REFRIGERANTS

This TECHnote discusses the background and implications of Australia's phase-out of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants and the phase-down of hydrofluorocarbon (HFC) refrigerants, in conformance with international protocols and market forces. The alternatives to these refrigerants are less than ideal and impose obligations on designers, specifiers, installers and maintenance personnel to make sure resulting risks are managed. It discusses the impact of AS/NZS ISO 817 and AS/NZS 5149 Parts 1 to 4 on the selection and design for refrigerants.

THE IDEAL REFRIGERANT

A refrigerant is a fluid used to transfer heat from one place to another in a refrigeration cycle. An ideal refrigerant would have thermodynamic properties to do this efficiently, be chemically stable, non-toxic, not flammable, non-corrosive, operate at reasonable pressures, be non-conductive electrically and be compatible with system materials such as electrical insulation and lubricants.

The first synthetic refrigerant was a CFC, R12 (Freon). Introduced in the 1930s, R12 was hailed as a lifesaver, unlike earlier refrigerants such as ammonia, sulfur dioxide and carbon dioxide which are toxic and had been implicated in several fatalities. More halogenated hydrocarbons were developed in the following decades but the discovery of their effect on the earth's ozone layer led to their phasing out globally under the 1987 Montreal Protocol.

While the refrigerants that replaced the phased-out CFCs and HCFCs have zero ODP, most have substantial GWP. The following table drawn from *ASHRAE Fundamentals* Chapter 29 gives environmental properties of some refrigerants.

Refrigerant	Atmospheric lifetime	ODP	GWP
Some refrigerants with non-zero ODP			
R11 (CFC)	45 years	1.000	4,750
R12 (CFC)	100 years	0.820	10,900
R22 (HCFC)	11.9 years	0.040	1810
R123 (HCFC)	1.3 years	0.010	77
Some refrigerants with zero ODP			
R32 (HFC)	5.2 years	0.000	677
R134a (HFC)	13.4 years	0.000	1300
R407C (a mixture of HFCs R32, R125 and R134a)	-	0.000	1620
R410A (a mixture of R32 and R125)	-	0.000	1920
R513A	5.9 years	0.000	631
R1234yf	11 days	0.000	< 1
R717 (ammonia)	7 days	0.000	< 1
R744 (carbon dioxide, CO_2)	> 50 years	0.000	1

CFC AND HCFC PHASE-OUT

This table shows that not only does R22 have a significant ODP, but 1 kg of R22 has a GWP of 1810 or the same global warming effect as 1.81 tonnes of CO_2. Until the R22 phase-out began, most small and medium sized air conditioning systems used it as a refrigerant. Although now banned from manufacture and importation, the large quantity of R22 in existing systems in Australia (more than 11,000 tonnes in 2013, equivalent to over 20 million tonnes of CO_2) means that recycled refrigerant should continue to be available for existing systems. Drop-in replacements based on other refrigerants are also available.

CURRENT COMMON REPLACEMENT REFRIGERANTS

The two most common alternatives to R22 are R407C and R410A, both of which are mixtures of HFC refrigerants. For large chillers the most common replacement is R134a, another HFC, also used for automotive air conditioning and domestic refrigerators.

While the HFC refrigerants R407C, R410A and HFC-134a have zero ODP, they have comparatively high GWP. Reflecting this, in 2016, the Australian Department of the Environment announced a phase-down of HFC refrigerants, commencing January 2018 aiming to reduce HFC emissions by 85 per cent by 2036. This means that while HFC refrigerants may be viable for short lived- equipment currently, their use in more durable plant should be avoided.

ALTERNATIVE REPLACEMENT REFRIGERANTS

Refrigerant Safety Groups in AS/NZS ISO 817

With some significant exceptions (e.g. CO_2), refrigerants with lower GWP are more flammable than those with high GWP. Following international practice, AS/NZS ISO 817 classifies refrigerants into Safety Groups according to their flammability and toxicity, low toxicity refrigerants being prefixed A with higher toxicity refrigerants prefixed B. The prefixes are followed by a number indicating increasing flammability. For example, Safety Group A1 refrigerants (such as R22) have low toxicity and flammability while B3 refrigerants have both higher toxicity and flammability. AS/NZS 5149 Parts 1 to 4 impose more stringent requirements as toxicity and flammability increase, progressing from A1 to B3.

Refrigerant designations

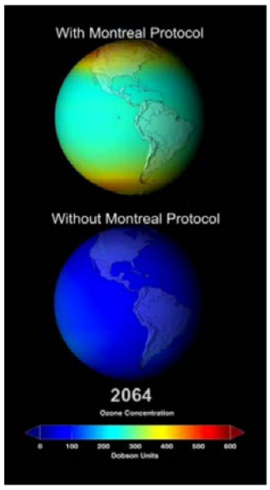
There are two common systems of designating refrigerants. One is a numbering system using the prefix R- or just R, for example R-22 and R22. A second uses a chemical composition designating prefix such as CFC and HCFC. For example, HCFC-22, HCFC22, R22 and R-22 are the same refrigerant. CFC, HCFC and HFC designations are more commonly used for halogenated hydrocarbons and R designations for mixtures and non-halogenated hydrocarbon and other compounds. This TECHnote uses the R designation consistent with AS/NZS ISO 817 (2016).

Ozone depletion potential (ODP)

ODP is the ratio of the impact of a substance on the ozone compared to that of CFC-11.

Global warming potential (GWP)

GWP is the ratio of global warming effect of a substance compared to that of carbon dioxide (CO_2).



What Does The Montreal Protocol Mean for Australia? (*Sourceable.net*)

Standards

AS/NZS ISO 817 Refrigerants – Designation and safety classification.

AS/NZS 5149 Refrigerating systems and heat pumps – Safety and environmental requirements Part 1 Definitions, classification and selection criteria

Part 2 Design, construction, testing, marking and documentation

Part 3 Installation site

Part 4 Operations, maintenance, repair and recovery

AS/NZS 60335.2 Household and similar electrical appliances – Safety

Part 40 Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

REFRIGERANTS

Significant in resolving the problem of low GWP has been the recent development of new refrigerants that have zero ODP, low GWP, low toxicity and are only mildly (and manageably) flammable. These are designated A2L in AS/NZS ISO 817. Crucially, although A2L refrigerants are flammable, they are unlikely to cause explosions.

Flammable and lower flammability refrigerants

Potential A2L alternatives to HFC refrigerants include R32 (GWP of 677) as a replacement for R407C and R410A in packaged equipment and R32 (GWP of 677), R513A (GWP of 631), and R1234yf (GWP of less than 1) as replacements for R134a in chillers. Some low GWP class A3 (highly flammable) refrigerants have also been proposed including R290 (propane), R1270 (propene) and R600a (isobutane).

AS/NZS 5149 Parts 1 to 4 place restrictions on flammable refrigerants including A2L that did not previously apply to A1 refrigerants. For example, AS/NZS 5149.1 sets a limit (called the Practical Limit) on the amount of refrigerant permitted in a space. For an R22, an A1 refrigerant, the Practical Limit is 0.3 kg/m³, for R32 (A2L) it is 0.061 kg/m³ and for R290 it is 0.008 kg/m³.

Other issues relating to flammable refrigerants include limitations on pipe routes and demountable joints, avoidance of ignition sources and provision of leak detection alarms.

Toxic refrigerants

Ammonia (R717) has been used for industrial refrigeration since the nineteenth century. Despite its low cost and desirable thermodynamic properties, it is toxic, corrosive and requires costly steel piping. The resulting restrictions make it unlikely to be used in air conditioning systems although ammonia chiller plant in a remote building could be used to supply chilled water. Similarly, less common toxic refrigerants such as sulfur dioxide are also precluded.

High pressure refrigerants

Among the high-pressure refrigerants, carbon dioxide (CO_2) was formerly used for air conditioning of spaces like theatres before the advent of synthetic refrigerants. Although safe in low concentrations, CO_2 requires very high pressures, making significant demands on plant and presenting a different set of hazards to be managed.

Absorption refrigeration

The systems and refrigerants described so far are all the vapour compression types however other means of refrigeration are possible, the most common being absorption refrigeration. Two types of absorption refrigeration system are in use: ammonia and lithium bromide, both materials being used in combination with water. In ammonia systems, ammonia is the refrigerant making low temperatures possible (typically -20°C) but limited to small capacities such as domestic refrigerators. In lithium bromide systems water is the refrigerant and so suitable for chilled water plant. It is only available in very large capacities.

Ammonia is toxic and lithium bromide is considered hazardous as it is harmful if swallowed, irritating to the skin, eyes and respiratory system and is psychoactive. Although both types of absorption system have zero ODP and use refrigerants with zero GWP they are extremely inefficient, typically requiring over 10 times the energy of vapour compression systems. Since this energy is primarily derived from fossil fuels, they can result in large CO_2 emissions unless the energy used is waste from another process, for example in a cogeneration or trigeneration system.

NATSPEC PROVISIONS

NATSPEC includes the following provisions:

- Worksections for plant using refrigerants contain a **Refrigerants** subclause that requires refrigerants be Safety Group A1 or A2L in AS/NZS ISO 817, have zero Ozone Depletion Potential and Global Warming Potential less than 700.
- These worksections also include the option of specifying refrigerant type or types in **SELECTIONS**. They also include requirements relating to the installation of systems that use flammable refrigerants.
  - *0771 Automatic controls* includes refrigerant leak detectors.
  - *0792 Mechanical maintenance* includes provisions relating to the servicing of systems that use flammable refrigerants.

DESIGNERS AND SPECIFIERS

Considerations for designers and specifiers include:

- Design life: Consider the design life of the plant and risks associated with possible phase-out of currently used refrigerants and either mandate or prohibit specific refrigerants.
- Standards and references: Designers should consult AS/NZS ISO 817 and AS/NZS 5149 Parts 1 to 4, manufacturer's recommendations and other references listed in the side bar and incorporate required provisions in their designs.
- Direct versus indirect global warming: The direct effect of refrigerants is not the only issue to consider as the efficiency of refrigerants varies. Benefits of low GWP refrigerants may be outweighed by greater lifetime energy use and greenhouse gas emissions. See *AIRAH Best Practice Guideline: Methods of Calculating Total Equivalent Warming Impacts (TEWI)*.

NATSPEC worksections

0715 Chillers – combined
0716 Chillers – centrifugal
0717 Chillers – water cooled screw
0718 Chillers – air cooled screw and scroll
0719 Chillers – absorption
0721 Packaged air conditioning
0722 Room air conditioners
0761 Refrigeration
0762 Cool rooms
0771 Automatic controls
0792 Mechanical maintenance

Reference documents

AIRAH Best Practice Guideline: Methods of Calculating Total Equivalent Warming Impacts (TEWI) (2012)

AIRAH Flammable refrigerants Safety Guide (2018)

ASHRAE Fundamentals Chapter 29 - Refrigerants (2021)

Outcomes of the Review of the Ozone Protection and Synthetic Greenhouse Gas Management Programme Department of the Environment and Energy, 2017

dcceew.gov.au/environment/protection/ozone/publications/factsheet-opsggm-review-outcomes