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Effectively Managing the Transition to Lower GWP Refrigerants

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Abstract

Environmental concerns raised by high global warming potential (GWP) refrigerants have triggered a series of regulatory activities around the world to curtail the use of hydrofluorocarbons (HFCs). This paper will review activities under the Montreal Protocol as well as actions taken by the U.S. Environmental Protection Agency and the European Commission on HFCs. Current research on lower GWP refrigerants will be summarized and efforts to update safety codes and standards so that many of the most promising alternatives could be safely used will be examined. Finally, initiatives aimed at improving the management of refrigerants to reduce leak and service emissions, and to promote the recycling, recovery, reclaiming, and end of life destruction of refrigerants will be discussed.

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Keywords: refrigerant, GWP, safety standards, Montreal protocol

1. Introduction

Concerns about climate change have led to worldwide efforts to reduce greenhouse gas emissions. A particular attention has been paid to hydrofluorocarbon (HFC) refrigerants because of their increased emissions in the atmosphere due to their use in air conditioning, heat pumps and refrigeration equipment. HFCs were identified in the 1990's as replacements to chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) which were found to destroy the ozone layer. However, while HFCs have zero ozone depleting potential (ODP), they are greenhouse gases with GWP values ranging from approximately 100 to several thousand times greater than that of carbon dioxide (CO_2). The increased amount of HFCs in the atmosphere has led to a flurry of regulatory activities around the world to curtail their use. This paper will review activities under the Montreal Protocol as well as actions taken on HFCs by the U.S. Environmental Protection Agency and the European Commission. An overview of the research currently ongoing on lower GWP refrigerants will be presented and efforts to update safety codes and standards so that many of the most promising alternatives could be safely used will be examined. Initiatives aimed at improving the management of refrigerants to reduce leak and service emissions, and to promote the recycling, recovery, reclaiming, and end of life destruction of refrigerants will also be discussed.

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2. Regulatory Drivers

The fast increase of fluorinated gases in the atmosphere prompted the international community to discuss ways to reduce the use of HFCs. For several years in a row, attempts to amend the Montreal Protocol to phasedown the use of HFCs were unsuccessful. Meanwhile, in 2014 the European commission promulgated regulations that introduced a phasedown of HFCs as shown in Figure 1[1]. In addition, specific bans on high global warning potential (GWP) HFCs will be implemented as early as January 2020 for stationary refrigeration equipment. A ban on refrigerants with GWP greater than 750 will be imposed on residential split air conditioners with less than 3 kg of refrigerant charge, effective January 2025.

Year	Reduction by
2015	100% (Freeze)
2016-17	93%
2018-20	63%
2021-23	45%
2024-26	31%
2027-29	24%
2030	21%

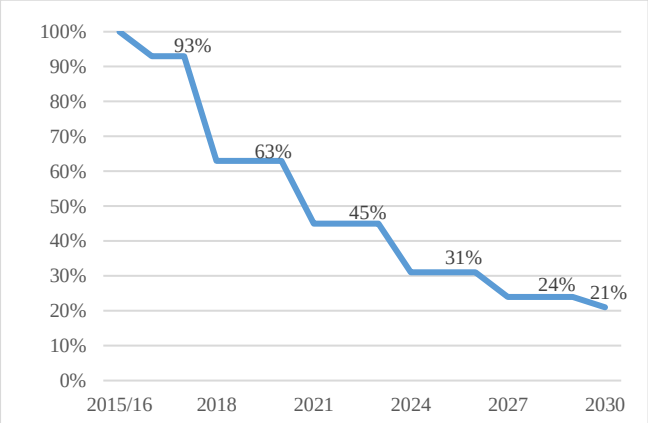


Figure 1: Phasedown Steps based on the European F-Gas Regulation

In the U.S., President Obama announced a Climate Action Plan to cut carbon emissions [2]. Among other things, the plan directed the U.S. Environmental Protection Agency (EPA) to use its authority under the Significant New Alternative Policy (SNAP) program to identify and approve low GWP alternatives while prohibiting certain uses of high GWP refrigerants and foam blowing agents. EPA then issued two rulemakings changing the listing status of several high GWP refrigerants used in commercial refrigeration equipment, chillers and cold storage warehouses to unacceptable, effectively banning their use [3,4]. As shown in Table 1, effective July 20, 2016, R-404A and R-507A are no longer allowed to retrofit supermarkets, remote condensing units and low and medium temperatures stand-alone commercial refrigeration equipment. More restrictions on the use of R-404A, R-410A, R-407A/C/F and R-134a will take effect from 2017 to 2020.

Table 1: Phase-Out Refrigerants and Dates for Commercial Refrigeration Equipment

Phase-Out Refrigerant	Super-market (New)	Super-market (Retrofit)	Remote Cond. Unit (New)	Remote Cond. Unit (Retrofit)	Stand-Alone			
					Medium Temp<2,200 Btu/h without flooded evap. (New)	Medium Temp≥2,200 Btu/h with or without flooded evap. (New)	Low Temp. (New)	Low & Medium Temp. (Retrofit)
R-404A/507A	Jan 1, 2017	Jul 20, 2016	Jan 1, 2018	Jul 20, 2016	Jan 1, 2019	Jan 1, 2020	Jan 1, 2020	Jul 20, 2016
R-410A	OK	-	OK	-	Jan 1, 2019	Jan 1, 2020	Jan 1, 2020	-
R-407A/C/F	OK	OK	OK	OK	Jan 1, 2019	Jan 1, 2020	Jan 1, 2020	OK
R-134a	OK	OK	OK	OK	Jan 1, 2019	Jan 1, 2020	OK	OK

Table 2 shows that all HFCs currently used in new chillers will be phased out in 2024. For retail food refrigeration (food processing and dispensing) and cold storage warehouses, most HFCs (at the exception of R-134a) will be phased out for new equipment in 2021 and 2023 respectively.

Table 2: Phase-Out Refrigerants and Dates for Chillers, Cold Storage Warehouses and Retail Food Refrigeration Equipment

Phase out Refrigerant	Chillers (New)	Cold Storage Warehouse (New)	Retail Food Refrigeration – Food Processing & Dispensing (New)
R-134a	Jan 1, 2024	OK	OK
R-404A	Jan 1, 2024	Jan 1, 2023	Jan 1, 2021
R-407 A&B	-	Jan 1, 2023	Jan 1, 2021
R-407C	Jan 1, 2024	-	Jan 1, 2021
R-410A	Jan 1, 2024	Jan 1, 2023	Jan 1, 2021
R-507A	Jan 1, 2024	Jan 1, 2023	Jan 1, 2021

In California, the Air Resources Board (CARB) issued a proposed strategy paper to accelerate emission reductions of short-lived climate pollutants [5]. Among other things, the strategy proposed to reduce HFC emissions in the state of California by 40% (from 2013 levels) in 2030. The strategy mentioned the ongoing international negotiations on the phasedown of HFCs and noted that California would implement its own phasedown if the negotiations are unsuccessful. In addition, the strategy proposed a ban on refrigerants with GWP levels greater than 2500 and a GWP limit of 750 on refrigerants used in air-conditioning (both residential and commercial) effective in 2021. For commercial refrigeration equipment, a GWP limit of 150 was proposed effective in 2020.

While regulations were promulgated in both Europe and the U.S., international discussions to amend the Montreal Protocol to address HFCs were ongoing. In October 2016, a historic agreement was reached in Kigali, Rwanda, by nearly 200 countries to adopt a global phasedown of HFCs. According to the agreement as shown in Table 3, the amendment to the Montreal Protocol provides separate baselines and reduction schedules for developed (A2) and developing (A5) countries as well separate accommodations for certain Parties within those categories. Developed countries such as the U.S. will start phasing down HFCs as early as 2019. Additional step downs are expected in 2024, 2029, 2034 and finally in 2036 where the production and consumption of HFCs will be capped at 15% of the original baseline. The agreement is expected to avoid the greenhouse gas emissions of at least 70 Gigatons CO_2 equivalent by 2050. As with past amendments, it will be guided by a technology and economic review process every 5 years and will provide financial assistance to developing countries. In the U.S., the amendment has to be signed by the President and ratified by the Senate. Once ratified, the EPA will promulgate regulations to implement it.

Table 3: Phasedown Schedule for Developed (A2) and Developing (A5) Countries

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

*For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025
**Group 1: Article 5 parties not part of Group 2
***Group 2: GCC, India, Iran, Iraq, Pakistan

In late 2016, CARB issued a revised proposed strategy paper [6]. While the revised strategy acknowledges the Montreal Protocol agreement reached in Kigali, it continues to propose a ban on refrigerants with GWP levels greater than 2500, and indicates that additional measures may be needed to achieve the emission reduction goals. Such additional measures could include setting GWP limits on refrigerants used in air-conditioning (both

residential and commercial) and commercial refrigeration equipment. A final decision will be made in the Spring 2017.

3. Safety Codes and Standards

In order to prepare the industry for an eventual phasedown of HFCs, the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) started researching lower GWP alternative refrigerants in 2011. This industry-wide cooperative research program, known as the Low Global Warming Potential Alternative Refrigerants Evaluation Program (Low-GWP AREP), was aimed at identifying and evaluating promising low-GWP alternative refrigerants for major air conditioning and refrigeration products. The program did not prioritize these alternatives; rather, it identified potential replacements for high GWP refrigerants, and presented the performance of these replacements in a consistent and standard manner. Phase I testing of the program was completed at the end of 2013 and produced 40 test reports [7]. Phase II testing started in 2014, and produced 33 test reports [8]. Phase II reports included compressor calorimeter testing, system drop-in testing, and soft-optimized system testing.

The Low-GWP AREP program identified viable alternative refrigerants, most of which are mildly (i.e. "2L" classification) or highly (i.e., "3" classification) flammable per ASHRAE Standard 34 [9]. However, current safety standards such as ASHRAE 15, severely restrict the use of flammable refrigerants [10]. The current version of ASHRAE 15 does not differentiate class 2 and 2L refrigerants, so all 2L refrigerants must meet the class 2 requirements which today limit the maximum refrigerant charge to 3 kg and 10 kg for residential and commercial equipment respectively depending on the location of the product in the building. On the other hand, highly flammable refrigerants (i.e.; "3" classification) cannot be used except if allowed by the Authority Having Jurisdiction (AHJ) or in certain exceptions such as laboratories with more than 9.3 m^2 area per person, industrial occupancies or in portable unit systems containing less than 150 g of refrigerant charge.

Efforts are currently underway to amend ASHRAE 15 to include requirements on equipment using 2L refrigerants. Two addenda were recently published for public review. The first, addendum d, addresses "high-probability systems" in applications for human comfort. The second, addendum h, addresses machinery room applications. More addenda are expected later which will address applications for industrial occupancies and refrigerated rooms. In addition, the standard committee is undertaking a complete re-write of the standard by making changes to the document structure and organization. It is expected that revisions to the standard will be completed by the end of 2017.

Meanwhile, a separate subcommittee, ASHRAE 15.2, was established by the ASHRAE 15 committee to specifically address residential applications. Equipment covered include split and single package air conditioners and heat pumps, whole house dehumidifiers/ventilators and permanently connected heat pump water heaters. The scope of the subcommittee includes one and two-family dwellings, multi-family structures with individual dwelling units, where each dwelling unit has its own dedicated heating and air-conditioning system, and detached outbuildings (and garages, guest houses, pool houses, etc.) located on the same private property defined above. The subcommittee plans to release two public draft reviews in 2017 and expects to issue a standard (either separately or as part of ASHRAE 15) by the end of 2017.

At the international level, efforts are currently underway to include requirements on 2L refrigerants. IEC Standard 60335-2-40, which covers residential air conditioners and heat pumps, dehumidifiers and heat pump water heaters, is currently under revisions to address 2L refrigerants [11]. Completion of this work is expected by the end of 2017. Similarly, IEC standard 60335-2-89, which covers commercial refrigeration equipment is under review to increase the refrigerant charge limit of flammable refrigerants [12]. Completion is expected in 2018/2019.

While safety standards such as ASHRAE 15 have requirements for the safe use of air conditioning, heat pumps and refrigeration equipment that manufacturers are obligated to follow, the implementation of such requirements is usually done through safety codes. In the U.S., relevant codes include the International Mechanical code (IMC), the International Fire Code (IFC), the International Residential Code (IRC), the Uniform Mechanical Code (UMC) and the National Fire Protection Association, NFPA 1 – Fire Code. These codes usually reference ASHRAE 15 in its entirety, and are on a 3-year cycle. However, the U.S. code adoption process for new refrigerants is relatively slow. First, a refrigerant has to obtain the proper safety classification under ASHRAE 34. Second, it has to be approved by EPA under the SNAP program. Third, the refrigerant must meet the requirements of relevant safety

standards and codes. In all, it could take 3 to 5 years from the time an application is filed with ASHRAE 34 to the time the refrigerant is listed in a safety standard or code.

Currently, the safety codes in the U.S. make reference to a version of ASHRAE 15 that severely restricts the use of flammable refrigerants. Revisions to the 2018 IMC were completed in 2015 and do not include requirements on 2L refrigerants. The 2018 IFC code cycle is underway and a proposal addressing 2L refrigerants on machinery room ventilation was approved. Similarly, the 2018 UMC code cycle has started and several proposals addressing 2L refrigerants are expected to be considered. However, given that the 2018 IMC will not have requirements on 2L refrigerants, the next opportunity to amend the code to address the 2L classification will be for the 2021 version. This means that the wide use of 2L refrigerants in the U.S. is not expected until 2024 or later given that it takes several years for states and local jurisdictions to adopt the latest versions of safety codes.

4. Research on Flammable Refrigerants

The revisions of safety codes and standards to address class 2L, and to a certain extent class 3 refrigerants, identified a lack of publicly available knowledge about the safe use of flammable refrigerants. To address this challenge faced by the industry, AHRI established a Flammable Refrigerants Subcommittee (FRS) to identify critical research needs that relevant standards and codes are depending upon for their timely inclusion of flammable refrigerants. To determine knowledge gaps in existing flammable refrigerant research, the FRS surveyed 46 relevant committees and Working Groups (WGs) currently working on codes and standards activities. AHRI also sought international input by distributing the survey through its global partners and UNEP contacts to their individual countries' relevant committees/WGs. Through this survey, AHRI identified the gaps in existing flammable refrigerant research and developed a roadmap with priorities and a timeline to complete the critical research toward the safe use of flammable refrigerants.

In total, 134 research needs were identified through survey responses and industry experts' inputs. The list of projects was narrowed down and prioritized by a group of industry experts. Projects which would deliver scientific findings and produce publicly available technical references to support the current code and standard activities related to the use of flammable refrigerants were retained first. AHRI solicited the financial support of other organizations and ASHRAE, the California Air Resource Board (CARB) and the US Department of Energy (DOE) joined the initiative. In total, $5.6 million were allocated for the research program with DOE contributing $3 million, ASHRAE $1.3 million, AHRI $1 million and CARB $0.3 million. The research is managed by the Air-Conditioning, Heating, and Refrigeration Technology Institute (AHRTI), the research arm of AHRI. AHRTI initiated the following key research projects that were identified as highly important and of high urgency (leading organization undertaking the project is listed in parenthesis):

- Benchmarking risk by real life leaks and ignitions testing (AHRTI)
- Investigation of hot surface ignition temperature for A2L refrigerants (AHRTI)
- Leak detection of A2L refrigerants in HVACR equipment (AHRTI)
- Flammable refrigerants post-ignition risk assessment (ASHRAE)
- Guidelines for flammable refrigerant handling, and equipment servicing and installation (ASHRAE)
- Servicing and installing equipment using flammable refrigerants: assessment of field-made mechanical joints (ASHRAE)
- Investigation of proper basis for setting charge limits of A2L, A2, and A3 refrigerants for various types of products (Oak Ridge National Laboratory)

The majority of the projects listed above will be completed in the second or third quarter of 2017, on time to be considered by various safety standard committees. AHRTI is currently assessing projects that were identified as highly important but not as urgent and will decide in the next few months which new projects to launch.

5. Refrigerant Management and Technician Training

The introduction of low GWP refrigerants in air conditioning, heat pumps and refrigerant equipment present unique challenges to technicians who have very little or no experience handling flammable refrigerants. That is why education and training is critical and cannot be ignored. In 2015, AHRI teamed up with ABRAVA, the

Brazilian Association, and with the Alliance for Responsible Atmospheric Policy to establish the Global Refrigerant Management Initiative (GRMI). Since then, other HVACR organizations in many different countries and regions, including Australia, China, Canada, Columbia, the EU, Japan, and Korea have joined the effort. GRMI seeks to identify and explore opportunities to educate the HVACR industry's global supply chain on ways to improve the management of refrigerants to reduce leak and service emissions, and to promote the recycling, recovery, reclaiming, and end of life destruction of refrigerants and foam blowing agents. The initial, primary purpose of GRMI is to improve global education, training and certification of the service industry associated with air conditioning and refrigeration industries. GRMI intends in the next couple of years to become a focal point for developing common approaches among national, and regional actors to ensure global success.

6. Summary

Efforts to reduce greenhouse gas emissions into the atmosphere has led to a flurry of regulatory activities around the world to restrict the use of HFCs. Europe and the U.S. took the lead in promulgating regulations to ban certain high-GWP refrigerants. The historic amendment to the Montreal Protocol adopted in Kigali, Rwanda, is a major policy step forward in the global effort to reduce greenhouse gas emissions and the threat of climate change. The amendment sets a gradual phasedown schedule for high-GWP HFCs, which were introduced more than 20 years ago in an effort to replace CFCs and HCFCs that were destroying the earth's ozone layer. Many of the alternative refrigerants being considered as replacements to high-GWP HFCs are flammable and their use is severely restricted by current safety codes and standards. Efforts are currently underway to amend these safety standards so that low-GWP alternatives could be safely and widely used in the next few years. Research spearheaded by industry is ongoing to support the codes and safety standards amendment process and initial results will become available in the first half of 2017. Finally, industry is getting together to adopt or develop best practices as well as the training and certification programs that will be necessary to ensure proper management, servicing, and end-of-life practices for equipment using lower GWP refrigerants. Implementing these changes will ensure a smooth transition to lower GWP refrigerants.

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