AIR CONDITIONING AND REFRIGERATION INDUSTRY REFRIGERANT SELECTION GUIDE

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"WELCOME TO THE REFRIGERANT SELECTION GUIDE"

This edition of the AIRAH Refrigerant Selection Guide brings you the latest information about refrigerants currently on the market in Australia.

For this reason a combined operation between AIRAH and the Environment Protection Group of Environment Australia (formerly the EPA) is ensuring that a wide range of people in the industry receives a copy and up to 30,000 copies will be distributed in Australia, New Zealand and other countries.

You will note that the pages of the Guide are crammed with information about all the new and old refrigerants. It was compiled by a committee headed by Past AIRAH National President, Cees Lommers, and is now in its sixth edition. Environment Australia has provided Trust Funds for the printing and dissemination of the Guide under the Ozone Protection Act of 1989.

Receiving publications such as this is one of the many benefits of AIRAH membership. Members also receive:

- A Technical Handbook
- A monthly Journal
- Monthly Divisional newsletters
- Access to Technical Application Manuals and other technical materials
- Education courses
- Conferences and other events at reduced rates

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PART 1: OVERVIEW OF ISSUES

INTRODUCTION

This guide includes information for designers and contractors in the refrigeration and air conditioning industry that assists in judgements on environmental issues and the effect refrigerants and systems can have on the environment. This document briefly explains the differences between Ozone Depletion and Global Warming and the impact these two distinctly different processes have on the environment.

The Australian Government is a signatory to the Montreal Protocol, which sets out a mandatory timetable for the phase out of ozone depleting substances and urges additional action to minimise damage to the ozone layer. This guide includes current requirements of the Montreal Protocol and an overview of the document entitled "Revised Strategy for Ozone Protection in Australia 1994" prepared by ANZECC. The Revised Strategy, prepared by the Environmental Protection Agency on behalf of the intergovernmental Ozone Protection Working Group of the Australian and New Zealand Environment and Conservation Council (ANZECC) conveys to industry and the community a clear understanding on the accelerated timetable to phase out ozone depleting substances.

This document covers CFC (ChloroFluoroCarbon), HCFC (HydroChloroFluoroCarbon), HFC (HydroFluoroCarbon) and HC (Hydrocarbon) refrigerants and their allocated ASHRAE numbers. Further alternatives may be included when testing and safety requirements have been addressed in the applicable Australian Standards and Codes. This guide provides a better understanding of alternative refrigerants and system performance effects resulting from the use of refrigerants that have little or no effect on the ozone layer and a minimal impact on global warming.

WHAT IS OZONE DEPLETION?

Ozone depletion is a thinning of the Ozone Layer, which first occurred in the stable stratospheric air over the Antarctic in the early 1970's and was later discovered over the Artic in 1992. The polar vortex makes the Antarctic air appreciably colder, by about 5 - 101C, than that air above the Artic. Polar stratospheric clouds which form during the Antarctic winter in the very cold stratosphere play a major role in creating the conditions for the loss of Ozone. The low temperature (-78'C) clouds comprise tiny particles of frozen water vapour, nitrogen and nitrogen oxides. The clouds act as reservoirs of chlorine held in inactive compounds such as hydrogen chloride, hydrochloric acid and chlorine nitrate, which do not react with ozone. With the coming of spring and the end of a long winter over the Antarctic, ultraviolet radiation from the sun encounters the stratospheric ice clouds and catalyses reactions on their surfaces, converting the inactive compounds to reactive chlorine monoxide. The chlorine monoxide destroys ozone at a very rapid rate - as much as 1 % per day at the peak.

Similar reactions occur with bromine which is derived from halon and is responsible for between 10% and 30% of ozone loss. The key conditions are the extreme cold, the still air within the polar vortex, the reservoir of chlorine components in the polar clouds and the presence of ultraviolet radiation. The ozone hole and ozone depletion resulted from CFCs released to atmosphere, making its presence felt in the stratosphere. The Ozone Depletion Potential reflects the combination of percentage (by weight) of chlorine atoms and the lifetime of the compound in the atmosphere. Ozone protects life on earth from damaging ultraviolet "B" radiation. It acts as a global sun screen absorbing the rays thus preventing loss them from reaching the earth. Further loss of ozone will thus allow more ultraviolet "B" radiation to penetrate to the earth and adversely affect human health and the environment.

WHAT IS GLOBAL WARMING?

The earth is surrounded by a thin film of gases which form the atmosphere. It is the composition of the atmosphere that distinguishes the earth from other planets in our solar system and creates the conditions necessary for the diversity of life on the earth's surface and in the oceans. Greenhouse gases have the potential to increase the earth's average temperature by trapping some of the heat the earth radiates back into space. The greater the concentration of greenhouse gases in the atmosphere, the greater the potential for a warmer planet and changes to the earth's climate.

The composition of the atmosphere has changed over geological time. Such changes usually take place over thousands of years. Human activities over the last two hundred years have measurably changed the composition of the atmosphere through the emission of greenhouse gases.

Since pre-industrial times, C02 concentration in the atmosphere has increased by about 28%, methane by 145% and nitrous oxide by 13%. These are the three main greenhouse gases. Fluorinated compounds such as HFCs, PFCs and SF_6 are also greenhouse gases. Although their atmospheric concentrations are small, they have a long atmospheric life.

GWPs (Global Warming Potential) are used by the policymakers to compare the impact on the climate system of emission of different greenhouse gases. The GWP index is relative to carbon dioxide (C02), which is normalised at 1. As greenhouse gases differ in their atmospheric lifetimes, GWPs also have a time component. A time horizon of 20 years and 100 years is used in this document to enable the proper evaluation on the environment.

WHAT IS AN ACCEPTED METHOD OF ESTIMATING THE IMPACT OF GLOBAL WARMING?

Methods of calculating the total effect on Global Warming have been developed using the direct (due to emission) and indirect (due to energy requirement) effects of refrigerants considered for use in a system.

The introduction of TEWI (Total Equivalent Warming Impact) enables designers and contractors to estimate the equivalent C02 emission to atmosphere from system leakage (direct emission) and energy consumption (indirect emission). The highest portion of the global warming effect of a system is normally attributed to the (indirect) C02 emission due to the required energy generation. Based on the high percentage of fossil fuels used in power stations the average European C02 release is around 0.6 kgs per kWhr of electrical power generated. The methods of generating power vary from state to state and from country to country, as do their respective effects on Global Warming (eg. coal fire generation will release between 0.6 and 0.8 kg Of C02 per kWhr of electrical energy generated, whereas hydro power generation will only contribute a negligible quantity Of C02 to atmosphere). The total energy required for the operation of a system would therefore have a direct impact on global warming effect.

The criteria used to estimate the Total Equivalent Warming Impact can be summarised as follows:

$$\text{TEWI} = \text{direct} + \text{indirect emission}$$

or

$$\text{TEWI} = \text{leakage} + \text{energy consumption}$$

or

$$\text{TEWI} = (\text{GWP} \times L_{annual} \times n) + (E_{annual} \times ß \times n)$$

Where:
GWP = Global Warming Potential of Refrigerant, relative to CO_2 (GWP $C0_2$ = 1.0)
L_{annual} = Leakage rate (kgs) per annum
n = Number of Years
E_{annual} = Energy consumption (kWhr p.a.)
ß = CO_2 emissions per kWhr

Refrigeration and air conditioning systems account for about 10 to 20% of total electricity consumption in developed countries. Research on TEWI (Total Equivalent Warming Impact) has shown that for most applications the impact on global warming will be greater from energy consumption than from $C0_2$ emission from refrigerants. Current and future technological advances for improving the energy efficiency of refrigerating and air conditioning systems will play a decisive role in reducing the greenhouse effect.

PART 2: NATIONAL AND INTERNATIONAL CODES

MONTREAL PROTOCOL

The timetable set by the Montreal Protocol is for production and consumption of ozone depicting substances in developed countries. Consumption is defined as the quantities manufactured and imported less those quantities exported or destroyed in a given year. Percentage reductions relate to the base year production for the substance. The following table summarises the requirements laid down under the 1987 Montreal Protocol, the 1990 London, the 1992 Copenhagen Amendments, and includes the requirements for those CFC and HCFC refrigerants commonly used in the air conditioning and refrigeration industry in Australia.

SUMMARY OF CONTROLS UNDER THE MONTREAL PROTOCOL

Substance:	Control Measures:		
	Montreal 1987	London Revision 1990	Copenhagen Revision 1992
CFCs (R11, R12, R113, R114, R115, R500, R502 and others)	1989 freeze at '86 levels 20% cut by mid 1993 Further 30% cut by mid 1998	50% cut by 1995 (i) Further 35% cut by 1997 100% phase-out by 2000	75% cut by 1994 100% phase-out by 1996 (other than essential uses)
HCFCs (R22 and others)	Not included	Not included, but to be reviewed in 1992	Freeze by 1996 35% cut by 2005, 65% by 2010, 90% by 2015, 99.5% by 2020, 100% by 2030
Note: Dates are 1 January unless otherwise indicated		(i) at 1986 levels: (ii) at 1989 levels	
Source: Environmental Protection Agency, CSIRO – Div. Of Atmosphere. Research.			

CFCs: Production and imports of CFC refrigerants ceased totally on 1 January 1996.

HCFCs: The Commonwealth Government introduced controls on the import and manufacture of HCFC refrigerants from 1 January 1996. The Commonwealth Government has formulated a set of HCFC controls, which allow an adequate ongoing supply of HCFC refrigerants for both new and used equipment, for the economic life of that equipment.

Supply controls have been set at levels approximately half the amount allowable under the Montreal Protocol, but have been estimated by industry to be adequate to meet the demand in Australia. Unless industry estimates of the total market are exceeded, quota systems will not apply, ensuring competition among suppliers and free entry and exit to the market.

The allowable supplies of HCFC refrigerants will peak in 1998-1999, then gradually decrease to zero by the year 2030. For the last 15 years of the phase out period only a small amount will be available, but this will be adequate for the servicing of long lived air conditioning equipment. States and Territories will continue their emission policies in regard to HCFC refrigerants. There will be no end use controls but sale of HCFC refrigerants will be restricted to registered persons. Service personnel will need to undertake proper training and work in accordance with the appropriate Australian Standards and Codes of Good Practice.

ANZECC "REVISED STRATEGY FOR OZONE PROTECTION IN AUSTRALIA 1994"

The ANZECC "Revised Strategy for Ozone Protection in Australia 1994" represents Australia's latest response to the global phase-out program for ozone depleting substances established under the *Montreal Protocol on Substances that Deplete the Ozone Layer.* Chapter headings include Policy Statements, Ozone Layer Depletion - Causes and Effects, Progress in Implementing the 1989 Strategy Recommendations, Issues for the Future, plus Industry Sectors and Targets.

HOW WILL THIS PHASE OUT AFFECT CFC BASED REFRIGERATION SYSTEMS?

If a system uses CFC as a refrigerant, it may not be possible to purchase replacement CFC refrigerants to re-charge/refill systems with refrigerant leaks. This would result in a deficient or inoperative refrigeration or air conditioning system. If the system operates on HCFC refrigerants, it is not necessary to take any action in the immediate future, although any type of refrigerant leak should always be rectified.

KYOTO SUMMIT

From 4 to 11 December 1997, more than 160 countries met in Kyoto, Japan, to discuss potential controls and reduction targets for Greenhouse Gas emissions for developing countries.

The outcome of the summit, adopted by the participating countries on 11 December 1997, when ratified as a legally binding Protocol, can be summarised as follows:

1. The average reduction of greenhouse gas emissions accepted by the 38 participating Industrialised countries is 5.2% from 1990 levels. Each of the 38 countries has a specific reduction target ranging from an 8.0% reduction for the European Union to an increase of 10.0% for Iceland. New Zealand's target is a 0% variation and Australia is permitted to increase its greenhouse gas emission levels by 8.0% from 1990 levels. The Australian target represents an overall reduction of 35.0% from its estimated 15 year projected emission levels. Targets are to be met by the 5 year emissions average over the years of 2008 to 2012. The qualified emission or reduction commitments agreed by the participating industrialised countries can be summarised as follows:

Party:	Qualified emission control limitation or reduction commitment (% of base year)	Party:	Qualified emission control limitation or reduction commitment (% of base year)
Australia	108	Leichtenstein	92
Austria	92	Lithuania*	92
Belgium	92	Luxembourg	92
Bulgaria*	92	Monaco	92
Canada	94	Netherlands	92
Croatia*	95	New Zealand	100
Czech Republic*	92	Norway	101
Denmark	92	Poland*	94
Estonia*	92	Portugal	92
European Community	92	Romania*	92

Finland	92	Russian Federation*	100
France	92	Slovakia*	92
Germany	92	Slovenia*	92
Greece	92	Spain	92
Hungary*	94	Sweden	92
Iceland	110	Switzerland	92
Ireland	92	Ukraine*	100
Italy	92	United Kingdom	92
Japan	94	U.S.A.	93
Latvia*	92		

* denotes countries that are undergoing the process of transition to a market economy.

2. The six gases covered by the treaty are: Carbon Dioxide ($C0_2$); Nitrous Oxide (N_20); Methane (CH_4); Perfluorocarbons (PFCs); Sulfur Hexafluoride (SF_6) and Hydrofluorocarbons (HFCs).

3. The binding controls are currently applicable only to developed countries. There are no commitments or voluntary participation by developing countries. The subject was postponed until further discussion at the next Conference of Parties scheduled for Buenos Aires in November 1998.

4. The agreement contains a "Clean Development Mechanism" which allows developed countries to finance emission reduction projects in developing countries and receive credit for doing so.

5. Emissions trading (which allows industrialised countries to buy and sell excess emissions credits amongst themselves) is included, although details have not been worked out.

6. Countries will be allowed to subtract the amount of greenhouse gases absorbed by forests within their own borders.

7. The enforcement issue was postponed until the next meeting when parties will decide how to penalise countries failing to meet their Protocol commitments.

8. The Protocol will be opened for signature for one year from 16 March 1998 to 15 March 1999. It will enter into force after it has been ratified by 55 countries representing 55% of the total 1990 emissions for developed countries.

9. The next conference of the Parties is scheduled for Buenos Aires from 2 to 13 November 1998. Preparatory meetings will be held in Bonn in June 1998.

PART 3: SYSTEM ASSESSMENT - CFC, HCFC AND HFC REFRIGERANT SELECTION

ALTERNATIVE REFRIGERANTS

The availability of CFC refrigerants to service existing plant is now becoming unreliable. Equipment owners should plan to have their CK based equipment made leak free, converted or replaced within the next few years. The conversion/retrofitting options available for the air conditioning and refrigeration industry can be summarised as follows. If equipment is normally leak free, such as domestic refrigerators, there is no need to convert the system. The equipment can see out its commercial life with the original charge, as there is no requirement to withdraw CFC Refrigerants from service. Alternatives for new equipment are not confined to HCFC and HFC refrigerants. Consideration should be given to other technologies and refrigerants such as Ammonia, Hydrocarbons, Absorption and the like.

The following table summarises the manufacturers recommendations for retrofit and new equipment replacement refrigerants. The final application of refrigerants should be checked for compatibility with equipment and system design. A thorough investigation should be undertaken with both refrigerant suppliers and equipment manufacturers to ensure replacement or alternative refrigerants are fully compatible with, and suitable for, the application and system design.

SECTOR	EXISTING CFC REFRIGERANT	EXISTING COMPRESSOR TYPE	RETROFIT CONVERSION	NEW EQUIPMENT	COMMENTS
Domestic Fridge/Freezers	R12	Sealed Unit	R134a, R401A, R409A, R413A	R134a	
Commercial Equipment Medium Temp.	R12	Sealed Unit	R134a, R401A[1], R409A, R413A	R134a, R22, R404A, R407A, R507	[1] R401A for Evap. temp. between -23ºC and 7ºC
	R12	Accessible Hermetic	R134a, R401A[2], R409[2], R413A	R134a, R22, R404A, R407C, R507	[2] R401A and R409 are not suitable for beverage coolers ie: Temprite, Drinkrite, coolers, etc.
	R12	Reciprocating Open Drive	R134a, R22, R401A[2], R407C, R409A[2], R413A	R134a, R22, R404A, R407C, R507	
Commercial Equipment Low Temp.	R502	Sealed Unit	R402A, R402B, R403A, R407B, R408A	R134a, R22, R404A, R407C, R507	
	R502	Accessible Hermetic	R402A, R402B, R403A, R407B, R408A, R507	R22, R403A, R404A, R407B, R507	
	R502	Reciprocating Open Drive	R402A, R402B, R403A, R407B, R408A, R507	R22, R403A, R404A, R407B, R507	
	R22	All	R407C, R410A	R407C, R410A	
Large Commercial and Industrial	R12	Reciprocating Open Drive	R22, R134a, R401A, R401B, R409A, R413A	R22, R134a, R404A, R507, R717, or absorption	
	R12	Centrifugal	R134a	R134a, R123, R22, R717, or absorption	
	R502	Reciprocating Open Drive	R402A, R403A, R404A, R407B, R408A, R507, possibly R22	R717, R22, R404A, R407B, R507	
	R113	Centrifugal	None	R134a, R123, R22, R717, or absorption	[3] usually extensive mod's required
	R114	Centrifugal	R124[3] (possibly)	R124[3] (possibly)	
	R22	All	R407C[4], R410A[4]	R407C[4], R410A[4]	[4] not for use with flooded evaporators
Mobile Air Cond. or Refrig.	R12	Reciprocating Open Drive	R134a, R401B, R401C, R409A, R409B, R413A (possibly R22)	R22, R134a, R404A, R407C, R507	
	R500	Reciprocating Open Drive	R409B	R22, R134a, R404A, R407C, R507	
	R502	Reciprocating Open Drive	R402A, R403A, R407B, R408A, R507 (possibly R22)	R22, R403A, R404A, R407B, R507	
Air Conditioning	R12	Reciprocating Open Drive	R134a, R401A, R409A, R413A, R22	R22, R134a, R717, or absorption	
	R12	Centrifugal	R134a	R134a, R123, R22, R717 or absorption	
	R500	Accessible Hermetic	R401B, R409B (possibly R401A or R134a[5])	R22, R404A, R407C	[5] severe loss of cooling capacity
	R11	Centrifugal	R123[6]	R123	[6] usually extensive mod's required
	R11	Hermetic	R123[6]	R123	
	R22	All	R407C, R410A	R407C, R410A	

Note: The above table provides only an overview of alternative refrigerant options. It is recommended that final selection and performance details are verified with the refrigerant supplier and equipment manufacturer before any work is undertaken.

COPING WITH THE PHASE OUT OF CFC BASED REFRIGERANTS

Designers and contractors should offer the following advice to their clients:

The accelerated phase out of new CFC production has reached the stage where good management of existing CM is vital in the successful transition to non-CFC refrigerants.

Systems using CFC refrigerants must be identified. All refrigeration and air conditioning systems must have labels showing the type of refrigerant and lubricant used.

If refrigerants or lubricants cannot be identified, contact the equipment manufacturer or a qualified refrigeration engineer to identify the refrigerant and/or lubricant used in the system.

If WC refrigerants are used, act now by planning containment *and/or replacement of the ozone depleting substance. CFC* **leakage must be minimised now.** No further action is required for ozone benign refrigerants such as ammonia or HFCs such as R 1 34a, R404A, R507 etc.

Determine the importance of the affected refrigeration system by assessing the nature and dependence of the system to the facility. For example, if *a plant failure could halt production or sales, phase out plans should take a very high priority.* Conversely, if a system consists of a small air conditioning plant in an office, and the facility owner feels that he can afford to be without it for a while, a technician or refrigeration engineer can respond on a crisis management basis.

It is therefore necessary to determine how crucial the refrigeration/air conditioning plant is to the facility.

Examples:

Small self contained units (i.e. domestic refrigerators, small retail display cases, small air conditioners) Refrigeration systems of this type are very reliable and often run for 20 years without maintenance. In these circumstances your actions should be to:

1.Continue running the existing plant until it reaches the end of its useful life.

2.Make the appropriate contingency plans in case the system breaks down and loses its charge of CFC refrigerant.

3.Plan how to safely dispose of an old system without venting refrigerant to atmosphere.

Small. medium and large systems use more complex items of refrigeration equipment and usually require some on site system assembly and refrigerant filling. *Refrigeration systems in this category are susceptible to refrigerant leakage and often require regular maintenance.* Typical examples are coolrooms, freezer rooms, split system air conditioners, chilled water systems, and built up direct expansion plant. There is a wide range of technical solutions that can be applied to achieve CFC phase out. In some cases the correct line of action is quite clear, but in most instances there are options that require further assessment.

The following step by step approach will ensure that all relevant options are properly assessed.

Step 1: Equipment Identification

Before assessing the available technical options it is important to know the type of equipment and refrigerant that is used in EACH plant or system, as this will have direct impact on the choices available.

REFRIGERANT AND LUBRICANT: Identify the type of refrigerant and lubricant being used.

CAPACITY: It is important to note the size of each plant, as this may affect the technical options to be adopted.

COMPRESSOR TYPE: The type of compressor used in a refrigeration system has a strong influence on conversion opportunities (eg. Hermetic, semi-hermetic and open drive compressors have varying opportunities and limitations for conversion).

SYSTEM OPERATING PRESSURES: The operating pressures of CFC refrigerants will limit the alternatives and types of replacement refrigerants available for the existing system.

AGE OF PLANT: The age and life expectancy of the plant will influence the decision to convert existing equipment or replace it with new plant.

COMPATIBILITY: Various materials used in CFC and HCFC refrigeration systems can affect conversion options. When considering conversion to a different refrigerant, establish the type of lubricant, elastomers (rubber / plastic seals, gaskets, etc.) and metals used. New refrigerants must be chemically compatible with all materials used in the existing system

COOLING: Determine the required cooling capacity for the facility and the shortfall/surplus capacity installed on the site. System conversions can accommodate system shortfalls and/or optimise on total energy input by utilising current technologies, design and installation techniques.

Step 2 - Refrigerant Usage Audit

AVAILABLE CFC BANK: Determine the total quality of each CFC refrigerant being stored on site in existing systems and equipment. This will provide important data on the needs for replacement and the potential to re-use CFCs from converted or replaced plants and systems.

ANNUAL REFRIGERANT USAGE: Many plants suffer from a considerable degree of refrigerant leakage. A low CFC consumption may sustain continued usage for a few more years. If the equipment is susceptible to leaks either implement a leakage reduction campaign or replace the equipment and use a new refrigerant. Annual consumption can be checked by consulting purchasing and maintenance records.

Step 3 - Review Options

OPTION 1

Continue using existing CFC plant: If a refrigeration system is leak free, usage of the existing refrigerants can continue, providing an emergency plan is established to take care of a plant failure.

OPTION2

Leakage reduction: Many refrigeration plants leak relatively badly. It will prove impossible to continue usage of existing plants unless levels of leakage are considerably reduced

OPTION 3

Refrigerant recovery and re-use: Whenever an old plant is being decommissioned or a plant is being serviced **it is essential that the refrigerant is recovered.** During the recovery process, it is important that refrigerant is transferred into a cylinder that is empty or that **contains the same type of refrigerant.**

Refrigerant should only be handled by a qualified refrigeration engineer or accredited refrigeration technician.

OPTION 4

Using alternative refrigerants: One of the most important options to consider for CFC phase out is the use of an alternative ozone benign refrigerant.

It should be noted that all refrigerants must be used with caution. For further information refer to the respective manufacturer of the refrigerant.

IMPLEMENTATION

After the options have been reviewed you are in a position to implement those that are appropriate. It is important to remember that the refrigeration contracting industry has limited capacity. If you or your client's facility is not to suffer from a lack of refrigeration you must ACT NOW. If the financial impact of CFC phase out is required to be minimised it is necessary that a REFRIGERANT MANAGEMENT PROGRAM is established without delay.

This will include a combination of several of the options described. It will allow maximum possible operation of the existing plant and equipment, whilst ensuring that the phase out occurs in a controlled way with minimum risk to the facility and the environment.

The elements of a Refrigerant Management Program should include:

1.Minimise leaks and ensure no refrigerant is being vented to atmosphere;

2.Identifying which equipment can be converted or replaced most easily/cheaply and which plant is old and due for replacement anyway;

3.In year one (1), convert or replace enough equipment to supply sufficient recovered CFC for annual servicing requirements for your remaining equipment;

4.In year two (2) and beyond, continue the process until all plant and equipment has been converted to **Ozone Benign** refrigerants. The investment cost for conversion and/or replacement of existing equipment operating on CFCs can be spread over several years by adopting the above steps. Benefits can also be gained from new technology, equipment and refrigerant developments.

Options can be reviewed and strategies can be modified as new refrigerants or technologies become available on the market. In some instances, such as CFC 11 chiller systems, it is not possible to convert the plant to operate on an ozone benign refrigerant. Equipment of this type should, if possible, be converted to a low ozone depleting HCFC refrigerant until such time as an ozone benign replacement is available.

SELECTING AN OZONE FRIENDLY REFRIGERANT

The numerous "alternative" refrigerants available on the market today present a somewhat confusing situation for designers and contractors. ANSI/ASHRAE standard 34 provides refrigerant numbering system assigning composition-designating prefixes for the various refrigerant groups. ASHRAE refrigerant number groups are as follows:

- R10 to R50 are Methane Series Refrigerants;
- R110 to R170 are Ethane Series Refrigerants;
- R216ca to R290 are Propane Series Refrigerants;
- RC316 to RC318 are Cyclic Organic Compound Refrigerants;
- R400 to R411B are Zeotropic Blend Refrigerants**;
- R500 to R509 are Azeotropic Blend Refrigerants;
- R600 to R620 are Miscellaneous Organic Compound Refrigerants;
- R630 and R631 are Nitrogen Compounds;
- R702 to R764 are Inorganic Compounds and;
- R1112a to R1270 are Unsaturated Organic Compounds.

**Zeotropic Blend refrigerants that are commercially available have been assigned an identifying number in the 400 Series. This number designates which components are in the mixture but not the amount of each. The letter added to the refrigerant number distinguishes between zeotropic blends having the same components in different proportions.

Replacement refrigerants can be segregated into two distinct categories:

Category 1 - Transitional or Retrofit Refrigerants;

Transitional or Retrofit refrigerants are HCFC (HydroChloroFluoroCarbon) refrigerants which also contain reduced amounts of Chlorine. They are primarily intended as substitute refrigerants for existing systems, where a shortage of CFC refrigerants is expected.

These refrigerants should be considered as an interim medium term alternative and not a long term replacement refrigerant, as HCFCs must also be phased out in Australia by the year 2030 under of the Montreal Protocol. HCFC blends available in Australia have a very low Ozone Depletion Potential (i.e less than 0. 1) and a relatively low Global Warming Potential (i.e. less than 1.0).

Category 2 - Medium and Long Term Refrigerants;

Chlorine free refrigerants are considered a long term substitute refrigerants for current CK based refrigerants. HFC (HydroFluoroCarbon) refrigerants available in Australia have a zero Ozone Depletion Potential (ODP) and a relatively low Global Warming Potential (GWP) (i.e. less than 1.0).

Refrigerant Selection Considerations:

ENVIRONMENTAL PROPERTIES: A long term replacement refrigerant should have zero or a low Ozone Depletion Potential, a low Global Warming Potential and a short estimated atmospheric life.

No:	Name:	Chemical Formula:	O.D.P.:	G.W.P.: 20; 100 yrs	Safety Classification
CFC's:					
R11	Trichlorofluoromethane	$C.Cl_3.F$	1.00	5,000; 4,000	A1
R12	Dichlorodiflouromethane	$C.Cl_2.F$	0.95	7,900; 8,500	A1
R113	Trichlorotrifluoroethane	$C.Cl_2.F.C.Cl.F_2$	0.85	5,000; 5,000	A1
R114	Dichlorotetrafluoroethane	$C.Cl..F_2.C.Cl.F_2$	0.70	6,900; 6,300	A1
R500	CFC Blend	CFC-12 (74%) HFC-152a (26%)	0.70	6,000; 6,300	A1
R502	CFC Blend	CFC-115 (51%) HCFC-22 (49%)	0.70	6,000; 6,300	A1
HCFC's					
R22	Chlorodifluoromethane	$C.H.Cl.F_2$	0.055	4,300; 1,700	A1
R123	Dichlorotrifluoroethane	$C.H.Cl_2.C.F_2$	0.020	300; 100	B1
R124	Chlorotetrafluoroethane	$CH.F.Cl.C.F_3$	0.022	1,500; 480	A1
R401A	HCFC Blend	HCFC-22 (53%) HCFC-124 (34%) HFC-152a (13%)	0.037	2,900; 1,100	A1/A1
R401B	HCFC Blend	HCFC-22 (61%) HCFC-124 (28%) HFC-152a (11%)	0.040	3,100; 1,200	A1/A1
R401C	HCFC Blend	HCFC-22 (33%) HFC-124 (52%) HFC-152a (15%)	0.030	2,300; 850	A1/A1
R402A	HCFC Blend	HCFC-22 (38%) HFC-125 (60%) HC-290 (propane) (2%)	0.021	4,400; 2,600	A1/A1
R402B	HCFC Blend	HCFC-22 (60%) HFC-125 (38%) HC-290 (propane) (2%)	0.033	4,400; 2,200	A1/A1
R403A	HCFC Blend	HCFC-22 (75%) HFC-218 (20%) HC-290 (propane) (5%)	0.041	4,200; 2,700	A1/A1
R403B	HCFC Blend	HCFC-22 (56%) HFC-218 (39%) HC-290 (propane) (5%)	0.030	4,300; 3,700	A1/A1
R405A	HCFC Blend	HCFC-22 (45%) HFC-142b (5.5%) HFC-152B (7%) HFC-318 (42.5%)	0.028	4,800; 4,800	A1/A1
R406A	HCFC Blend	HCFC-22 (55%) HCFC-142b (41%) HC-600a (isobutene) (4%)	0.057	4,100; 1,800	A1/A2
R408A	HCFC Blend	HCFC-22 (47%) HFC-125 (7%) HFC-143a (46%)	0.026	4,800; 3,000	A1/A1
R409A	HCFC Blend	HCFC-22 (60%) HCFC-124 (25%) HCFC-142b (15%)	0.048	3,600; 1,400	A1/A1
R409B	HCFC Blend	HCFC-22 (65%) HCFC-124 (25%) HCFC-142b (10%)	0.039	3,600; 1,510	A1/A1

R411A	HCFC Blend	HCFC-22 (87.5%) HCFC-152a (11%) HCFC-1270 (1.5%)	0.048	3,900; 1,600	A1/A2
R411B	HCFC Blend	HCFC-22 (94%) HCFC-152a (3%) HCFC-1270 (3%)	0.052	4,100; 1,600	A1/A2
R412A	HCFC Blend	HCFC-22 (70%) HCFC-142b (25%) HFC-218 (5%)	0.055	4,300; 2,000	A1/A1
R509	HCFC Blend	HCFC-22 (44%) HFC-218 (56%)	0.024	4,600; 4,700	A1
HFC's					
R125	Pentafluoroethane	$C_2.H.F_5$	0.0	4,800; 3,200	A1
R134a	Tetrafluyoroethane	$C.F_3.C.H_@.F$	0.0	3,300; 1,300	A1
R404A	HFC Blend	HFC-125 (44%) HFC-134a (4%) HFC-143a (52%)	0.0	5,000; 3,700	A1/A1
R407A	HFC Blend	HFC-32 (20%) HFC-125 (40%) HFC-134a (40%)	0.0	3,600; 1,900	A1/A1
R407B	HFC Blend	HFC-32 (10%) HFC-125 (70%) HFC-134a (20%)	0.0	4,200; 2,600	A1/A1
R407C	HFC Blend	HFC-32 (23%) HFC-125 (25%) HFC-134a (52%)	0.0	3,400; 1,600	A1/A1
R410A	HFC Blend	HFC-32 (50%) HFC-125 (50%)	0.0	3,300; 1,900	A1/A1
R413A	HFC Blend	HFC-134a (88%) HFC-218 (9%) HC-600a (3%)	0.0	3,400; 1,200	A1/A2
R507A	HFC Blend	HFC-125 (50%) HFC-143a (50%)	0.0	5,500, 3,800	A1
OTHER					
R717	Ammonia	NH_3	0.0	0.0	B2

Note:**O.D.P.** referenced to Ozone Depletion Potential of CFC- 11 (ie. O.D.P. of CFC-11 = 1.0).

G.W.P. referenced to the absolute Global Warming Potential for C02 using a time horizons of 20 and 100 years have been included, with the first figure referring to the 20 year time horizon. Calculated GWP values for refrigerant blends utilise GWP_{20} of 4,800; GMT_{100} of 7,000 for HFC218 and GWP_{20} of 6,000; GWP_{100} of 9, 100 for HFC318.

Safety Group Classifications are indicated by Alphanumeric characters (eg. AI, A2, B3 etc). The capital letters A or B indicate low or higher toxicity and the numeric value refers to the refrigerant's flammability (the number 1 being no flame propagation and 3 being higher flammability).

PERFORMANCE: As all refrigerants perform differently, it is necessary to cheek the performance characteristic of each *alternative refrigerant* being considered for a particular system.

A full comparative *performance analysis* should be based on identical operating conditions (such as evaporating and condensing *temperatures) and* should include *Coefficient of* Performance, Compression Ratio, Mass Flow Rate and Temperature Glide. All comparisons should be based on a standard method such as that published by ASHRAE.

A variation in operating conditions will result in a meaningless comparison. Should a refrigerant be selected as a replacement refrigerant for an existing system, it will then be necessary to include the existing refrigerant in the comparative analysis. Properties and performance characteristics of refrigerants and blends, based on ASHRAE conditions have been summarised as follows:

	Properties:		**Performance*:**				
	Boiling Point at 101.3 kPa (atmos.) (ºC)	**Freezing Point: (ºC)**	**Evaporator Pressure: (kPa)**	**Condensing Pressure: (kPa)**	**Comp. Ratio:**	**C.O.P. Cooling Mode:**	**Temp. Glide: (ºC)**
CFC's							

R11	23.82	-111	20	125	6.19	5.01	0
R12	-29.79	-158	183	745	4.08	4.71	0
R113	47.57	-35	7	54	7.84	5.77	0
R114	3.8	-94	47	250	5.37	4.76	0
R500	-33.5	-159	214	879	4.11	4.69	0
R502	-45.4	-	349	1319	3.78	4.36	0
HCFC's							
R22	-40.9	-160	296	1192	4.03	4.64	0
R123	27.9	-107	16	110	6.96	4.93	0
R124	-13.2	-199.15	90	445	4.96	4.68	0
R401A	-33.0/-26.7	-	177/223	806/925	4.45	4.68	4.8/-5.0
R401B	-34.6/-28.7	-	193/236	864/974	4.37	4.67	4.3/-4.4
R401C	-28.3/-23.6	-	142/188	673/795	4.63	4.70	5.2/-6.0
R402A	-48.9/-46.9	-	415/431	1585/1610	3.80	4.22	0.7/-0.6
R402B	-47.1/-44.8	-	372/403	1455/1512	3.87	4.38	1.6/-1.5
R403A	-50.0/-47.5	-	343/380	1350/1405	3.87	4.44	2.0/-1.6
R403B	-49.5/-48.6	-	380/400	1448/1470	3.76	4.26	1.1/-0.6
R405A	-35.5/-30.0	-	N/A	N/A	N/A	N/A	N/A
R406A	-36.0/-26.6	-	144/208	672/848	4.51	4.76	7.7/-8.4
R408A	-45.6/-44.6	-	331/337	1310/1323	3.95	4.48	0.4/-0.4
R409A	-34.3/-25.8	-	168/231	771/945	4.29	4.82	7.0/-7.5
R409B	-35.5/-27.8	-	184/244	834/992	4.38	4.67	6.2/-6.4
R411A	N/A	-	N/A	N/A	N/A	N/A	N/A
R411B	N/A	-	N/A	N/A	N/A	N/A	N/A
R412A	-40.1/-32.0	-	175/255	801/1013	4.43	4.70	7.8/-8.7
R509A	-47.5	-	380	1430	3.76	4.12	0
HFC's							
R125	-48.6	-103	410	1568	3.83	4.07	0
R134a	-26.1	-97	164	770	4.70	7.63	0
R404A	-46.5/-45.7	-	359/367	1410/1423	3.91	4.22	0.6/-0.4
R407A	-45.5/-38.9	-	273/351	1211/1394	4.34	4.45	4.8/-5.2
R407B	-47.3/-42.9	-	315/378	1342/1476	4.18	4.27	3.6/-3.6
R407C	-44.0/-36.8	-	259/329	1155/1333	4.45	4.47	4.9/-5.3
R410A	-52.7	-	482/484	1877/1884	3.89	4.35	0.0/-0.1
R413A			178/222	830/906	4.64	4.50	2.5/-3.2
R507A	-46.7	-	378	1465	3.87	4.26	0
OTHER							
R717	-33.3	-77.7	236	1164	4.94	4.84	0

*** Note:**

- Performance details are calculated in accordance with the requirements for ASHRAE Book of Fundamentals Chapter 16 and are based on 258 K Evaporation and 303 K Condensing temperatures.
- Where two pressures are shown (i.e. 1801223) the first value indicates absolute vapour (dew) pressure and the second value indicates absolute liquid (bubble) pressure.
- Temperature glide values for zeotropic blends (R400 series refrigerants) include the evaporating glide as the first value and the condensing glide as the second value.
- N/A Denotes information not available at the time of publication.

TEMPERATURE GLIDE: A single component refrigerant, such as CFC-12 or HFC-134a, boils at a constant temperature for a given pressure.

Mixtures containing more than one component, such as R-500 and R502 (ASHRAE 500 series refrigerants) that boil at a constant temperature are called azeotropes.

Near-Azeotropic and non-Azeotropic mixtures (ASHRAE R400 series refrigerants) behave somewhat differently. Their compositions and boiling points do change as the material boils.

When a non-Azeotropic mixture boils as it passes through the evaporator, the vapour given off is richer in the more volatile (lower boiling point) component. The liquid therefore tends to become richer in the less volatile (higher boiling point) component and boils at a higher temperature.

This increase in boiling temperature during the evaporation process is called temperature glide. The reverse applies to condensation. The mixture is at its original composition when fully evaporated or fully condensed. In simple terms, the vapour temperature leaving an evaporator will be higher than the liquid temperature entering the evaporator. This is reversed in the condensing process. This temperature glide, together with the thermodynamic properties of the substances should be checked prior to establishing the most suitable replacement refrigerant.

Your assessment of a suitable replacement refrigerant should include the following:

SAFETY: All refrigerants used in the air conditioning and refrigeration industry are potentially dangerous and require different safety procedures and provisions. Ongoing use, design development and tests for safety change the requirements and safety provisions for each respective refrigerant. In some instances it may be necessary to provide additional refrigerant detection and oxygen level detection systems to ensure that the plant provides a safe operating environment to the operators and occupants.

COMPATIBILITY: When selecting a replacement refrigerant for an existing system it is necessary to cheek the compatibility of the fluid with existing system components and operating conditions such as operating pressures, lubricants used, component seals and the like.

AVAILABILITY. The development of replacement refrigerants overseas has resulted in poor availability of many refrigerants in Australia. It is therefore necessary to ensure that your selected refrigerant is commercially available in the short, medium and long term.

Should a refrigerant be relatively new, the technician or refrigeration engineer should ensure that a second alternative drop-in replacement refrigerant is available without the requirement of any significant system changes.

COST: As the cost of refrigerants varies with supply and demand it is necessary to check the cost of both your first and second choice refrigerants to ensure that future purchases of replacement refrigerants remain affordable.

REFRIGERANTS, LUBRICANTS AND SYSTEM CONSIDERATIONS:

New generation refrigerants, in some instances, are more dependent on the correct application and type of refrigerant oil. Particular care should therefore be taken to ensure that the replacement refrigerant and compressor manufacturers' requirements are satisfied and conversion procedures (if necessary) are adopted.

HCFC-123 is classed as a low pressure refrigerant, designed to replace CFC-11 in centrifugal chillers. HCFC-123 is compatible with most material used on CFC-11 systems (including refrigerant oil) with the exception of motor windings and gasketing materials.

HCFC-123 has been subjected to rigorous analysis by the National Industrial Chemical Notification and Assessment Scheme (NICNAS), a division of Worksafe Australia in their Priority Existing Chemical No. 4 report dated March 1996.

The report indicates that HCFC-123 should be classified as Carcinogen - Category 3. Toxicity testing of HCFC-123 has indicated caution is needed with long term exposure, in the work place. The report has set a maximum recommended acceptable exposure limit (AEL) for HCFC-123 of 100 parts per million.

HFC-134a operates at pressures similar to CFC-12 and it is compatible with most materials in CFC-12 systems. However different HFC-134a driers are required and other minor system changes may be necessary. HFC-134a will not operate with the conventional mineral oils used with CFC-12. The industry has elected in most cases to use a synthetic polyol ester lubricant in new HFC-134a systems. Polyol ester lubricants absorb moisture and should not be left open to the atmosphere. CFC-12 and the mineral oils used in CFC-12 systems are compatible with polyol ester lubricants, enabling existing CFC-12/mineral oil systems to be retrofitted to HFC-134a/Poly Ester.

The only deviation from the above is the automotive industry where PAG (poly alkylene glycol) oils are recommended for new compressors and occasionally for retrofit. PAG oils absorb moisture ten times more readily than polyol ester lubricants. PAG oils are not generally compatible with either CFC-12 or mineral oil and so are not usually suitable for retrofits.

R401A is a HCFC blend or mixture refrigerant designed to replace CFC-12 refrigerant in existing systems, with evaporating temperatures between -23ºC and -7ºC, and is compatible with most materials in CFC-12 systems. Drier cores may require upgrading or changing and other minor design changes may be necessary.

It is recommended that 50% of the mineral oil in existing systems be replaced with alkyl benzene lubricant (polyol ester oil may be used). Alkyl benzene does not readily absorb moisture and can therefore be handled in the same way as mineral oil.

R401B is a HCFC blend or mixture refrigerant designed to replace CFC-12 refrigerants in existing systems with evaporating temperatures between -40ºC and -23ºC. It is recommended that 50% of the mineral oil in the existing CFC-12 systems be replaced with alkyl benzene lubricant (polyol ester oil may be used). Alkyl benzene lubricant does not readily absorb moisture and can therefore be handled in the same way as mineral oil. Drier cores may require upgrading or changing and other minor system changes may be necessary.

R401C is a HCFC blend or mixture refrigerant designed to replace CFC-12 in existing automotive air conditioning systems. The receiver/drier should be replaced with a suitable desiccant core and the flexible hoses should be replaced with nylon barrier hoses. It is not necessary to flush mineral oil from the system, but it is necessary that the 55cc's of alkyl benzene lubricant be added to replace the mineral oil lost during evacuation of the CFC-12 and also in the receiver/drier.

R402A is a HCFC blend or mixture refrigerant designed to replace CFC-502 refrigerant. R402A is compatible with most materials in CFC-502 systems. Drier cores may require upgrading or changing and other minor system changes may be necessary. The manufacturers recommend that 50% of the mineral oil in existing systems be replaced with alkyl benzene lubricant. Alkyl benzene does not absorb moisture. Drier cores may require replacing or changing and other minor system changes may be necessary.

R402B is a HCFC blend or mixture refrigerant designed to replace CFC-502 in existing small hermetic systems, such as ice-making machines. No oil changes are necessary and only the filter driers need to be changed to a suitable desiccant core.

R403A is a HFC blend or mixture refrigerant designed to replace CFC-502 refrigerant. R403A is compatible with most materials in CFC-502 systems and will operate with conventional mineral oils used with CFC-502 refrigerants.

R403B is a HCFC blend or mixture refrigerant designed to replace CFC-502 refrigerant. R403B is compatible with most materials in CFC-502 systems and will operate with conventional mineral oils used with CFC-502 refrigerants.

R404A is a HCFC blend or mixture refrigerant designed to replace CFC-502. R404A is compatible with most materials used in CFC-502 systems. These refrigerants will not operate with conventional mineral oils used with CFC-502 refrigerants. The manufacturers recommend that polyol ester lubricants are used. These refrigerants can be used as replacement refrigerants for R502 in existing systems. However, since they are all HFC based, it will be necessary to remove the existing mineral oil to less than 5% by flushing with polyol ester oils. Polyol ester oils readily absorb moisture and cannot be left open to the atmosphere without detrimental effects. Drier cores may require replacing or changing and other minor system changes may be necessary.

R405A is a HFC blend or mixture refrigerant designed to replace CFC-12 refrigerant. R405A is compatible with most materials in CFC-12 systems and will operate with conventional mineral oils used with CFC-12 refrigerants.

R406A is a HCFC blend or mixture refrigerant designed to replace CFC-12 refrigerant. R406A is compatible with most materials in CFC-12 systems and will operate with conventional mineral oils used with CFC-12 refrigerants.

R407A is a HCFC blend or mixture refrigerant designed as a replacement refrigerant for CFC-502 systems. Drier cores may require upgrading or changing and other minor system changes may be necessary. The manufacturer recommends that polyol ester lubricant is used with R407A refrigerants.

R407B is a HFC blend or mixture refrigerant designed as a replacement refrigerant for CFC-12 systems. Drier cores may require upgrading or changing and other minor system changes may be necessary. The manufacturer recommends that polyol ester lubricant is used with R407B refrigerants.

R407C is a HFC blend or mixture refrigerant designed as a replacement refrigerant for HCFC-22. Drier cores may require upgrading or changing and other minor system changes may be necessary. The manufacturer recommends that polyol ester lubricant is used with R407C refrigerants.

R408A is a HCFC blend or mixture refrigerant designed to replace CFC-502. R408A is compatible with most materials used in CFC-502 system and will operate with conventional mineral oils used with CFC-502 refrigerants. Polyol ester lubricants will however provide improved results. Drier cores may require replacing or changing and other minor system changes may be necessary.

R409A is a HCFC blend or mixture refrigerant designed to replace CFC-12. R409A is compatible with most materials used in CFC-12 systems. R409A will operate with conventional mineral and alkyl benzene lubricants. Drier cores may require replacing or changing and other minor system changes may be necessary.

R409B is a HCFC blend or mixture refrigerant designed to replace CFC-12. R409B is compatible with most materials used in CFC-12 systems. R409B can also be used as a replacement for R500, which is extensively used in transport refrigeration. R409B will operate with conventional mineral and alkyl benzene lubricants. Drier cores may require replacing or changing and other minor system changes may be necessary.

R410A is a near-azeotropic HFC blend refrigerant, designed to replace HCFC-22. R410A is compatible with most materials used in HCFC-22 systems. Drier cores may require upgrading or changing and other minor system changes may be necessary. R410A will not operate with conventional mineral oils used in HCFC-22 systems. The manufacturer recommends that polyol ester lubricants are used in R410A systems.

R411A is a HCFC blend or mixture refrigerant designed to replace HCFC-22. R411A is compatible with most materials used in HCFC-22 systems and will operate with conventional mineral and alkyl benzene lubricants. Drier cores may require replacing or changing and other minor system changes may be necessary.

R411B is a HCFC blend or mixture refrigerant designed to replace CFC-502. R411B is compatible with most materials used in CFC-502 systems and will operate with conventional mineral and alkyl benzene lubricants. Drier cores may require replacing or changing and other minor system changes may be necessary.

R412A is a HCFC blend or mixture refrigerant designed to replace CFC-500. R412A is compatible with most materials used in CFC-500 systems. R412A will operate with conventional mineral and alkyl benzene lubricants. Drier cores may require replacing or changing and other minor system changes may be necessary.

R413A is a HFC blend or mixture refrigerant designed as a replacement refrigerant for CFC-12 systems. Drier cores may require upgrading or changing and other minor system changes may be necessary. R413A will operate with conventional mineral oils, polyol ester and poly alkylene glycol lubricants.

R507 is an Azeotropic HFC blend refrigerant, designed to replace CFC-502 and is compatible with most materials used in CFC-502 systems. Drier cores may require upgrading or changing and other minor system changes may be necessary. R507 will not operate with conventional mineral oils used in CFC-502 systems. The manufacturer recommends that polyol ester lubricants are used in R507 systems.

R509A Is a HCFC blend or mixture refrigerant designed to replace CFC-502. R509A is compatible with most materials used in CFC-502 system and will operate with conventional mineral oils used with CFC-502 refrigerants. Ablyol ester lubricants will however provide improved results. Please note that R509A has a low critical temperature and is therefore not suitable for operation at high discharge pressures and temperatures. Drier cores may require replacing or changing and other system changes such upgrading condensers etc. may be necessary.

HANDLING REFRIGERANTS

The following recommendations concerning the practical handling of refrigerants should also be considered:

- Plants should always be charged with liquid refrigerants. When vapour is taken from the charging cylinder, shifts in concentration may occur.

- Many blends contain at least one flammable component. The entry of air into the system must be avoided. A critical displacement of the ignition point can occur under high pressure when a high proportion of air is present.

- The use of blends with a significant temperature glide would not be recommended for systems with flooded evaporators. A large concentration shift/layer formation expected in this type of evaporator.

RECLAIMING, RECYCLING OR REPROCESSING USED REFRIGERANTS

As the requirements of the Montreal Protocol took effect from 1 January 1996 by preventing or controlling the manufacture or import of CFC and HCFC refrigerants, the need to increase the rate of reclaiming, recycling and reprocessing of used refrigerants has become more demanding. Reclaimed, recycled and reprocessed refrigerants are exempt from the phase out controls and can therefore be used without contravening current legislation.

Refrigerant Reclaim Australia was established to facilitate reclaim, reprocessing and safe destruction of used refrigerants. Refrigerant Reclaim Australia (previously known as the ODS Reclaim Fund) is financed by a contribution from the importers of ozone depleting refrigerants and refrigerant wholesalers, which is passed down through the distribution chain. Refrigerant Reclaim Australia is an independent entity, audited by an independent accounting firm.

To encourage the reclamation of used refrigerants, the wholesalers pay $2.50 per kilogram for reprocessable refrigerant and $0.50 per kilogram for unusable refrigerant. Wholesalers will arrange for storage and ultimately the disposal of contaminated and unusable refrigerants. Refrigerant Reclaim Australia will facilitate the reprocessing, storage or safe disposal of used refrigerants.

PART 4: HYDROCARBON REFRIGERANTS

INTRODUCTION

Hydrocarbons provide alternative options to a number of CFC and HCFC refrigerants. In addition to their zero ozone depletion potential (ODP) and low global warming potential (GWP), they are compatible with common elastomer materials found in refrigerating systems and are soluble in conventional mineral oils. Since Hydrocarbons contain no Chloride of Fluoride molecules, they cannot undergo reaction with water and hence, do not form the corresponding strong acids that can lead to premature system failure.

ARE HYDROCARBONS SAFE TO USE?

The most important concern regarding the adoption of Hydrocarbons as refrigerant is their flammability. It should be remembered that millions of tonnes of hydrocarbons are used safely every year throughout the world for cooking, heating, powering vehicles and as aerosol propellants. In these industries, procedures and standards have been developed and adopted to ensure the safe use of the product. It is essential that the same approach is followed by the refrigeration industry. Hydrocarbons do not spontaneously combust on contact with air. Three elements need to coincide:

1. There must be a release of Hydrocarbons.
2. The Hydrocarbon needs to mix with the correct proportion of air. The range of flammability being approximately between 2 and 10%. *Outside these limits* combustion can not occur.
3. An ignition source with an energy greater than 0.25 millijoules or a surface with a temperature exceeding 440'C must be present.

Solutions to eliminate the scenario for potential fire or explosion can be summarised as follows:

1. Contain the Hydrocarbon either in a sealed system and/or reduce the number of connections.
2. 2. Restricting the maximum charge of Hydrocarbons.
3. Install ventilation such that the final concentration of Hydrocarbons in air is below the lower flammability limit.
4. Eliminate the source of ignition associated with the system.

It only needs one of these measures to be effective to prevent an incident.

ENVIRONMENTAL PROPERTIES: Hydrocarbon refrigerants have zero Ozone Depletion Potential, a very low Global Warming Potential and a short estimated atmospheric life.

No:	Name:	Chemical Formula:	O.D.P.:	G.W.P.: 20 / 100 yrs	Safety Classification:
R290	Propane	$CH_3CH_2CH_3$	0.0	3 / 3	A3
R600	Butane	$CH_3CH_2CH_2CH_3$	0.0	3 / 3	A3
R600a	Isobutane	$CH(CH_3)_3$	0.0	3 / 3	A3

Note: Refer footnotes for CFC, HCFC and HFC tables

PERFORMANCE: Properties and performance characteristics of hydrocarbon refrigerants, based on ASHRAE conditions have been summarised:

	Properties:		Performance*:				
No:	**Boiling Point at 101.3 kPa (atmos.) (ºC)**	**Freezing Point: (ºC)**	**Evaporator Pressure (kPa)**	**Condensing Pressure: (kPa)**	**Comp. Ratio:**	**C.O.P. Cooling Mode:**	**Temp Glide (ºC)**
R290	-42.07	-187.7	284	1053	3.70	4.59	0
R600	-0.5	-138.5	57	284	5.02	4.80	0
R600a	-11.73	-160.0	90	406	4.53	4.69	0

***Note:** Refer footnotes for CFC, HCFC and HFC tables

CAN HYDROCARBONS BE USED IN AUSTRALIA?

The use of Hydrocarbons is banned or restricted for use in some Australian states. The proposed new Standard AS/NZ 1677.2-1998 "Refrigerating Systems Part 2: Safety Requirements for fixed applications", provides for the use of Hydrocarbon refrigerants (within group A3), subject to certain conditions, building requirements and plant locations being satisfied. The following table lists the requirements of AS/NZ 1677.2-1998 and British Standard BS:4434:1995 for Group A3 refrigerants.

Category	Example	Key Requirements
I	Hospitals, prisons, theatres, supermarkets, schools, hotels, restaurants, dwellings	Not exceeding 1.5 kg* per sealed system Not exceeding 5.0 kg in special machinery rooms for indirect systems
II	Offices, small shops, small restaurants, places for general manufacturing and where people work	Not exceeding 2.5 kg* per sealed system Not exceeding 10.0 kg in special machinery rooms for indirect systems
III	Industrial cold stores, dairies, abattoirs, non public areas of supermarkets	Not exceeding 10.0 kg* in humanly occupied spaces Not exceeding 25.0 kg for systems with high pressure side in special machinery rooms No restriction of charge if all refrigerant containing parts in a special machinery room or open air
ALL	• All associated electrical contacts shall be sealed or non-sparking • Charge in systems below ground not to exceed 1.0 kg • Sealed systems not exceeding 0.25 kg can be sited in any location • For systems with charges exceeding 0.25 kg a sudden loss of refrigerant shall not raise the concentration in the room or occupied compartment above the practical limit (0.008 kg/m^3) • Piping for systems exceeding 1.5 kg must be restricted to the room containing the refrigerant	

Other standards to be considered are: AS 2430.1-1987 "Classification of Hazardous Areas"; AS 1861.2-1991 "Refrigerated Packaged Air-conditioners"; AS 1861.1-1988 "Refrigerated Room Air-conditioners"; AS 1430 1986 -Household Refrigerators and Freezers".

WHAT CONSIDERATIONS SHOULD BE MADE IN THE SELECTION & APPLICATION OF A HYDROCARBON REFRIGERANT?

- Use Hydrocarbons only with the written approval of the respective equipment manufacturer,
- Service and Installation personnel should be suitably trained;
- Work should be carried out on appropriately approved premises;
- Satisfy the requirements of all relevant and applicable Australian Standards;
- Comply with the legislative requirements of the respective state;
- Comply with the requirements of the respective local governing Authorities (ie. Department of Minerals and Energy, etc.);
- All refrigerants and lubricant used any system must be identified with permanent labelling;
- Use only Hydrocarbon refrigerant having an ASHRAE or ISO "R" number

SUMMARY

The accelerated CFC phase-out and controls on HCFCs have considerably shortened the lead time available to introduce long term solutions to the ozone problem. The current level of awareness in our industry of alternative refrigerants appears to be limited with regard to their global environmental impact and system performance. Today numerous choices of refrigerants provide a wide range of alternative solutions.

Our industry should now take the opportunity of addressing the requirements of the Montreal Protocol in a professional manner by selecting zero ozone-depleting refrigerants with a minimal global warming potential where possible. The new refrigerants are supported by a broad base of service capabilities and experience within Australia. Therefore acceptable plans can be developed which lead directly to environmentally acceptable long-term products, within time frames which are consistent with both international and Australian legislative requirements.

ACKNOWLEDGMENT

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REFERENCES

ANZECC "Revised Strategy for Ozone Protection in Australia 1994"; 1993 ASHRAE Hand Book of Fundamentals;

Product literature provided by Allied Signal Chemicals; Product literature provided by ICI Klea;

Product literature provided by Rhone-Poulenc; Product literature provided by Elf Atochem;

Product literature provided by DuPont Fluorochemicals;

International Institute of Refrigeration, International Journal of Refrigeration Volume 19, Number 8 1996, Review paper "Working fluids for mechanical refrigeration - Invited paper presented at the 19th International Congress of Refrigeration, The Hague, August 1995",

International Institute of Refrigeration, Applications for Natural Refrigerants, Refrigeration Science and Technology Proceedings, 1996-3, "Experiences with Hydrocarbon Blends in the UK Market, by T.J. Ritter".

International Institute of Refrigeration, 12th Informatory Note of the HR on Fluorocarbons and Refrigeration, Fluorocarbons and global warming, dated July 1997.

International Climate Change Partnership - results of Kyoto Meeting, dated 18 December 1997. Climate Change: More than just Carbon Dioxide by Ministry for the Environment, NZ

Refrigeration and Air Conditioning Industry Registration Board, Training Guide.

FURTHER INFORMATION

As this document considers a very dynamic subject, which will change with the development of new refrigerants and technologies, we invite those interested parties or persons to contribute their comments for consideration in future issues of this guide. Your comments can be forwarded to:

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