrigeration systems, such as split-system air-conditioners, single-package air-conditioners, split-system heat pumps, single-package heat pumps, whole house dehumidifiers, whole house dehumidifying ventilators and permanently connected heat pump water heaters."*[40] The scope further describes the covered residential dwellings. The standard is not applicable to self-contained, cord-connected products.

ANSI/ASHRAE 34 – Designation and Safety Classification of Refrigerants

ANSI/ASHRAE 34 is the standard that provides us with the familiar "R" designation for refrigerants. During the current period of new refrigerant development, the standard is being regularly updated to include these refrigerants (mostly blends) along with introducing/refining methods used to characterize refrigerant properties. As previously noted, in 2010, the concept of an A2L refrigerant was introduced as a subclass to the already existing class A2. An A2L refrigerant is a *"class 2 refrigerant with a burning velocity less than or equal to 10 cm/s."*[41]

In 2016, there were a number of A2L refrigerants added to ANSI/ASHRAE 34. R-32, R452B, R-455A, and R1234yf are the primary A2L refrigerants (alone or blended with other refrigerants) in use or seriously contemplated. The latter is used in automotive air conditioning applications and air-conditioning is the expected principal application for A2L refrigerants. The potential value of A2L refrigerants can only be realized when the standards and codes begin to handle them differently from class A2, and this work is underway.

There have been fifteen new A2L refrigerant designations published since the "L" subclass was established and there were a total of seventeen such classifications as of July 2016. R-32 and R143a were existing designations that were changed from A2 to A2L when the "L" sub-class was established. R-717 (ammonia) was an existing B2 that became a B2L.

Increasingly, the formulations of refrigerants and refrigerant blends are approaching the flammable/non-flammable threshold. This is expected to require the consensus committees to further refine the means by which the distinction is determined.

Flammable refrigerants used in new equipment are generally understood to have a minimum purity of 99.5% by weight[42] and conform to AHRI Standard 700 (Specification for Refrigerants) in purity unless otherwise specified by the equipment manufacturer.[43] Though not an "impurity," it was originally postulated during the UL Flammable Refrigerant Stakeholder Forum that refrigeration system lubricants could contribute to the potential for fire in the event of a refrigerant leakage. While this possibility continues to be studied, it has not had a substantive impact on the ANSI/ASHRAE requirements to date except for the stipulation that the original refrigerant/lubricant combination be retained in any reclamation/recycling.

Much consideration was originally given to whether hydrocarbon refrigerants should be odorized since leakage of un-odorized hydrocarbon refrigerant systems in household and commercial applications could result in an undetectable flammable gas–air mixture in the occupancy. Industry expert feedback in the interim was that traditional odorization compounds (e.g. thiols or mercaptans) used successfully with natural gas were not compatible with HVAC systems. Though occasional interest is raised, there has been insufficient evidence of a need to pursue research on odorization compounds or otherwise revisit this topic.

Fire and Mechanical Codes

While the adoption of specific alternative refrigerants is driven at the US Federal policy and regulatory level, it is the responsibility of the states and thousands of local AHJs to determine what equipment is acceptable for installation within their jurisdictions. It would be especially daunting to implement changes at the very local levels, one at a time. Fortunately, the US employs a system of model codes which are produced by experts representing appropriate stakeholders and adopted at state and local levels. There can be and are local variations to the model codes but this is not so widespread as to be problematic.

The codes are promulgated by three different publishing bodies (IAPMO, ICC, NFPA) with some scope duplication (see Table 7). They are adopted regionally and, for refrigerants applications, are reasonably well aligned.

Table 7 Code Publishing Organizations

Code Publisher		Code	Latest Edition
IAPMO	International Association of Plumbing and Mechanical Officials	Uniform Mechanical Code (UMC)	2015
ICC	International Code Council	International Mechanical Code (IMC) International Residential Code (IRC) International Fire Code (IFC)	2015 2015 2015
NFPA	National Fire Protection Association	Fire Code (NFPA 1)	2015

Uniform Mechanical Code (UMC)

The UMC Model Code substantially relies upon ANSI/ASHRAE 15 and 34 (Chapter 11). It currently specifies that in *"nonindustrial occupancies, Group A2, A3, B1, B2 and B3 refrigerants shall not be used in high-probability systems for human comfort."*[44]

IAPMO has received proposed revisions to the UMC to further align with ANSI/ASHRAE 15, including addressing A2L refrigerants. In response, IAPMO formed a task group *"to review all of the A2L proposed code changes and propose recommendations to coordinate the requirements with a pending update to ANSI/ASHRAE 15; provide recommendations as to how the UMC should address the A2L low global warming potential refrigerants."*[45] The recommendations of the task group will be referred to the relevant technical committee as it addresses the content of the 2018 edition of the code.

International Mechanical Code (IMC), International Residential Code (IRC), International Fire Code (IFC)

The ICC Model Codes are coordinated such that the technical requirements in each are consistent and the responsible technical committee determines the content regardless of the code in which it may appear. For example, requirements associated with fire hazard in the IMC are addressed by the committee responsible for the IFC. They are on the same three year maintenance cycle with the next editions of each (2018) already under review.

The 2015 IMC is substantially aligned with ANSI/ASHRAE 15 and 34. The refrigeration requirements are specified in Chapter 11. The 2015 IRC Section M1411 addresses heating and cooling equipment. It references the relevant product safety standards and has requirements addressing protection of refrigerant piping and access to refrigerant circuit ports located outdoors. There are no current proposals to amend it to include A2L refrigerants.

Relevant 2015 IFC requirements are in Section 606, which refers to the IMC for refrigeration systems. It additionally specifies that, *"refrigeration systems having a refrigerant circuit containing more than … 30 pounds (14 kg) of any other group refrigerant shall be accessible to the fire department at all times as required by the fire code official."*[46] For large refrigeration systems, such as in supermarkets, this becomes an important consideration.

Similar to the UMC, the IFC has a number of proposals to better align it with the ANSI/ASHRAE standards and to address A2L refrigerants. These include provision of a refrigerant detection system that operates emergency mechanical ventilation in the event of a leak.

NFPA

NFPA 1 addresses the installation of mechanical refrigeration in Chapter 53 and is applicable where more than 30 pounds (13.6 kg) of flammable refrigerants are present in any refrigeration unit or system installation. For large equipment, NFPA 1 references ANSI/ASHRAE 15 and specifies that vapor discharge to the atmosphere *"shall be through an approved treatment system... or flaring system"*[47] for refrigerants having a density equal to or greater than the density of air. For other refrigerants, discharge to the atmosphere is acceptable *"provided that the point of discharge is located outside of the structure and not less than 15 feet (4.6 m) above the adjoining grade level and not less than 20 feet (6.1 m) from any window, ventilation opening, or exit."*[48]

Summary

Code adoption is an important part of market acceptance of flammable refrigerant equipment. Code making bodies rely heavily on product safety standards for equipment while focusing on where and how such equipment can be installed. There is increasing acceptance of class A2L refrigerants, though the code development and adoption process will continue to require coordination and time for this class of refrigerants to be widely accepted. It is anticipated that this process will not be completed until 2021 or 2022. It is worth observing that the potential presence of flammable refrigerants in appliances has not yet resulted in changes or proposals to change the fire hazard classification of the appliances or the distribution and storage facilities where these appliances will be kept prior to installation.

Product Safety Standards Committees Respond

Responding to regulatory and other demand drivers, equipment manufacturers are studying alternative refrigerants for their efficacy in refrigeration and air conditioning applications. Table 8 illustrates product categories that already have global experience with selected flammable refrigerants and where it is considered feasible to implement them. Product safety standards developers take this type of information into account in the prioritization and development of requirements for these applications.

Table 8 Emerging Trends in Alternative Selection[49]

	R-600a	R-290	R-32
Domestic refrigeration	C		
Commercial refrigeration			
- Stand-alone equipment	C	C	F
- Condensing units	F	L	F
- Centralized systems		L	F
Transport refrigeration		C	F
Large size refrigeration		L	F
Air conditioners and heat pumps			
- Small self-contained		C	L
- Mini-split (non-ducted)		C	C
- Multi-split			L
- Split (ducted)		F	L
- Ducted split commercial and non-split		L	L
- Hot water heating HPs	C	C	L
- Space heating HPs	L	C	L
Chillers			
- Non-displacement		C	L
- Centrifugal		L	

"C" indicates current use on a commercial scale
"L" indicates limited use such as for demonstration, trials, niche applications, etc.
"F" indicates use is potentially feasible on a commercial scale, based on fluid characteristics

UL Product Safety Standards Updates

Product safety standards are developed following a voluntary, consensus process accredited by the American National Standards Institute (ANSI). Standards are developed and maintained by Standards Technical Panels (STPs) that represent a balanced interest of stakeholders. These stakeholders can vary according to the product in question. Therefore, one challenge for these standards developers is keeping the many different standards up to date, technically consistent with each other and with all relevant regulations and externally referenced documents.

One immediate conclusion drawn from the Stakeholder Forum was the need for formal coordination of the STPs involved with flammable refrigerants so that consistency could be achieved. UL fulfilled this need when it formed a Joint Task Group (JTG) of STP members and other key stakeholders with the objective to develop recommendations to the appropriate UL STPs regarding key issues for the safe use of flammable refrigerants. The key issues were as follows:

- *Identify current UL Standards status regarding flammable refrigerants.*
- *Identify safety concerns regarding the safe use of flammable refrigerants.*
- *Consider common framework recommendations.*
- *Establish working groups where appropriate.*

Before beginning to revise the aforementioned standards, a framework was established for this work. That framework led to the current UL requirements for products employing flammable refrigerants as cited in Table 9.

Table 9 Status of Flammable Refrigerant Charge Requirements in UL Standards

UL Standard	Charge Limits oz (g)		Comments
	A2	A3	
UL 250, Household Refrigerators and Freezers	8.0 (225)	2.0 (57)	
UL 399, Drinking-Water Coolers	9.6 (270)	2.0 (60)	
UL 427, Refrigerating Units	17.7 (500)	5.3/10.6 (150/300)	The A3 charge size can increase to 10.6 oz (300 g) if leak detection or minimum room volume provided.
UL 471, Commercial Refrigerators and Freezers	17.7 (500)	5.3 (150)	
UL 474, Dehumidifiers	NA	NA	No flammable refrigerant requirements are being developed based on requirements proposed to UL 60335-2-40
UL 484, Room Air Conditioners	3 x LFL+	3 x LFL+	For propane (R-290), charge limit is 3 x 0.038 = 0.114 kg (114 g)
UL 541, Refrigerated Vending Machines	17.8 (500)	5.3 (150)	
UL 563, Ice Makers	17.7 (500)	5.3 (150)	
UL 621, Ice Cream Makers	NA	NA	No requirements being developed (no demand from industry for them).
UL 1963, Refrigerant Recovery/Recycling Equipment	See Comments	See Comments	Equipment must comply with Class 1, Div. 2 (or similar) requirements. Special requirements apply to hoses. Class A2L requirements have been developed.

UL Standard	Charge Limits oz (g)		Comments
	A2	A3	
UL 1995, Heating and Cooling Equipment	NA	NA	No flammable refrigerant requirements are being developed based on requirements proposed to UL 60335-2-40
UL 60335-2-24	8.0 (225)	1.7 (50)	Increased charge limits are presently being discussed.
UL 60335-2-40	NA++	NA++	Present version does not permit flammable refrigerants. 2nd Edition includes flammable refrigerants and will be re-balloted in Q1 2017++. A2L requirements are being developed with balloting in Q1 2017.

\+ - LFL: Refrigerant Lower Flammable Limit expressed in kg/m^3
++ - Changes proposed to UL 60335-2-40 for "direct" systems have the same charge limits as UL 484 above. For "indirect" systems, the proposed charge limit is 130 x LFL where an "indirect" system must be installed outdoors or in a machine room.

NOTE: Except for UL 1963, there are presently no A2L requirements for the above standards.

The charge limit for flammable refrigerants in specific equipment remains a principal area of concern for safety. Some manufacturers selling equipment in markets outside the US and advocates for "natural refrigerants"[50] have sought higher charge limits than currently permitted by the US product safety standards or the aforementioned framework. Of particular interest is the charge limit of household refrigerators and freezers, commercial refrigerators and freezers, and "packaged" air conditioning units (e.g. window units and packaged terminal units).

The current charge limits for refrigerators and freezers are based on research done in the 1990s on equipment typically available in the US market. Assumptions regarding the probability and nature of leakage, gas accumulation, gas dispersal and the presence of ignition sources were taken into account, along with laboratory test results. Market experience outside the US, additional research and analysis and, of course, the demand for alternative refrigerants has renewed interest in additional laboratory research testing of US-style equipment/installations employing flammable refrigerants. One such analysis (probability of ignition due to a leak[51]) is prompting revisiting the current 150 g charge limit for A3 refrigerants by the relevant standards committee for household refrigerators and freezers.

Air conditioning equipment followed a different track with respect to charge limits. Because comfort cooling was not permitted to employ flammable refrigerants, the charge limits were not initially set until much later than for refrigeration equipment. In 2011, UL 484 established a limit of 26 x the lower flammable limit (LFL) for room volumes greater than 4 m^3 and up to 26 m^3. This equates to 1 kg for propane. This limit was established, in part, to begin aligning with the International Electrotechnical Commission (IEC) requirements of IEC 60335-2-40. However, the installation codes did not permit flammable refrigerants in comfort cooling, so the charge limit was arguably useful only for specially approved trial installations and not mass produced air conditioning equipment. Subsequently, efforts to harmonize with the IEC requirements brought greater attention to the subject of charge limits.

The voluntary consensus committee addressed new (not previously discussed) concerns raised by stakeholders regarding off-season storage of window units and operation of units in relatively confined spaces (e.g. ticket booths) and lowered the charge limit to 3 x LFL (e.g. 114 g of propane). This was not without controversy and is an ongoing subject of STP discussion. At the time this paper is being prepared, there is an active proposal to revert to the earlier and higher charge limit for room air conditioners.

Maintaining consistency between product safety standards, the installation codes and government regulations is often not a technical challenge, but one of timing as each relevant document is maintained and published on its own timetable. However, the membership of committees responsible for the standards, codes and regulations are not identical, meaning technical differences in the requirements can be introduced and may need to be reconciled to avoid marketplace confusion.

The foregoing being typical, there have been several recent instances where requirements typically addressed in product safety standards (e.g. provision for valves, color coding), have been promulgated via US Federal regulation. While it is the prerogative of the government rulemaking process to do so, it puts the STPs and product safety standards in the position of having to "catch-up" with such regulations and can discourage participation in the voluntary consensus process. Comments to this effect were submitted by UL on recent rulemaking and were well received.

Technical differences in requirements can and do occur, as is the case between US and IEC standards. These sometimes simply reflect a different but equivalent approach to arriving at the same basic safety requirement. The standards harmonization process underway within North America and with IEC and ISO standards is effective in eliminating or reducing such differences.

Other differences can be more difficult to eliminate, especially where they may be based upon national regulatory requirements (e.g. EPA SNAP regulations, local installation codes), basic safety principles and requirements (e.g. assumed use conditions for the marketplace in question) or existing safety practices (e.g. minimizing indoor storage of flammable gases). Standards found suitable for one global market may need to be modified for application in another; this is common in IEC standards where the differences are known as "in some country" clauses. Fortunately, there is global consensus to minimize differences and much effort goes into accomplishing this goal. See Table 10 for the identity of key safety standards development committees in the US and their international counterparts.

Table 10 Key Safety Standards Development Committees

US (UL)*	International (IEC/ISO)	Comments on US Standard
Air Conditioning		
STP474		Includes UL 484. The two legacy UL standards (474/484) will be replaced by UL60335-2-40
STP60335-2-40 CANENA WG 6	IEC SC 61D IEC SC 61D WG11 IEC SC 61D WG16	Addressing publication of tri-national UL60335-2-40 based on IEC standard.
STP60335-2-40 CANENA WG 10	IEC SC 61D WG 9	At CDV stage in IEC with proposal for A2L refrigerants. Class A2L refrigerants are conservatively treated as Class A2 refrigerants. All air conditioning/heat pump equipment shall be self-contained factory sealed, factory charged (no field equipment charging) and without service ports.
STP60335-2-40 CANENA WG 11		Addressing phase out of UL 1995
Motor Compressors		
STP60335-2-34 CANENA WG 7	IEC SC61C MT 1	
Refrigerants		
STP2182	ISO TC 86/ SC 8	UL 2182 revisions to more closely harmonize the flammability testing with ASHRAE 34 and ISO 817 are underway. ISO TC85/SC8 is currently drafting the first normative test method standard for burning velocity.

US (UL)*	International (IEC/ISO)	Comments on US Standard
Commercial Refrigeration		
STP471 THC471	IEC SC61C WG 4	Also known as CANENA WG 5 even though only a bi-national standard effort. If IEC 60335-2-89 adopts 13m2 x LFL, as is being considered, this would mean an approx. charge limit of 4 kg for R-32. This would be sufficient for most self-contained refrigerated display cases.
Household Refrigeration		
STP250, THC250	IEC SC61C	
* The US consensus committee is known as a UL STP (Standards Technical Panel). Where the relevant standard is a bi-national (US/Canada) standard, there is a Technical Harmonization Committee (THC) process step before the STP decides via ballot on the standard. A tri-national (US/Canada/Mexico) standard has a THC process step as well. This is done under the auspices of CANENA and the THC is known as a Working Group (WG).		

Summary

Over the past several years, the technical challenges involved in using flammable refrigerants within various refrigeration and air conditioning equipment were thought to have been largely resolved. The recommendations provided by the UL JTG were instrumental for updating many standards to include requirements covering equipment intended for use with these flammable refrigerants and serve as the basis for needed future standards work. However, the dynamic regulatory and market conditions environments are demanding additional work by industry stakeholders to address the implementation of higher than contemplated refrigerant charge limits and the use of A2L refrigerants in comfort cooling equipment.

Research

Product safety standards and installation codes need to be predicated on good safety science. As was noted, there are differences in technical requirements in the standards that need to be reconciled. Flammable refrigerants are essentially "new" to the US marketplace that has somewhat unique characteristics compared to other markets (e.g. larger appliances, extensive use of window air conditioners, high DIY ethic). Therefore, what might be considered "settled science" in other markets is not automatically considered so in the US. For this reason, extensive research is underway to consider the impact of implementing flammable refrigerant use in the US, especially regarding the consequences of installation, equipment, and personnel "faults" that are known to occur in this market.

A notable Public–Private partnership exists where *"ASHRAE, the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and the U.S. Department of Energy (DOE) are collaborating to fund vital research that will establish a more robust fact base about the properties and the use of flammable refrigerants."*[52]

AHRI is hosting a *"research initiative to find more environmentally friendly alternatives to high global warming potential refrigerants. ...(Their) Low Global Warming Potential Alternative Refrigerants Evaluation Programme (Low-GWP AREP) is testing 15 new low-GWP refrigerant candidates. When the programme first began, the goal was to test and evaluate promising alternative refrigerants for major product categories, including air conditioners, heat pumps, chillers, ice makers and refrigeration equipment. After successfully completing this first phase in December 2013, AHRI continued research in areas that were not previously addressed: refrigerants in high ambient conditions (ie warmer climates); refrigerants in applications not tested in the first phase; and new refrigerants identified since testing for the programme began."*[53]

"AHRI's research arm has identified six key research topics:

- *Benchmarking risks from real-life leak and ignition testing*
- *Assessing flammable refrigerants' post-ignition risk*
- *Determining set charge limits for various types of equipment employing flammable refrigerants*
- *Investigating hot surface ignition temperature for A2L refrigerants*

- *Creating a guide to A2L refrigerant handling and system installation and servicing*
- *Detecting A2L refrigerant leaks in HVACR equipment"*[54]

Additional topics being addressed by ASHRAE include:

- Servicing and installing equipment using flammable refrigerants: Assessment of field-made mechanical joints [ASHRAE WS 1808]
- Guidelines for flammable refrigerant handling, transporting, storing and equipment servicing, installation and dismantling [ASHRAE WS 1807]
- Flammable refrigerants post-ignition simulation and risk assessment update [ASHRAE TRP 1806]

The body of knowledge relevant to the US market will be greatly increased as the results of these research projects become known.

Training Installers, Service Personnel, Disposal Personnel

The 2011 Stakeholder Report observed: *"No public training or certification program is known to exist for service technicians and other handlers of flammable refrigerants during servicing and disposal. "EPA 608" requires a one-time certification of technicians working with ozone depleting substances and EPA develops the test(s) for certification that are administered by organizations recognized by EPA. This certification is not required for hydrocarbon refrigerant service technicians."*

Since then, a number of training initiatives have been developed and implemented. They focus on raising awareness of the hazards involved in servicing equipment with flammable refrigerants and on practices to minimize the risks.

Awareness of the risks with flammable refrigerants remains a key concern. ANSI/ASHRAE 15 has long had a requirement addressing a change in the type of refrigerant used in equipment already installed in the field (Clause 5.3). This has taken on increased significance as some in the market have replaced the original non-flammable refrigerant with a flammable refrigerant.[55] US EPA issued several warnings and recently took an enforcement action[56] regarding improper refrigerant substitutions.

Raising awareness concerning the hazards of substituting flammable refrigerants for others will need to be a priority for the foreseeable future. This will need to be accomplished in a variety of ways, including training of technicians and service personnel, use of warnings and instructions, use of color coding to distinguish these from other refrigerants, and general education of the public.

The AHRI 2016 Guideline for Assignment of Refrigerant Container Colors recommends that a *"red band on the shoulder or top of the container should designate flammable compounds, or mixtures that could become flammable in the event of a leak."*[57] However, it no longer seeks to distinguish between containers of different refrigerants via the container color. Instead, required container labels and markings are to be relied upon.[58]

Disposal of refrigerant cylinders

In addition to concerns about venting refrigerant, there are practical concerns associated with the disposal of flammable refrigerant containers. The AHRI 2016 Guideline for Content Recovery & Proper Recycling of Refrigerant Cylinders provides cylinder recycling recommendations. DOT-39 Non-refillable cylinders shall have their contents appropriately recovered, the valve left open, and a hole punched in the cylinder side following a recommended procedure. The hole is to be circled and the word "EMPTY" written adjacent to it. When this process is completed, the cylinder can be appropriately disposed. Refillable DOT cylinders shall be returned to their supplier/owner.[59]

Figure 1 Marking a cylinder prepared for disposal[60]

Shipping

The 2011 White Paper *"Revisiting Flammable Refrigerants"* (page 9) provided a discussion of US Department of Transportation (USDOT) regulations concerning transportation of flammable refrigerant gases (in cylinders as well as in equipment). These materials are described as "Division 2.1" gases in the regulations. The relevant requirements are substantially the same, but the regulations were amended for clarity in the interim. Specifically, shippers are required to comply with 49 CFR Part 173, Subpart G - Gases; Preparation and Packaging. The 49 CFR 173.307 exceptions - materials not subject to the requirements of this subchapter - were expanded for shippers of compressed gases as follows:

(4) Refrigerating machines, including dehumidifiers and air conditioners, and components thereof, such as pre-charged tubing containing:

(i) 12 kg (25 pounds) or less of a non-flammable, non-toxic gas;

(ii) 12 L (3 gallons) or less of ammonia solution (UN2672);

(iii) Except when offered or transported by air, 12 kg (25 pounds) or less of a flammable, non-toxic gas;

(iv) Except when offered or transported by air or vessel, 20 kg (44 pounds) or less of a Group A1 refrigerant specified in ANSI/ASHRAE Standard 15 (IBR, see § 171.7 of this subchapter); or

(v) 100 g (4 ounces) or less of a flammable, non-toxic liquefied gas.

It should be noted that, with respect to household refrigeration equipment with flammable refrigerants, the carrier's own requirements on what they will transport are most relevant.[61]

What does the Future Hold?

Now more than ever, the wide-spread use of flammable refrigerants appears inevitable. Refrigerants such as R-290 and R-600a will be used in commercial and household refrigeration applications, while R-32, alone or blended with other refrigerants, will be used in air conditioning. Numerous others are currently under development and may become the preferred option over time. The regulatory environment will remain a major driver for what will be preferred and how soon the individual and global marketplaces will respond.

Installation codes and product safety standards committees will continue to actively address the use of these refrigerants and will be motivated by the results of the many research initiatives currently underway. Harmonization of technical requirements will remain a priority for global equipment manufacturers and this, too, will keep the committees busy.

As the current major issues are resolved, new issues will surface. Experience will dictate what those issues will be and how they should be handled; fortunately, the stakeholder community will be, by then, well versed in the challenges presented by the use of flammable refrigerants and how best to resolve them.

Eventually, when the implementation of flammable refrigerants has been successful, there will no longer be a need to distinguish them from legacy products. When that day comes, the market will refer to all such materials simply as "refrigerants" and global stakeholders will likely be addressing new market challenges.

References

[1] "Revisiting Flammable Refrigerants," UL White Paper, 2011, http://www.ul.com/global/documents/library/white_papers/UL_WhitePaper_FlammableRefrigerants.pdf

[2] Underwriters Laboratories Inc. Flammable Refrigerant Stakeholder Forum – Report, January 11, 2011.

[3] https://www.epa.gov/snap

[4] A mildly flammable refrigerant (ammonia) has long been permitted for both refrigeration and comfort cooling. It represents a somewhat special case that typically lies outside of the discussion around the use of other flammable refrigerants and equipment.

[5] The designation appeared in both ASHRAE 34 (Designation and Safety Classification of Refrigerants) and ISO 817 (Refrigerants — Designation and safety classification). All refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm are designated class A with the "A" appearing as a prefix to the refrigerant class (e.g. class A2L).

[6] Rough estimate based on UNEP TEAP estimates that take into account years-of-service. UNEP Report of the Technology and Economic Assessment Panel MAY 2014 Vol. 4 Decision XXV/5 Task Force Report Additional Information to Alternative on ODS, page 98, http://42functions.org/Assessment_Panels/TEAP/Reports/TEAP_Reports/TEAP_Task%20Force%20XXV5-May2014.pdf

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[8] Protection of Stratospheric Ozone: Listing of Substitutes for Ozone-Depleting Substances--Hydrocarbon Refrigerants, Final Rule, https://www.gpo.gov/fdsys/pkg/FR-2011-12-20/html/2011-32175.htm, EPA-HQ-OAR-2013-0748

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[14] Protection of Stratospheric Ozone: New Listings of Substitutes; Changes of Listing Status; and Reinterpretation of Unacceptability for Closed Cell Foam Products under the Significant New Alternatives Policy Program; and Revision of Clean Air Act Section 608 Venting Prohibition for Propane, https://www.epa.gov/sites/production/files/2016-09/documents/snap_status_change_rule_2_2060_as80.pdf, EPA-HQ-OAR-2015-0663.

[15] SNAP Fact Sheet, Proposed Rule - Protection of Stratospheric Ozone: New Listings of Substitutes; Changes of Listing Status; Reinterpretation of Unacceptability for Closed Cell Foam Products under the Significant New Alternatives Policy Program; and Revision of Clean Air Act Section 608's Venting Prohibition for Propane, https://www.epa.gov/sites/production/files/2016-03/documents/snap_action_factsheet.pdf

[16] "The Doha Amendment is an amendment to the Kyoto Protocol that was adopted by the Conference of the Parties serving as the meeting of the Parties to the Protocol (CMP) on 8 December 2012 in Doha, Qatar. The Amendment establishes the second commitment period of the Kyoto Protocol, which began on 1 January 2013 and will end on 31 December 2020," https://unfccc.int/files/kyoto_protocol/doha_amendment/application/pdf/frequently_asked_questions_doha_amendment_to_the_kp.pdf

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[27] Regulations and Standards in México for the Use of Natural Refrigerants, Presented at ATMOsphere America 2016 on June 17, 2016 by Agustin Sanchez Guevara, National Coordinator of Ozone Protection Unit in México, http://www.atmo.org/media.presentation.php?id=905

[28] "Bids Solicited For First Project In ASHRAE Flammable Refrigerants Research Program," ASHRAE press release dated Oct 11, 2016, https://www.ashrae.org/news/2016/bids-solicited-for-first-project-in-ashrae-flammable-refrigerants-research-program

[29] Press Release Home Appliance Industry Sets Goal to Eliminate Use of HFC Refrigerants, February 9, 2016, https://www.aham.org/AHAM/News/Latest_News/Home_Appliance_Industry_Sets_Goals_to_Eliminate_Use_of_HFC_Refrigerants.aspx

[30] ANSI/ASHRAE 34 was amended in 2010 to include the A2L classification which differs from A2 in its burning velocity characteristic. An A2L refrigerant is one where the burning velocity is less than 10 cm/s.

[31] Consensus standards development can take different forms. A widely used process, required for a standard or code to be considered an American National Standard, is the process published by ANSI. See ANSI Essential Requirements: Due process requirements for American National Standards, https://share.ansi.org/shared%20documents/Standards%20Activities/American%20National%20Standards/Procedures,%20Guides,%20and%20Forms/2016_ANSI_Essential_Requirements.pdf

[32] ANSI ASHRAE 15-2013, "Safety Standard for Refrigeration Systems," FOREWORD, page 2

[33] Ibid, clause 7.2, page 7.

[34] Ibid, Table 7.4, page 8.

[35] Ibid, clause 7.5.3, page 9.

[36] Ibid, clause 7.5.2, page 9.

[37] Ibid, clause 7.5.3, exception 1, page 9.

[38] International Institute of Ammonia Refrigeration (IIAR) is a good resource for information on ammonia refrigerant.

[39] Two publication public reviews (PPRs) have been submitted for voting by the 2L WG: one for high probability systems and one for machinery rooms. According to 5.2.1 of ANSI ASHRAE 15-2013 a “high probability system” is “any system in which the basic design, or the location of components, is such that a leakage of refrigerant from a failed connection, seal, or component will enter the occupied space.”

[40] ASHRAE Standards, Research & Technology, III Titles, Purposes and Scopes, July 2016, Standards, SPC 15P, https://www.ashrae.org/standards-research--technology/standards--guidelines/titles-purposes-and-scopes#spc15-2

[41] ANSI ASHRAE 34-2010, “Designation and Safety Classification of Refrigerants,” Foreword, page 2

[42] Ibid, clause 6.1.3, page 15.

[43] ANSI/ASHRAE 15-2013, Refrigerant type and purity, clause 7.5.1.3, page 8.

[44] Uniform Mechanical Code, IAPMO, Clause 1104.6 Applications for Human Comfort and for Nonindustrial Occupancies

[45] Press Release, “IAPMO Seeks UMC A2L Task Group Members To Examine A2L Refrigerants,” June 15, 2016, http://codes.iapmo.org/docs/2018/UMC/Press%20Releases/2016-06-15%20IAPMO%20Seeks%20UMC%20A2L%20Task%20Group%20Members.pdf

[46] Excerpt from International Fire Code, ICC, Clause 606.5 Access

[47] NFPA 1-2015 “Fire Code,” Chapter 53 “Mechanical Refrigeration,” clause 53.2.2.1.2(1), page 316.

[48] Ibid, clause 53.2.2.1.2(2), page 316.

[49] UNEP TEAP estimates that take into account years-of-service. UNEP Report of the Technology and Economic Assessment Panel MAY 2014 Vol. 4 Decision XXV/5 Task Force Report Additional Information to Alternative on ODS, page 12, http://42functions.org/Assessment_Panels/TEAP/Reports/TEAP_Reports/TEAP_Task%20Force%20XXV5-May2014.pdf

[50] “Natural refrigerants are chemicals which occur in nature's bio-chemical processes. They do not deplete the ozone layer and make a negligible - or zero in the case of R717 (ammonia) - contribution to global warming. The high efficiency of natural refrigerants also means that they make a lower indirect contribution to global warming.” Description obtained from: http://www.linde-gas.com/en/products_and_supply/refrigerants/natural_refrigerants/index.html.

[51] “Probability of Ignition As A Result Of Flammable Refrigerant Leak From A Household Refrigerator Appliance,” CSA Group, M. Chowdhury, R. Morrison, November 14, 2016.

[52] ASHRAE, AHRI and DOE Partner to Fund Flammable Refrigerant Research, ASHRAE press release, June 2, 2016, https://www.ashrae.org/news/2016/ashrae-ahri-doe-partner-to-fund-flammable-refrigerant-research

[53] “A vision for the future,” RAC, January 6, 2016, http://www.racplus.com/features/a-vision-for-the-future/10001186.fullarticle

[54] “Flammables study focus on A2L refrigerants,” Cooling Post, June 18, 2016, http://www.coolingpost.com/world-news/flammables-study-focus-on-a2l-refrigerants/

[55] Two examples from outside the US market are as follows: Canadian Property Management, “Flammable refrigerants demand caution, Regulatory gap allows sale to public,” Tuesday, October 15, 2013, Barbara Carss https://www.reminetwork.com/articles/flammable-refrigerants-demand-caution/ and 2014 International Refrigeration and Air Conditioning Conference, “Fire Hazards of Refrigerants in Air Conditioning Control System,” Y.W. Ng and W.K. Chow, http://docs.lib.purdue.edu/iracc/1478/

[56] News Release, “EPA Warning: Recharging Air Conditioners with Wrong Refrigerant Poses Injury and Fire Risks,” https://www.epa.gov/newsreleases/epa-warning-recharging-air-conditioners-wrong-refrigerant-poses-injury-and-fire-risks and News Release, EPA Warns Against Use of Refrigerant Substitutes That Pose Fire and Explosion Risk, https://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/61416ea839b0618e85257b9b0065aec0!OpenDocument

[57] 2016 Guideline for Assignment of Refrigerant Container Colors, AHRI GUIDELINE N-2016, clause 4.7, page 2.

[58] The NEWS, "Revised AHRI Guideline Removes Color Assignments for Refrigerant Containers," June 29, 2016, http://www.achrnews.com/articles/132836-revised-ahri-guideline-removes-color-assignments-for-refrigerant-containers

[59] 2016 Guideline for Content Recovery & Proper Recycling of Refrigerant Cylinders, AHRI GUIDELINE Q-2016, Figure 6. Label Pierced Hole, page 3-4.

[60] Ibid, page 4

[61] For instance, Federal Express has extensive guidance (the following reference is a little dated (2013). FedEx Ground Package Systems Inc. Guide, reference to 173.306 Limited quantities of compressed gases (e) Refrigerating machines, pg. 107 http://www.fedex.com/us/services/pdf/HazmatShippingGuide.pdf

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