# ASHRAE Position Document on Refrigerants and Their Responsible Use

Approved by ASHRAE Board of Directors
June 27, 2018

Reaffirmed by Technology Council
June 29, 2020

Expires
June 29, 2023


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## HISTORY OF REVISION/REAFFIRMATION/WITHDRAWAL DATES

The following summarizes this document's revision, reaffirmation, or withdrawal dates:

1/25/2012—BOD approves Position Document titled *Refrigerants and their Responsible Use*

7/2/2014—Technology Council approves reaffirmation of Position Document titled *Refrigerants and their Responsible Use*

1/30/2017—Technology Council approves reaffirmation of Position Document titled *Refrigerants and their Responsible Use*

6/27/2018—BOD approves Position Document titled *Refrigerants and their Responsible Use*

6/29/2020—Technology Council approves reaffirmation of Position Document titled *Refrigerants and their Responsible Use*

***Note:*** ASHRAE's Technology Council and the cognizant committee recommend revision, reaffirmation, or withdrawal every 30 months.

***Note:*** ASHRAE position documents are approved by the Board of Directors and express the views of the Society on a specific issue. The purpose of these documents is to provide objective, authoritative background information to persons interested in issues within ASHRAE's expertise, particularly in areas where such information will be helpful in drafting sound public policy. A related purpose is also to serve as an educational tool clarifying ASHRAE's position for its members and professionals, in general, advancing the arts and sciences of HVAC&R.

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## ASHRAE Position Document on Refrigerants and Their Responsible Use

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## ABSTRACT

Heating, Ventilation, Air-Conditioning and Refrigeration (HVAC&R) equipment provide many benefits to society, but realizing these benefits has environmental and societal consequences. Many of these consequences stem directly from the refrigerant chosen and its management during the life of the equipment. Environmental concerns have caused ozone-depleting potential (ODP), global warming potential (GWP), energy efficiency, and life-cycle climate performance (LCCP) (IIR 2016) to become important factors in the design and use of equipment. This often results in conflicts between choices. For example, if a lower GWP refrigerant is less efficient than the fluid it replaces, any direct global warming benefit may be offset by the indirect global warming effect of increased energy consumption. Additionally, flammability, toxicity, equipment longevity, system performance , and refrigerant management practices must be considered for refrigerant selection. A very low GWP refrigerant may be more toxic than a higher GWP alternative. However, it is difficult to analyze how the health and safety harm done by the release of a mildly toxic but 0 GWP refrigerant compares to the environmental and health harm done by the release of a non-toxic but higher GWP refrigerant. And for both, there are design, operational, and safety planning practices that when followed can mitigate a release, or the amount of release, and the effects of a release. It is important, therefore, for ASHRAE to play a key role in guiding refrigerant choices and related design considerations.

ASHRAE's position is that the selection of refrigerants and their operating systems should be based on a holistic analysis of multiple criteria. ASHRAE promotes the responsible use and management of refrigerants during the processes of design, manufacturing, operation, and servicing of systems as well as at the end of life.

## EXECUTIVE SUMMARY

*Refrigerants are the working fluids in heat pumping, ventilation, air-conditioning and refrigeration, (HVAC&R) systems. They absorb heat from one area, such as an air-conditioned space, and reject it into another, such as outdoors, usually through evaporation and condensation, respectively. (ASHRAE 2017)*

Refrigeration and air conditioning have made many of the technological advances we enjoy today possible and in that way have been highly beneficial. The benefits, however, carry environmental and societal consequences, many of which stem directly from the refrigerant selected for each application. This document represents ASHRAE's position on the selection and management of refrigerants during their life and at end of life of heating, ventilating, air-conditioning, and refrigerating (HVAC&R) equipment and ASHRAE's recommendations for moving forward in the rapidly changing landscape of refrigerant selection.

Throughout the history of air conditioning and refrigeration, numerous substances have been used as refrigerants (Calm 2008), and for many years refrigerant choice was not of primary concern when selecting equipment. This changed over the last three decades as choosing a refrigerant became increasingly more complex due to the evolving environmental criteria applied to refrigerant selection that resulted in many new substances and blends being invented, tested, and commercialized, or revisiting the use of nonfluorinated refrigerants (frequently referred to as *natural refrigerants*: such as ammonia, carbon dioxide (CO2), hydrocarbons, water, and air).

Earlier generations of commercial fluorinated refrigerants were mostly chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). They contributed to the depletion of stratospheric ozone and are being phased out globally under the international treaty called The Montreal Protocol (UNEP 2017). CFCs and HCFCs have largely been replaced with hydrofluorocarbons (HFCs), some of which have high global warming potential (GWP) and are being restricted as the world deals with global climate change. More recently, fluorinated alternatives referred to as hydrofluoroolefins (HFOs) have been introduced. They have zero ozone-depleting potential (ODP) and very low GWP, but some of them are mildly flammable. There are also blends (mixtures of different HFCs & HFOs from the same or different class/group) that are available as transitional or long-term solutions with different flammability and GWP value characteristics. The energy that refrigeration systems consume is often produced from fossil fuels, which results in emissions of $CO_2$, a contributor to global climate change over the lifetime of the equipment. This indirect effect, associated with electricity generation, frequently presents a larger environmental carbon footprint impact than the direct effect of refrigerant emissions. The selection of refrigerants and their operating systems should thus be based on a holistic analysis of multiple criteria. All refrigerants have trade-offs, and it is important for users to know these limitations when selecting the appropriate fluid for their application.

ASHRAE's position on responsible selection and use of refrigerants and our commitments are outlined in this document. But as new technologies develop ever more rapidly and our understanding of the environmental effects of technology grows, ASHRAE recommends and is committed to continuing and intensifying efforts in the following areas:

- Research and standards development
- Improved design and equipment applications
- Improved field practices and training
- Regulatory guidelines and measures

Sustainability means looking forward, and ASHRAE will continue to be at the forefront of HVAC&R development.

## 1. ISSUES

Choosing a refrigerant for a given HVAC&R application has become increasingly complex. Environmental concerns have caused ozone-depleting potential (ODP), global warming potential (GWP), energy efficiency, and life-cycle climate performance (LCCP) to become important factors for consideration. Some countries have developed regulatory constraints, international protocols, or voluntary agreements in response. Since the implementation of the 1987 Montreal Protocol (UNEP 2017), chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) containing chlorine (e.g., CFC-11, CFC-12, HCFC-22, R-502, and HCFC-123) are being phased out due to their ODP. In October 2016, the Kigali Amendment to the Montreal Protocol (UNEP 2016) was negotiated over concerns about climate change, prompting transitions to lower GWP options as well.

The need for lower GWP refrigerants has led to increased development and utilization of flammable or toxic options to meet GWP targets. As a result, safety standards are being reassessed and updated to reflect the increasing interest in flammable or mildly flammable or toxic or mildly toxic working fluids. As standards are being developed and research into new fluids, or better use of existing fluids, is under way, the shift from hydrofluorocarbons (HFCs) to lower GWP HFOs and natural refrigerants is happening in both developed and some developing nations.

While each class of refrigerant may offer favorable performance and/or environmental aspects, none present an ideal solution. All refrigerants, depending on the fluid, have application trade-off considerations that can include flammability, toxicity, high working pressures, low intrinsic operating efficiencies, incompatibilities with materials of construction, cost effectiveness, and environmental impacts The lower GWP refrigerants also present a new level of training, market acceptance, and refrigerant management challenges during the working life of the equipment.

End-of-life disposal of HVAC&R systems is another important issue. At the end of the life of an equipment, refrigerant should be safely recovered and recycled when possible or disposed of in accordance with applicable regulations.

## 2. BACKGROUND

### 2.1 Overview

HVAC&R equipment provide a broad range of benefits to society, including the preservation of food, comfort cooling, heating of occupied spaces (home, work, and transport), and temperature/humidity control of industrial processes. The vast majority of refrigeration and air-conditioning equipment operates via the application of vapor-compression cycles, and such cycles require a working fluid or refrigerant to operate. Refrigerants are therefore at the heart of most modern refrigeration and air-conditioning equipment, and refrigerant selection has significant impacts on the cost, safety, reliability, performance, and energy consumption of the equipment.

A refrigerant must satisfy a number of technical requirements related to safety, chemical stability, environmental properties, thermodynamic characteristics, compatibility with materials of construction (McLinden and Didion 1987), and impact on total system cost. There is no single set of optimum characteristics (especially for thermodynamic properties), and often there are trade-offs among desirable characteristics. Thus, a variety of refrigerants, having a range of properties, are needed to meet the requirements of varied applications.

A broad range of fluids has been used as refrigerant over the past century, and the current usage is dominated by a range of fluorinated chemicals, such as HFCs, in addition to hydrocarbons and several inorganic compounds, including ammonia and $CO_2$ (Calm 2008). An earlier generation of refrigerants, the CFCs and HCFCs, contained chlorine and was capable of reaching and releasing free chlorine molecules in the stratosphere, thereby damaging the ozone layer. This resulted in the phaseout of the CFC refrigerants and an ongoing phaseout of HCFC refrigerants under the Montreal Protocol. And now, global climate change concerns have focused attention on the HFC refrigerants. With the European Union regulation on certain fluorinated greenhouse gases (EU F-Gas) (EU 2014) and other recently enacted regulations in various countries, HFCs are facing restrictions and/or phase-downs. This trend to reduce the global warming impact of HFCs culminated in the Kigali Amendment to the Montreal Protocol in October 2016 (UNEP 2016).

The net climate impact of a refrigerant is dependent on direct and indirect effects. The direct effect is from its GWP and the amount of the refrigerant emitted to the atmosphere (from either a leak, an accident, or improper handling or disposal). The indirect effect is associated with the energy consumed during the operation of the HVAC&R equipment. Over the operating life of the equipment, this indirect effect, which occurs as a result of the $CO_2$ produced by fossil fuel power plants, is usually much greater than the direct effect due to the GWP of the refrigerant itself. The refrigerant is contained within a sealed system and is not intended to be emitted to the atmosphere under normal operation and with proper end-of-life disposal. In actual practice, however, systems are subject to leakage and require proper maintenance to minimize losses. Operation of a system with a lower-than-the-design refrigerant charge results in increased energy use. Both direct and indirect effects are considered in metrics such as Total Equivalent Warming Impact (TEWI) (AIRAH 2012) and LCCP. It should be recognized that the total climate impact of an operating refrigeration system can increase if the replacement lower GWP refrigerant has a lower energy efficiency as applied in the system.

A more thorough discussion of the history, classes of refrigerants and their attributes, tradeoffs, and means of mitigating risks associated with refrigerant use are available in the literature (Calm 2008; Calm and Hourahan 2007).

## 2.2 ASHRAE's Role

ASHRAE has a direct interest in refrigerant transitions because the operation of much of the HVAC&R equipment depends on refrigerants. ASHRAE contributed to the successful effort to phase out the ozone-depleting CFC and HCFC refrigerants, and it has a significant role to play in encouraging the proper and safe use of refrigerants going forward. ASHRAE plays an active role in the following areas: policy, research, standards, codes, guidelines, technology transfer, and education.

### 2.3 Policy (Includes Standards, Codes and Guidelines)

ASHRAE plays a major role in the development of voluntary standards and guidelines governing the application and use of all types of refrigerants. Other organizations adopt the technical requirements developed by ASHRAE into various codes and regulations. The most relevant ASHRAE standards dealing with refrigerants are ANSI/ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants* (ASHRAE 2019, ANSI/ASHRAE Standard 15, *Safety Standard for Refrigeration Systems* (ASHRAE 2019), and ANSI/ASHRAE Standard 147, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment* (ASHRAE 2013).

### 2.4 Education

ASHRAE plays an important role in providing technical information on the proper application of refrigerants and in educating the technical community. These activities are carried out through research, handbooks, journals, technical meetings, special publications, educational training and digital media. Local ASHRAE chapters also host refrigerant-related programs and speakers. Technical activities in this area are addressed within ASHRAE by the Refrigeration Committee, by committees responsible for the maintenance and updating of the standards listed above, and by numerous technical committees (ASHRAE 2018).

### 2.5 Research and International Perspective

ASHRAE is unique among technical engineering societies in sponsoring extensive member-supported research programs. The research plan for the Society includes items to facilitate the application of lower GWP refrigerants, to investigate methods to reduce refrigerant charge in systems, and to improve system efficiency. For example, ASHRAE has been actively involved in several research programs to understand the safety implications and to develop mitigation plans for use of flammable and mildly flammable refrigerants (ASHRAE 2016c). These results are beneficial in the development of safety standards to enable the transition to the next generation of refrigeration technology. Some of this research has been performed jointly with the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and the United States Department of Energy (DOE).

Another major focus of ASHRAE’s activities is on improving the energy efficiency of buildings. Reducing the heating and cooling loads of buildings implies smaller HVAC&R systems with smaller amounts of refrigerant and lower indirect climate impacts resulting from electricity generation.

## 3. POSITIONS AND RECOMMENDATIONS

ASHRAE acknowledges that the use of HVAC&R systems has environmental consequences and ASHRAE is committed to making these systems sustainable. Because of the environmental impacts of refrigerants, ASHRAE holds to the principle that refrigerants should be used prudently to provide the best value to society.

## 3.1 ASHRAE Positions

ASHRAE's positions on the responsible selection and use of refrigerants are as follows:

- Selection of refrigerants and their systems must be based on a holistic analysis including energy efficiency and performance attributes, environmental impacts, employee and public safety, and economic considerations. A refrigerant should not be selected based on any one single factor such as GWP, operating pressure, flammability, etc. The wide range of HVAC&R applications and their requirements throughout the world necessitates a variety of refrigerants to meet these needs.
- To limit direct and indirect impacts on the environment, emissions of refrigerants should be reduced through research, education, improved design, manufacturing/construction of equipment, field commissioning, leakage monitoring, maintenance procedures, decommissioning, and enforcement of applicable standards and regulations.
- Where possible, refrigerants should be safely recovered for reuse, recycle, reclamation, or destruction during service or at the end of the life of the equipment. Refrigerant inventory and management programs should be implemented to closely track refrigerant use.

ASHRAE encourages and supports ongoing efforts to develop new refrigerants and improve the application of existing refrigerants to meet these criteria.

## 3.2 ASHRAE Commitments

ASHRAE is committed, in a timely manner, to the following:

- Supporting research to develop and advance HVAC&R technologies and practices that minimize refrigerants' impacts on the environment while enhancing performance, cost-effectiveness, and safety.
- Developing and revising guidelines and standards that reduce refrigerant impact while maintaining or improving system effectiveness safety, and sustainable design. .
- Supporting responsible refrigerant use through education, information dissemination, and proper training.
- Working with societies, universities, private industries, government agencies, and international organizations to promote responsible use of refrigerants.

## 3.3 Recommendations

### 3.3.1 Policy, Research, Education, and Training

To support responsible design and use of refrigerants, ASHRAE also recommends efforts in the following areas for governmental and nongovernmental institutions.

*Research, Standards, and Guidelines Development*

- Promote research and development programs for investigating and adoption of lower GWP refrigerants to achieve better LCCP.

- Evaluate flammable and/or toxic refrigerants to understand the safety implications and mitigation techniques and to develop safe-use standards, practices, and training.
- Support the development, update, and/or adoption of relevant standards and guidelines that facilitate the deployment of lower GWP refrigerants.

*Improved Design and Equipment Applications*

- Balance the safety, energy efficiency, cost, and environmental impacts of refrigerants using a consistent and comprehensive methodology across all refrigerants and system types using benchmarks like LCCP or TEWI.
- Advance the design, development, and application of refrigeration and air-conditioning equipment and systems that optimize refrigerant charge and minimize emissions during the life of the equipment.
- Develop tools, equipment, methodologies, and practices to minimize or prevent refrigerant loss during installation, operation, maintenance, and decommissioning of refrigeration systems.

*Improved Field Practices and Training*

- Introduce and manage on-site emission prevention measures including, but not limited to, improved system tightness for leak prevention, good commissioning and installation practices, regular leak checking, monitoring, labeling, and record keeping. These elements can be incorporated as part of a comprehensive refrigerant management program.
- Establish programs that promote refrigerant recovery, recycling (reuse), reclamation, and safe disposal practices, including at the end of equipment life.
- Develop and enact certification programs for specialists (practitioners) in relation to setting benchmarks and competencies of good practices.
- Promote the introduction of corporate social responsibility policies and programs in relation to the responsible use of refrigerants.
- Introduce training programs about lower GWP refrigerants and their responsible use for different stakeholders.

*Regulatory Guidelines and Measures*

- Develop relevant measures that promote the use of lower total system GWP (refrigerant charge multiplied by the GWP of the refrigerant) and energy-efficient HVAC&R systems.
- Introduce procedures and guidelines, working with the United Nations Environmental Programme (UNEP) and other organizations and regulatory bodies, to enable sustainable procurement policies that promote the deployment of lower total system GWP refrigerants and their responsible use while commissioning, operating, and servicing HVAC&R systems.

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