MAKING A GOOD CATCH:

NON-CFC TECHNOLOGIES IN THE FISHERY COLD CHAIN

United Nations Environment Programme
Division of Technology, Industry and Economics
OzonAction Programme

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The project was managed by:
Ms Jacqueline Aloisi de Larderel, Director, UNEP DTIE
Mr Rajendra Shende, Chief, Energy and OzonAction Unit, UNEP DTIE
Mr Jim Curlin, Information Officer, UNEP DTIE OzonAction Programme
Ms Dana Mun, Consultant, UNEP DTIE OzonAction Programme

The case studies were prepared by:
Dr Naresh Srivastava, Institute of Building Technology, University of Nottingham, United Kingdom

Quality review of specific sections of this document was done by
Dr Lambert Kuijpers, Co-chair, UNEP Technology and Economic Assessment Panel

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Contents

Preface

Fisheries are a key economic sector in most developing countries, and play an especially vital role in small island developing states whose economies are largely dependent on fishery products. Fish, shellfish and other products harvested from oceans, lakes and rivers are essential to national food security: nearly one billion people depend on fish for their primary source of protein[1]. Fishery products also provide significant employment and export earnings: in 1997 alone developing countries produced some 135.3 million tonnes of primary and processed fishery products, representing a total export value of approximately US$26.5 billion[2].

Throughout the journey from catch to consumer, the fishing industry relies on a cold chain to ensure the commercial viability of many of these products. The safety of the food, its shelf life, taste and appearance all depend on reliable refrigeration to retard spoilage. This cold chain may take various forms including ice, refrigerated seawater, refrigerated compartments and cold stores, but a common feature in all of these applications has been the traditional use of CFC-based refrigeration technology.

Due to the destructive effect of CFCs, HCFCs and other ozone depleting substances (ODS) on the earth's stratospheric ozone layer, the international community has agreed to reduce and eliminate the production and use of these substances. Under the Montreal Protocol on Substances that Deplete the Ozone Layer, developing countries agreed to a specific phase-out timetable, beginning with the freeze in consumption and production of CFCs in July 1999. This will be followed by a 50 per cent reduction by 2005, an 85 per cent reduction by 2007 and total phase out by 2010. HCFCs, another category

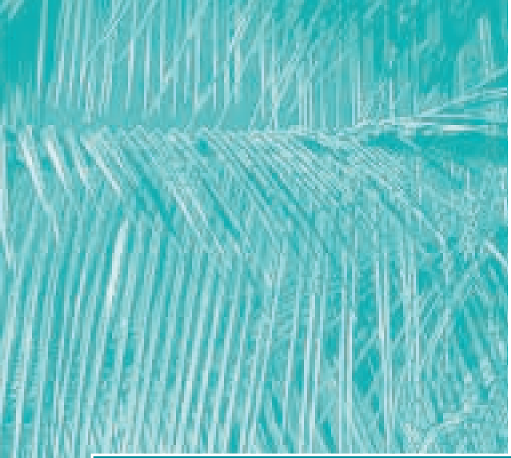
[1] UNEP, Global Environmental Outlook 2000 (London, 1999), page 45
[2] FAOSTAT Fisheries Database (http://apps.fao.org/page/collections?subset=fisheries).

of refrigerants that deplete the ozone layer, considered 'transitional substances', share the fate of CFCs and will also be phased out eventually (see table overleaf).

To meet the phase-out targets, the fishery industry must adopt new non-CFC refrigeration technologies and implement good servicing practices, containment measures and recovery and recycling. This has been recognized and supported by the Food and Agriculture Organization in a code of practice that encourages fishers and those engaged in processing and marketing of fish and fishery products to expeditiously reduce and eliminate CFCs and HCFCs (see page 5).

In order to encourage this process, UNEP DTIE OzonAction Programme has developed this publication to inform National Ozone Units (NOUs) and the fishery industry about alternative technologies to replace CFCs in the cold chain. It provides examples of non-CFC technologies used in eight countries: France, Greenland, Jamaica, Malaysia, Micronesia, the Philippines, the United Kingdom and the United States. The applications include a fish processing plant, a conditioning facility, ice plants, harbour cold stores, transport refrigeration and retail display cases. The document includes an overview of refrigeration equipment used in the fishery industry, an introduction to alternative refrigerants, case study examples, refrigerant data and sources of further information.

UNEP hopes that this booklet will stimulate further investigation by enterprises and organizations in the fishery sector and, ultimately, lead to a smooth transition away from ozone depleting refrigerants.



Control measures under the Montreal Protocol

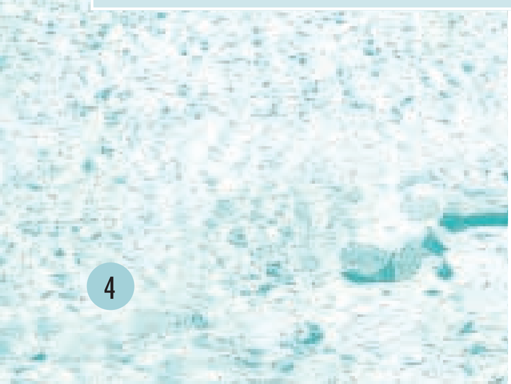
Timetable for CFC and HCFC phase out

Developing countries

Year beginning and thereafter[1]	*Control measures*	*Applicable to:* Consumption[2]	*Applicable to:* Production[3]
1999	Freeze of Annex A CFCs[4] at 1995–97 average level[5]	●	●
2003	Annex B CFCs[6] reduced by 20% from 1998–2000 average consumption[5]	●	●
2005	Annex A CFCs reduced by 50% from 1995–97 average level[5]	●	●
2007	Annex A CFCs reduced by 85% from 1995–97 average level[5]		
	Annex B CFCs reduced by 85% from 1998–2000 average level [5]	●	●
2010	Annex A and Annex B CFCs phased out[5]	●	●
2016	Freeze HCFCs[7] at the base line figure of year 2015 average level	●	
	Freeze HCFC production at the average of 2015 HCFC consumption and 2015 HCFC production[5]		●
2040	HCFCs phased out	●	

Developed countries

Year beginning and thereafter[1]	*Control measures*	*Applicable to:* Consumption[2]	*Applicable to:* Production[3]
1989	Freeze of Annex A CFCs at 1986 level[8]	●	●
1993	Annex B CFCs reduced by 20% from 1989 level[8]	●	●
1994	Annex A CFCs reduced by 75% from 1986 level[8]	●	●
	Annex B CFCs reduced by 75% from 1989 level[8]	●	●
1996	Annex A and B CFCs phased out [8, 9]	●	●
	Freeze of HCFC consumption at 1989 levels of HCFC consumption + 2.8% of 1989 CFC consumption (base level)	●	
2004	HCFC consumption reduced by 35% from base level	●	
	Freeze of HCFC production at the average of (a) 1989 HCFC consumption level + 2.8% of 1989 of the CFC consumption level (b) 1989 HCFC production level + 2.8% of 1989 of the CFC production level[8]		●
2010	HCFCs reduced by 65% from base level	●	
2015	HCFCs reduced by 90% from base level	●	
2020	HCFCs reduced by 99.5% from base level	●	
2030	HCFCs phased out	●	



[1] The effective date for every year, except 1999, which is 1 July, is 1 January. [2] The Protocol defines 'consumption' as production + imports - exports of controlled substances at a national level. [3] The Protocol defines 'production' as the amount of controlled substance produced at a national level - [amount destroyed + used a feedstock in the manufacture of other chemicals]. [4] Annex A CFCs 11, 12, 113, 114, 115 [5] With an allowance for production to meet the basic domestic needs of Article 5 Parties. Please see the Montreal Protocol for detail. [6] Annex B: CFCs 13, 111, 112, 211, 212, 213, 214, 215, 216, 217. [7] 40 hydrochlorofluorocarbons [8] With an allowance for production to meet the basic domestic needs of Article 5 Parties. Please see the Montreal Protocol for details. [9] With possible essential use exemptions.

FAO code of conduct for responsible fisheries

The Food and Agriculture Organization (FAO) Code sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources. This voluntary code is directed toward members and non-members of FAO, fishing entities, sub-regional, governmental and non-governmental regional and global organizations, and all persons concerned with the conservation of fishery resources and management and development of fisheries, such as fishers, those engaged in processing and marketing of fish and fishery products and other users of the aquatic environment in relation to fisheries. The Code was adopted in October 1995 by the FAO Conference. Section 8 of the Code, 'Protection of the Atmosphere', includes the following guidance:

'Owners, charterers and managers of fishing vessels should ensure that their vessels are fitted with equipment to reduce emissions of ozone depleting substances. The responsible crew members of fishing vessels should be conversant with the proper running and maintenance of machinery on board.

Competent authorities should make provision for the phasing out of the use of chlorofluorocarbons (CFCs) and transitional substances such as hydrochlorofluorocarbons (HCFCs) in the refrigeration systems of fishing vessels and should ensure that the shipbuilding industry and those engaged in the fishing industry are informed of and comply with such provisions.

Owners or managers of fishing vessels should take appropriate action to refit existing vessels with alternative refrigerants to CFCs and HCFCs and alternatives to halons in fire fighting installations. Such alternatives should be used in specifications for all new fishing vessels.

States and owners, charterers and managers of fishing vessels as well as fishers should follow international guidelines for the disposal of CFCs, HCFCs and Halons.'

The full text of the Code is available on-line at www.fao.org/fi/agreem/codecond/codecon.asp

Introduction

For centuries mankind has been aware of the importance of cooling food to delay its deterioration. Natural ice has been used by Chinese and Egyptians for this purpose for more than 2000 years. Frozen fish in cold winter from northern countries was transported to towns in warmer areas. Ice and salt mixture was successfully used during the mid-nineteenth century. With the advent of mechanical refrigeration during the third quarter of the nineteenth century, artificial ice was produced on commercial scales in North America and the European countries. By the end of the nineteenth century, both vapour compression machines using ammonia and carbon dioxide, and absorption machines using ammonia-water were developed for use in cold stores, ice factories and for quick freezing of fish by direct immersion in brine at –18 °C.

During the first quarter of the twentieth century, the technology of quick freezing of fish by direct immersion in brine found its way on board trawlers and ships in the United States of America and in Europe. Production by ice plants of around 50 tonnes of ice per day and cold storage at –10 °C became normal practices. By the second quarter of the twentieth century large boats, trawlers and ships with on-board refrigerated holds and quick brine freezers were commercialized. However, since the quality of frozen fish was found to be inferior to that of freshly caught fish, the beneficial effects of storage at lower temperatures of –23 to –29 °C were realized by late 1930s. With the advent of CFCs, ozone depleting refrigerants found their way into refrigerated trawlers, ships and cold stores. Trichloroethylene became a modern substitute for brine. By the 1960s, large capacity trawlers and ships, with fish holds at –20 °C and the brine at –35 °C, were manufactured. Freezing at sea was rapidly commercialized in the Europe and the USA. Russia alone had 500 freezer trawlers and factory ships. Rapid growth of commercial fishing during the 1960s led to strong international concern about the invasion of coast lines by foreign vessels. Subsequent conferences on the Law of Sea during the 1970s, caused some decrease in the growth of trawlers and factory ships.

Today refrigerants R-12 (CFC-12), R-22 (HCFC-22), R-502 (an azeotropic blend of CFC R-115 and HCFC R-22) and ammonia are the predominant refrigerants in the fishery cold chain. In the past few decades R-12 has been more commonly used in small cold rooms, refrigerated transport and domestic refrigerators and freezers. R-502 found its way predominantly in the commercial display cabinets and the R-22 in refrigerated warehouses, ships, fishing trawlers and containers. Ammonia has been the refrigerant of choice in large refrigeration plants including ice plants, freezer stores, cold storage, chilled brine and refrigerated sea water (RSW) systems particularly in developing countries with temperate climates like Southern China, India and Indonesia. Because of the well developed and established technology, low refrigerant cost, ease of manufacture and availability, and total environmental friendliness, ammonia is also gaining acceptance in many other applications.

R-11 (CFC-11) has been used as a blowing agent in expanded polyurethane insulation in cold storage and refrigerators and freezers cabinets.

The fishery industry has contributed only a small portion of global emissions of ozone depleting substances (ODS). In many cases like the refrigerated cargo ships, display cabinets, small cold rooms, refrigerators and freezers, the refrigerated space is shared by all types of food products, including fishery products. So it is difficult to make estimates separately for fishery applications. Some indicative estimates based on the seaborne trade of refrigerated food products are given in Table 1.

In 1987, 70 per cent of cold stores used ammonia and 30 per cent used R-22. In 1990, 85 per cent of refrigerated cargo ships used R-22, 13 per cent used R-12 and only 2 per cent used ammonia. In 1996, total cold storage holdings of fish and shell fish in the USA alone were about 150,000 tonnes.

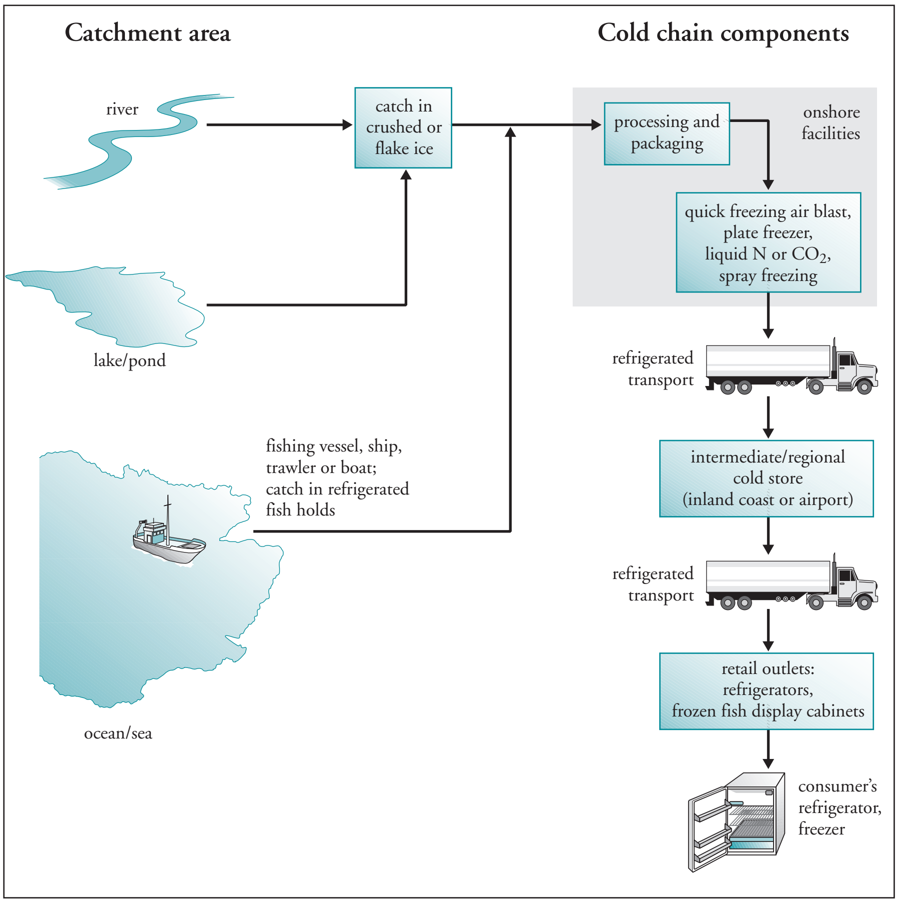
Phenomenal developments in biotechnology during the past three decades have resulted in enormous growth, not only in agricultural food produce like modern varieties of wheat, rice and corn, but also in aquaculture of vast varieties of food fish. Although some evidence of the existence of aquaculture of food fish in Egypt and China may be traced as far back as 2500 to 4000 BC, it is only in the past two decades that efforts have been made to develop large-scale aquaculture farms.

With limited and diminishing conventional wild fish resources, aquaculture has tremendous potential for growth, especially in the temperate climate of many developing countries, as it involves considerably less stringent refrigeration. Development of aquaculture ponds and farms nearer to the consumption area do not need large freezing, cold storage and refrigerated transport facilities. This provides for a better quality live fish for the consumer and lower costs for the producer. This has also led to the development of fish sperm refrigeration and live fish transport technology involving lower refrigeration requirements. Under the hot and dry climate conditions found in many

Table 1 Seaborne trade of refrigerated food products in 1992

Product	*Million tonnes*	*Percentage of total*
Bananas	9.1	33.0
Citrus	4.8	17.4
Deciduous	1.8	6.5
Fish	4.4	15.9
Meat	5.8	21.0
Dairy	1.7	6.2

Figure 1. The fishery cold chain



developing countries, evaporative cooling technology may be an effective and economic means of maintaining required temperature conditions in aquaculture ponds and during transport to retail outlet. As live fish are far better priced products than frozen fish, more and more efforts are being made to develop aquaculture of food fish and live fish transport. Such developments will have a significant effect on the fishery refrigeration industry.

Fishery cold chain requirements

The 'fishery cold chain' describes the logistics of handling the products at appropriate temperature and humidity conditions at all levels or stages from catch to consumption. Components of the fishery cold chain are shown in Figure 1.

The quality of all fishery products begins to deteriorate, due to bacterial growth, enzymatic changes and chemical actions, immediately after the animal's death either in water or on board the vessel. Bacterial actions degrade the fish quality; enzymatic actions cause unwanted flavour changes; and chemical actions involving oxidation of fat cause rancid flavours. All three actions are affected by temperature. The higher the

temperature, the faster the bacterial growth, and enzymatic and chemical actions, in the fish.

Careful handling, clean hygienic practices and low temperature conditions during processing, storage and transportation can be highly effective in retarding the spoilage of fish. Clean hygienic practices, involving careful processing, washing with clean water and handling of fish, are vital.

To ensure good quality, the fish catch should be cleaned and chilled to 0 °C and frozen, as quickly as possible. Chilling and freezing operations do not improve the fish quality, but slow down the bacterial, enzymatic and chemical actions thus prolonging the shelf life of the fish. However, these actions continue even after freezing at temperatures above –30 °C and in some high fat seafood continue below –30 °C. Accordingly, the high fat seafood should be kept at –40 °C to –50 °C if stored for long periods. The bacteria multiply rapidly at temperatures above 0 °C (melting ice). The shelf life of a fresh catch may be shortened by several days due to delays of only a few hours in handling as indicated in the following example:

Temperature, °C	Shelf life, days*
0	20
5	8
15	2

**depending upon initial temperature of catch, size and type of fish. Shelf life is improved by chilling the catch in ice or seawater slurry.*

To prevent dehydration and oxidation, the fishery product should be treated using a glazing compound and packaged tightly with a vapour/moisture resistant packing material before freezing.

Table 2 (overleaf) indicates storage temperature and humidity conditions required for a specific storage life for various fishery products. The effect of storage temperature on storage life of various types of finished (packaged or glazed) fishery products is shown in Table 3.

Refrigeration equipment

Commonly used refrigeration equipment in various types of facilities of the fishery industry are indicated in Table 4 on page 12. In most developing countries, smaller vessels (boats, trawlers) are used by small and medium size private entrepreneurs due to financial constraints. These boats have wooden ice bins or bunkers with or without insulation for holding 500 to 1,000 kg of fish catch per day. Depending upon the ambient temperature, 200 to 300 kg of crushed or flake ice produced by onshore ice making machines may be needed on board per 1,000 kg of fish catch.

In the developed countries, large size trawlers, factory ships, mother ships, special purpose tuna seiners, purse-seiners, cargo ships and reefers have been used for deep sea fishing and for fish transport involving trawl or transport duration of many weeks or even a few months.

Onshore facilities used for these ships include large ice plants, ice flake and crushed ice machines, processing cold rooms, freezer rooms, blast freezers, large size quick freezers, plate freezers and a fleet of refrigerated transport.

Table 2 Storage requirements of fishery products

Type of product	*Storage temperature (°C)*	*Relative humidity (%)*	*Approximate storage life*
Fish			
Haddock, cod, perch	–1 to 1	95 to 100	12 days
Hake, whiting	0 to 1	95 to 100	10 days
Halibut	–1 to 1	95 to 100	18 days
Herring			
Kippered	0 to 2	80 to 90	10 days
Smoked	0 to 2	80 to 90	10 days
Mackerel	0 to 1	95 to 100	6 to 8 days
Menhaden	1 to 5	95 to 100	4 to 5 days
Salmon	–1 to 1	95 to 100	18 days
Tuna	0 to 2	95 to 100	14 days
Frozen fish	-28 to -20	90 to 95	6 to 12 months
Shell fish			
Scallop meat	0 to 1	95 to 100	12 days
Shrimp	–1 to 1	95 to 100	12 to 14 days
American lobster	5 to 10	In sea water	Indefinitely
Oysters, clams (meat and liquid)	0 to 2	100	5 to 8 days
Oyster in shell	5 to 10	95 to 100	5 days
Frozen shellfish	–34 to –20	90 to 95	3 to 8 months

Source: 1998 ASHRAE Handbook, Refrigeration volume 4, p 10.3

Table 3 Effect of storage temperature on shelf fife of frozen fishery products*

Product	*Temperature (˚C)*	*Shelf life (months)*
Packaged haddock fillets	–12	4 to 5
	–18	11 to 12
	–29	Longer than 12
Packaged cod fillets	–12	5
	–18	6
	–23	10 to 11
Packaged pollock fillets	–7	1
	–12	2
	–18	8
	–23	11
	–29	24
Packaged ocean perch fillets	–9	1.5 to 2
	–12	3.5 to 4
	–18	6 to 8
	–23	9 to 10
Packaged striped bass fillets	–9	4
	–18	9
Glazed whole halibut	–12	3
	–18	6
	–23	9
	–29	12
Whole blue fin tuna	–12	4
	–18 to –20	8
	–29	12
Glazed white herring	–18	6
	–25	9
Packaged mackerel fillets	–9	2
	–18	3
	–23	3 to 5

*Prepared from 1 day old iced fish
Source: 1998 ASHRAE Handbook, Refrigeration volume 4, p 18.8

Table 4 Cold chain equipment used in the fishery industry

Type of operations	*Refrigeration equipment (commonly used)*	*Refrigerant used*
Catch and offshore facilities		
Small boat in lakes and offshore day trips, 6–12 m long	Wooden ice bin or bunker with or without insulation	Ice, salt-ice mixture
Fishing trawler, 20–50 m long	Immersion quick freezer, plate freezers, freezer holds.	Ammonia and brine in quick freezer, freezer holds
Factory trawler for catching, filleting, packaging and freezing, about 75 m long	Ice-making machines, refrigerated sea water (RSW), immersion quick freezer, freezer hold, plate freezer and blast freezer	Ammonia and brine in ice making, freezer holds and RSW; R-22 in plate and blast freezers
Mother ship for processing, freezing and storing only (no catch capacity)	Ice-making machines, RSW, freezer holds, plate freezer and blast freezer	Ammonia and brine in ice making, freezer holds; R-22 in plate and blast freezers
Tuna seiners	RSW and Brine tanks, freezer holds at –8°C	Ammonia, R-22
Purse-seining	Freezer and refrigerated dry wells at –18°C	Ammonia, R-22
Cargo ships and reefers	Refrigerated holds at –10°C to –29°C	R-22 and R-12 (old units)*
Onshore facilities		
Processing, packaging and storage	Ice plants, flake ice machines, ice storage, chill rooms, cold rooms, freezer rooms	Ammonia, R-22 R-12 (old units)
Transport		
– on land	Refrigerated truck, trailers and containers, temperature from +2°C to -29°C,	Ice, ice and salt, dry ice, liquid nitrogen and CO_2, Eutectic plates, R-22, R-12*
– by air for fresh water and live fish	Insulated containers or boxes with ice	Ice, dry ice (solid CO_2)
Land-based facilities		
Commercial storage facilities	Large deep freezer stores for frozen fish	Ammonia, R-22, R-12(old units)*
Retail outlets	Small freezer rooms and display cabinets	R-502, R-12(old units)*
User facilities: hotels, clubs and houses	Small freezer rooms, domestic freezers	R-12 (old units)*

* Since 1996 all new refrigeration equipment in developed countries use HFCs, HCs or their blends. R-12 in old sealed units only.

Overview of non-CFC alternative refrigerants

Alternative refrigerants fall into two main categories:

- synthetic chemicals composed of man-made molecules; and
- non-synthetic chemicals composed of molecules produced by natural processes and purified through industrial processes.

Refrigerants can be used either as simple (i.e. single) fluids or as blends of two or more fluids. Refrigerant blends can be either zeotropes or azeotropes.

Synthetic refrigerants used to replace CFCs include HCFC, HCFC blends, HFC and HFC blends, whereas non-synthetic alternatives include ammonia, hydrocarbons and carbon dioxide. The more widely used alternatives are described in greater detail below.

Synthetic refrigerants

HCFCs and HCFC containing blends

HCFC-22

This was first developed as a low temperature refrigerant and used as such in the 1950s and 1960s after which it was largely displaced in commercial refrigeration by R-502. It has continually been used for small and medium sized refrigeration systems. When the problem of ozone depletion became apparent, the refrigeration industry reaction was to switch back to R-22 from R-502. Unfortunately this meant dealing with a problem caused by using R-22 at low temperatures that HCFC-502 was designed to overcome. HCFC-22 heats up significantly when compressed. This effect increases with the pressure ratio of the system. The system discharge temperatures must not become excessive or damage will result. Thus a low temperature system must be engineered to prevent this from occurring. This can be done in two ways:

- injection of liquid refrigerant into the compressor body or suction pipe; and
- staged compression.

HCFC-22 forms the basis of a number of refrigerant blends designed to replace CFC-12 and R-502. Unfortunately, it possesses a small ODP of 0.05 and is therefore considered only a transitional substance. The global warming potential (GWP) is low by comparison with some of the zero ODP blends used to replace R-502.

R-408A (HCFC-22/HFC-143a/HFC-125)

This is developed as a replacement for R-502. GWP is relatively high. It is typically more energy efficient than R-502 with some improvements being noted in the 4–8 per cent range. Evaporator temperature glide is insignificant (0.6K).

R-409A, R-409B (HCFC-22/HCFC-142b/HCFC-124)

These are drop-in replacements for CFC-12 and can be used in similar categories. Both have high glide (7–8K) and their GWP and ODP are somewhat higher than R-401A & B. They are both suitable for use with mineral oil.

HFCs and HFC containing blends

It should be noted that most HFCs are not suited for use with mineral oils.

HFC-134a

This is intended to replace CFC-12 and was selected because its pressure/

The use of transitional substances as substitutes

In many applications, HCFCs are not the best option to replace CFCs. The Multilateral Fund's Executive Committee has a standing 'presumption against HCFCs' that recommends that these transitional substances should not be used whenever possible[1]. They should only be used as a last resort in cases where more environment-friendly and viable alternative technologies are not available.

[1] UNEP/OzL.Pro/ExCom/15/45, para. 90

Table 5 Acceptable alternatives to the CFC and HCFC refrigerants in the fishery industry*

CFC/HCFC to be replaced	*Type of refrigeration system*	*Type of alternative*	*Refrigerant alternatives available*
R-502	Display/storage	Long term Transitional	R-134a R-402A, R-402B, R-406A$^{(R)}$, R-408A$^{(R)}$ R-411A, R-411B, R-507, R-290$^{(HC)*}$
	Cold storage/freezers	Long term Transitional	R-134a R-402A, R-402B, R-406A$^{(R)}$, R-408A$^{(R)}$ R-411A, R-411B, R-507, R-717$^{(N)}$
	Retail unitary/Transport	Long term Transitional	R-134a R-402A, R-402B, R-406A$^{(R)}$, R-408A$^{(R)}$ R-411A, R-411B, R-717$^{(N)}$
R-12	Display/storage	Long term Transitional	R-134a R-401A, R-401B, R-290$^{(HC)*}$, R-600A$^{(HC)*}$
	Retail unitary	Long term Transitional	R-134a R-401A, R-401B, R-290$^{(HC)*}$, R-600A$^{(HC)*}$
R-22	Refrigerated storage	Long term Transitional	R-134a R-407C, R507$^{(N)}$, R-410A$^{(N)}$, R-410B$^{(N)}$
	Ice plants, RSW	Long term Transitional	R-134a R-407C, R507$^{(N)}$, R-410A$^{(N)}$, R-410B$^{(N)}$
	Sea transport	Long term Transitional	R-134a R-407C, R507$^{(N)}$, R-410A$^{(N)}$, R-410B$^{(N)}$

* based on US EPA information

Notes:

1. Refrigerant with superscript $^{(R)}$—for retrofit uses;
2. Refrigerant with superscript $^{(N)}$—for new uses
3. Refrigerant without any superscript—available for use in retrofit and new uses both.
4. Refrigerant with superscript $^{(HC)*}$—is hydrocarbons, for use in small capacity systems, but not in the transport applications.

temperature characteristics resemble those of CFC-12. However, its characteristics are not identical and, although retrofitting HFC-134a in existing CFC-12 systems is generally straightforward, this can lead to some problems relating to the higher system pressure rate that can occur under such circumstances (about a 10 per cent increase).

Comparisons on an identical thermodynamic cycle suggest that this refrigerant will have 10 per cent less capacity than CFC-12 and about 8 per cent less efficiency. However, performance measurements of actual retrofits show the capacity loss to be less and efficiency to be about equal to CFC-12 systems. This is probably due to improved heat transfer observed in the evaporators and condensers.

HFC-134a is regularly used as a CFC-12 replacement in single stage centrifugal systems. Here though the story is somewhat different. There are considerable capacity and efficiency losses (up to 20 per cent) although these can be reduced using various degrees of re-engineering.

R-404A
(HFC-143a/HFC-125/ HFC-134a)

This is a general replacement for R-502 in low temperature systems. It is a ternary blend of three HFCs. The temperature glide is negligible (0.7K). The GWP is the highest of the zero ODP R-502 replacements. Condenser pressures will increase with R-404A.

R-407A, R407B,R-407C
(HFC-32/HFC-125/HFC-134a)

These are intended as low temperature R-502 replacements. Unlike R-404A, the evaporator glide is significant (4–6K). GWP is rather lower than R-404A.

Non-synthetic refrigerants

Ammonia systems

Ammonia has been in use in refrigeration for decades even before the introduction of CFCs. Its superior efficiency and heat transfer properties relative to CFCs has made it the refrigerant of choice in many large chiller installations using vapour compression cycles. Ammonia systems are widely used today in the cold storage, food processing and chemicals industry. In the UK a large supermarket chain uses ammonia in its two main cold stores. In the USA, 81 per cent of refrigerated warehouses operate on ammonia systems. A similar trend can be found in Germany and the Nordic countries. In developing countries like China and India, ammonia is widely used in the large refrigeration systems of the fishery industry, due to its low cost and local production.

Hydrocarbon systems

Hydrocarbon (HC) refrigerants, R-600a (iso-butane) and R-290 (propane), have been accepted as long-term alternatives to R-12 in small capacity (<10 kW) stationary systems in many European countries. In China and India with the German assistance, refrigerators using HCs are now being produced.

New HC applications are being increasingly used and researched. Several German manufacturers, for example, Foron (Formerly called dkk Scharfenstein), Bosch and Siemens, now produce domestic refrigerators using

HC. Calor Gas Co. in the UK is also promoting the use of HC refrigerants.

However, due to the flammability potential, HCs have not been accepted in transport refrigeration or large capacity refrigeration systems. Where HC refrigeration systems have been accepted, it has been mainly because of their better energy efficiency than systems using other refrigerants. Although HCs may compete well with ammonia in the energy efficiency, their latent heat is much lower than that of ammonia. Therefore, in a large refrigeration capacity system, the size of refrigeration equipment for HC refrigerants has to be much larger. The increased size of the system using the flammable refrigerant also increases safety concerns.

Carbon dioxide systems

Carbon dioxide (CO_2 or R-744) can be used efficiently as a primary refrigerant in vapour compression refrigeration systems if suitable compressors for operation at high trans-critical pressures (around 100 bar) are provided. Air-to-refrigerant heat exchanger efficiency for CO_2 is better than halocarbons, making CO_2 more attractive for use in refrigeration systems. Considerable efforts are being made to develop CO_2 based refrigeration in the following types:

- commercial refrigeration with only CO_2 as the refrigerant;
- CO_2 as low temperature working fluid in a cascade system; and
- CO_2 as secondary refrigerant and ammonia as primary refrigerant.

Theoretical performance calculations for various systems indicate that CO_2 systems have efficiencies better than ammonia systems and can be developed with compressor swept volumes of about one-tenth of those in ammonia systems, resulting in lower power consumption. For this reason, a number of compressor manufacturers are developing high-pressure CO_2 compressors suitable for operation at trans-critical pressures.

Non-vapour compression systems

There is a wide range of alternative refrigeration technologies that use different types of natural refrigerants in the refrigeration cycles. Some of them, such as ammonia-based vapour compression and absorption systems, water-based evaporative cooling systems and hydrocarbon-based vapour compression systems, are already in wide use.

It is important to note that many of the alternative systems are competitive with, or even superior to, conventional vapour compression systems using CFCs, HCFCs, or HFC-134a in terms of cost and efficiency. The efficiency of the system depends on the system design, which needs to be optimized for a particular refrigerant, and according to the properties of the refrigerant. Not all of them are what one might call ‘mature’ technologies in all applications, but they are under investigation, and they can have potential applications in the future. These technologies, classified as vapour compression and non-vapour compression systems, are briefly discussed in the following sections.

Absorption systems
Absorption refrigeration systems are heat driven; this means that the process is operated by supply of heat instead of power to a mechanical compressor. In some applications these systems represent an alternative to the traditional vapour compression cycle. Currently, there is interest mainly in industrial refrigeration where large waste heat sources may be available.

Three-stage absorption systems are being developed to achieve efficiencies closer to vapour compression systems. Absorption chillers are inherently larger and considerably more expensive than mechanical type compression chillers. Therefore, absorption systems to date have limited market expansion mainly in the western world. In Japan, where electricity rates are much higher, the number of absorption chillers is growing more rapidly.

Adsorption systems
Adsorption refrigeration systems are similar to the absorption cycle, except that the refrigerant attaches to, and detaches from, a solid medium. Heat drives the refrigerant off the solid medium and cooling occurs when it returns to the solid medium by adsorption. Zeolite-water can be used as a refrigerant pair. Solar energy, natural gas and waste heat are among the possible heat sources for this system.

Zeolite is a naturally occurring mineral that is hygroscopic (i.e. it attracts water). Tests conducted on a heat pump using zeolite with natural gas as the heat source in the USA produced favourable results. In Germany and the USA this technology is being researched for applications such as mobile coolers, domestic refrigerators and automotive air conditioning.

Stirling cycle
The Stirling refrigeration cycle continuously expands (heats) and compresses (cools) a fixed mass of gas without changing physical state. These systems are highly efficient and can be used over a wider range of temperatures than other systems. Helium is being tested in Stirling systems. These systems are likely to be on the market in the near to mid term.

Liquid carbon dioxide and nitrogen (gas expansion)
A novel technique which is currently being used to cool highway freight trailers is gas expansion. It involves spraying a pre-cooled liquid such as liquid carbon dioxide or nitrogen into the refrigerated area which causes the liquid to evaporate and hence cool. Liquid nitrogen and carbon dioxide are also used in direct quick freezing of peas and chilled milk transport.

Air cycle
Air is environmentally benign and non-toxic and there should be no problem with the availability. The use of air as a refrigerant is based on the principle that when gas expands, its temperature at the final pressure is much lower and the gas can be used for cooling purposes. Air cycle is regarded as a promising alternative in industrial blast freezing, transport container refrigeration, automotive and railway air conditioning and other applications which involve very low temperatures.

Jamaica's Harbour Cold Stores Ltd. retrofits from R-502 to R-404A

Type of facility

Refrigerated warehouse

Location

Jamaica

Project background

Harbour Cold Stores Limited, founded in 1967, is the largest refrigerated warehouse in the English speaking Caribbean. The facility is situated strategically between the two main wharves at the port of Kingston. It occupies 114,378 sq. ft. land space with a refrigerated room capacity of approximately 85,000 cu. ft. of chill room space, together with 506,360 cu. ft. of freezer space. The operating temperature ranges from –23 °C to –18 °C for freezer and 10 °C to 5 °C for the chill room.

The plant is refrigerated by 27 low temperature and seven medium temperature discus air-cooled condensing units with matched evaporators.

Harbour Cold Stores Limited discussed with the Natural Resources Conservation Authority Jamaica's country programme to phase out ozone depleting substances in accordance with the Montreal Protocol and, in November 1997, the company decided to establish a master plan to retrofit all HCFC-22 and CFC-502 refrigeration systems with almost zero ODP and GWP Refrigerant.

Old system

Refrigerated warehouse using R-22 and CFC-502

New system/installation

In consultation with Copeland, Harbour Cold Stores investigated various refrigerants (R-507, R-290 and R-404A) that would maximize energy efficiency and would be environmental friendly while maintaining the operating temperatures.

A comparison of commercially available options was made and SUVA 404A (formally known as HP62) was found to be the most suitable refrigerant for the application since it exhibits thermodynamic properties similar to those of R-502. Although SUVA 404A has a lower critical temperature and higher operating pressure, the test indicated that if the system is operated at medium temperatures, no significant changes would be required to the system design.

In order to minimize the disruption to normal business, the company retrofitted on a phased basis that also allowed them to measure the performance of equipment using R-502 and R-404A.

Recommendation regarding compatibility of materials with R-404A was obtained from the equipment manufacturer. Procedures, material specifications and all relevant recommendations from equipment and lubricant manufacturers were researched, analyzed and used in the final assessment.

During the research, the following results were observed:

- **Performance**
  The process for sizing and selecting compressors and other system

components for R-404A was the same as for R-502A.

- **Lubrication**
  R-404A requires polyester (POE) lubricant to ensure complete miscibility between oil and refrigerant as R-404A is not miscible with existing lubricants (mineral oil) used in R-502 systems. The mineral oil would have to be replaced with POE lubricant to a residual mineral oil level less than 5 per cent.

In September 1997, the retrofitting programme began. All operating parameters before and after retrofitting were recorded and comparison was made. Operating the systems has shown no significant loss of efficiency in the R-404A installation, compared to historical R-502 performance. The temperature glide of the R-404A was less than 1.5 °F in all systems retrofitted; this glide was not noticeable compared to normal temperature changes due to pressure drops.

Project duration (time)

Not available

Cost and economic considerations

Not available

Applicability to developing countries

This technology is easily accessible since alternative technologies with R-404A are now available in many developing countries. However, technicians must be trained to observe specific precautions and good practices in refrigeration, as it applies to the use of near-azeotropic blends.

Contact for further information

Mr Carlton V. Richards
General Manager
Harbour Cold Stores Limited
3 Third Street Newport West
Port Bustamante
Kingston 11
Jamaica W.I.
Tel: (1 876) 923 9031 4
Fax: (1 876) 923 9081
E-mail: carlton.richards@gkco.com

A fishery conditioning facility chooses R-404A for its flooded type heat exchangers

Type of facility
Fishery conditioning factory

Location
France

Project background
Located in western France near Nantes, Matal has been a leading company in the industrial refrigeration sector for several decades. Matal is actively involved with developing environmentally safe solutions for this sector, including those related to the European schedule for phasing out ozone depleting refrigerants.

R-22 replacement in the refrigeration applications is now possible with refrigerants such as R-404A, R-507 and ammonia. Matal has had successful experiences with installations for both with ammonia and synthetic refrigerants.

Matal has been performing tests at several pilot installations. In order to obtain exhaustive information on new alternative technologies, Matal has equipped some of these pilot installations with adequate instrumentation and on-site measuring devices. This project was conducted with the participation of experienced laboratories in refrigeration, Centre d'Etudes des Machines Agricoles Eaux et Forêts (CEMAGREF), and was financially assisted by the Agence de L'Environnement et de la Maîtrise de l'Energie (ADEME).

Old system
Heat exchangers using R-502.

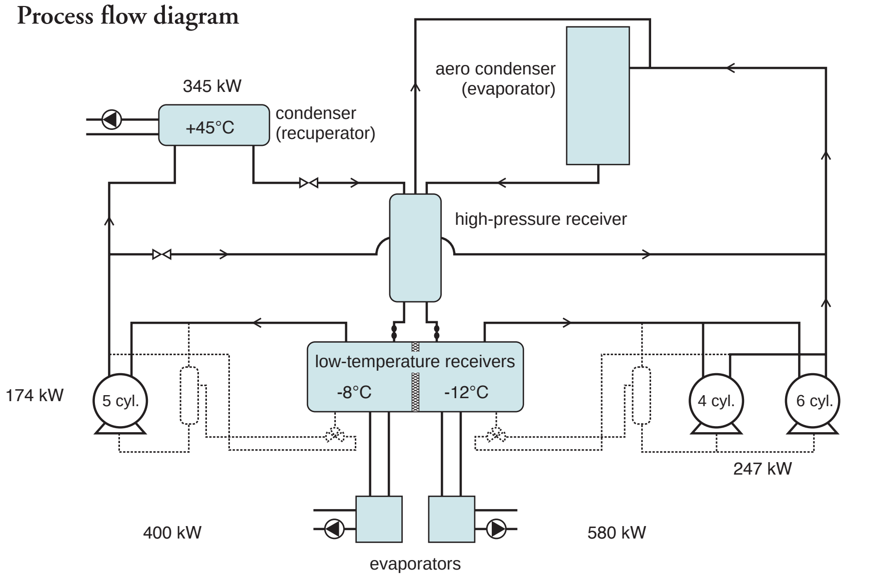
New system/installation
A fishery located in southeast France was recently built with refrigeration equipment using R-404A as the replacement. This technology was selected over HCFCs because it has several key advantages: it is a safe zero-ODP refrigerant with good refrigeration performance. An important criteria was the applicability of the refrigerant to flooded evaporators because of the small glide at the evaporator and condenser temperatures. The refrigerant is commercially available and distributed in France by Dehon.

Drying fish requires alternatively heating and cooling in order to perform adequate temperature control and humidity of the drying tunnels. Two cooling loops are linked to a common high pressure refrigerant capacity. The first loop has an evaporation temperature of –8 °C and is used for drying fish, and the second one operates at –12 °C and is dedicated to fish preparation and conditioning. Cooling is performed by the circulation of the secondary refrigerant. Energy performance is improved by heat recovery at the condensers at a condensing temperature of 45 °C. Refrigeration capacity of each loop is 230 kW for the low temperature loop and 1,000 kW for the –8 °C loop. Several measurements were performed and analysed. The measured coefficient of performance for the running conditions is around 2.4.

Also, refrigerant was sampled at different locations of the loops for analysis. No significant composition changes were detected as compared to the nominal composition of R-404A.

These results confirm that 404A is perfectly applicable to the flooded heat exchangers technology.

Process flow diagram



Contact for further information

Mr Gueguen
Quality Manager
GEA Matal
BP 24
Les Sorignieres
France
Tel: (33) 2 40 84 54 54
Fax: (33) 2 40 31 28 80

Project duration (time)

Not available

Cost and economic considerations

Not available

Applicability to developing countries

At present, R-404A refrigerant is not widely used in developing countries because of limited availability and relatively high cost. However, R-404A is a technically viable option for Article 5 countries, and its cost is expected to come down in the future as demand increases.

R-404A technology does not need any significant changes in terms of components such as heat exchangers and circuiting when compared to R-502. Compressors are of the same size and capacity, which renders the technology easily adaptable to both new and retrofitted installations from R-502 applications with only minor changes. However, particular attention must be given to changing lubricants to compatible polyolesthers.

Micronesia chooses ammonia turnkey fish processing plant

Type of facility
Coastal fish processing complex

Location
Pohnpei Island, the Federated States of Micronesia

Project background
In July 1992, Sabroe Industry was commissioned to construct a turnkey fish processing plant using ammonia (R-717) as a refrigerant for the Pohnpei State Government. Development of the fish processing plant, situated on the island of Pohnpei, is part of the government's integrated plan to increase the export of processed sea-foods.

Old system
Not applicable (it is a new installation).

New system/installation
The processing plant is equipped with processing and packing lines with a design capacity of 26 tonnes of tuna and reef fish per day. The finished products are chilled or frozen and packed into consumer cartons.

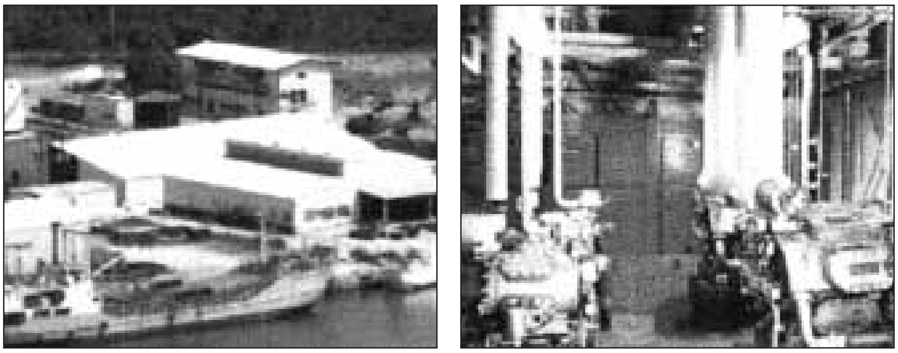
The R-717 refrigeration system is equipped with a two-stage system for an air blast freezer, a plate freezer and a cold store, whereas one-stage systems have been installed for air conditioning, ice production, and two chill stores. Sabroe reciprocating compressors have been installed. In order to improve the indoor climate and avoid draught from the air coolers, an air bag cooling system has been installed in all processing areas.

To ensure professional operation of the processing plant, Sabroe provided education and training of refrigeration system operating staff as well as management for a period of one year after commissioning.

Capacity of fish processing plant
Tuna: 19,000 kg/8h
Reef fish: 7,000 kg/8h

Buildings
- Processing facility: 45 x 36 m
- Workshop: 9 x 6 m, fully equipped
- Waste water plant building: 12 x 6m
- Water works building: 18 x 7m
- Administration building: 24 x 10 m, 3-story with laboratory, canteen, and sanitary facilities

Processing Equipment
- Fish reception: de-icing, sorting and weighing
- Fish processing: heading, gutting, filleting, skinning, trimming and yield control weighing
- Smoking oven: hot and cold smoking, drying, boiling and roasting
- Packing: blocks in cartons, shatter pack and vacuum packing
- Refrigeration:
  - Cold store: 9 x 8 m, capacity of 100 tonnes of finished product at –25 °C
  - Chill stores: 11 x 7 m, capacity of 60 tonnes of raw material at 2 °C ; 5.5 x 5 m, capacity of 30 tonnes of finished product at 2 °C
  - Blast freezer: 5 x 25 m, capacity of 2,000 kg/8h
  - Plate freezer: capacity of 1,350 kg/2h
  - Ice machine: 18 tonnes/day
  - Compressors: 3 x two-stage compressors and 3 x one-stage reciprocating compressors



A view of the processing plant and the machine room

Other installations
Water works: 70 m^3/h
Waste water: biological treatment
Ventilation: Novenco Climaster ZL
Diesel generators: 3 x Caterpillar gen-sets of 455 kW

Project duration (time)

Not available

Cost and economic considerations

Not available

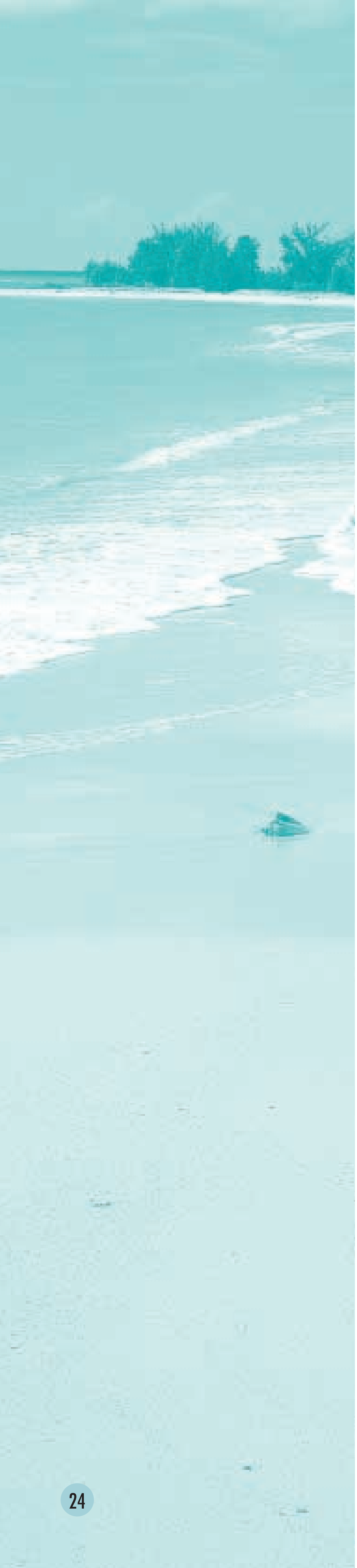
Applicability to developing countries

Many developing countries including Thailand, Indonesia, Philippines and Mexico already use ammonia systems and have trained technical manpower for their maintenance and repairs.

Ammonia is a zero ODP and zero GWP refrigerant. It has long been a refrigerant of choice in the fishery industry, particularly in the developing countries, because of its high refrigeration efficiency. Under the present scenario of phase out of ozone depleting substances, the option of ammonia refrigeration systems in new installations is very much obvious.

Contact for further information

York Refrigeration
Christian den X's Vej 201
8270 Hojbjerg, Arhus
Denmark
Tel: (45) 86 27 12 66
Fax: (45) 86 27 12 44
Telex: 68723
http://www.york.com



Philippines selects ammonia-based containerized block ice plants

Type of facility
Ice making plant

Location
Philippines

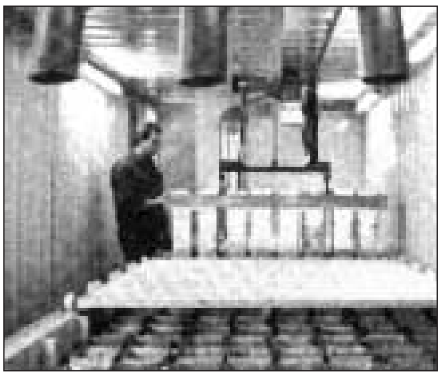
Project background
The use of block ice is an uncomplicated and reliable method for food preservation. It melts very slowly and transportable over long distances and can be used in whole blocks or crushed depending on the product specifications. Sabroe Industry has recently supplied a series of containerized block ice plants for the Philippine Fisheries Development authority.

The block ice plants are equipped with a complete refrigeration system using ammonia (R-717) as refrigerant.

Old system
Not applicable (it is a new installation).

New system/installation
Sabroe Industry's R-717 containerized block ice plants are built into 40 feet long cube containers with outside dimensions 12.2 x 2.4 x 2.9 metres, and can thus be transported to other locations if seasonal variations occur. The plants are factory-assembled turnkey plants and are tested before delivery. All parts necessary for operation are included; water and electricity need to be connected before operation.

Inside the containerized block ice plant



The refrigeration system is supplied with a Sabroe SMC 104 compressor, shell and tube evaporator, air-cooled condenser, liquid receiver, Unisab microprocessor control unit, switchboard and all ancillary valves for service and maintenance.

The supply also includes a 15-tonne storage container with a refrigeration unit, which ensures a storage temperature of –5 °C.

The operation of the block ice plant is simple, as only two operators are required.

Plant specifications
- Performance capacity: 9.2 tonnes of ice blocks per 24 hours in blocks of 25kg
- Refrigerant: R-717 (ammonia)
- Control system: Unisab microprocessor unit
- Compressor type:
  - SMC 104L
  - motor: 36kW
  - power consumption: 28kW
- Condenser type:
  - air cooled
  - motor: 2 x 1.2 kW
- Brine chiller type: shell and tube evaporator
- Brine pump type:
  - centrifugal
  - motor: 7.5kW
- Brine tank: 23 frames and 184 ice cans

- Storage container capacity: 15 tonnes
- Diesel generator capacity:
  - 66kW
  - fuel consumption: 22.7 litre/hour
  - fuel tank: 600 litres

Project duration (time)

Not available

Cost and economic considerations

Not available

Applicability to developing countries

Many developing countries, including Thailand, Indonesia, Philippines and Mexico, already use ammonia or R-22 systems and have trained technical manpower for their maintenance and repairs.

An external view of the containerized block ice plant

Ammonia is a zero ODP and zero GWP refrigerant. It has long been a refrigerant of choice in the fishery industry, particularly in the developing countries, because of its high refrigeration efficiency. Under the present scenario of phase out of ozone depleting substances, the option of ammonia refrigeration systems in new installations is very much obvious.

Contact for further information

York Refrigeration
Christian den X's Vej 201
8270 Hojbjerg, Arhus
Denmark
Tel: (45) 86 27 12 66
Fax: (45) 86 27 12 44
Telex: 68723
http://www.york.com

Ice plant production increases 36 per cent after Artic Ice converts from R-22 to R-411B

Type of facility
Ice manufacturing plant

Location
Florida, USA

Project background
Ice machines are widely used on board fishing vessels and in on-shore fish processing facilities. Ice is used for pre-cooling and storing of fish catch on board during transportation and fish processing. In the past 25 years, Artic Ice has grown from a small ice manufacturer to the second largest in Florida, producing about 200 tonnes of ice a day. The company has traditionally used R-22 equipment to produce ice.

Old system
Ice making system using R-22

New system/installation
Conversion technology and equipment selection
Artic Ice's mechanical contractor, Pool & Kent, proposed that the company should replace its R-22 refrigerant with Greencool R-411B (a blend of R-22/R-152a/R-1270). Artic Ice engineer John Feeks was sceptical and said that 'There are a lot of companies with new improved products out there that make great claims, [but they] haven't been tested, are more expensive and don't have much of a market share. I had to be convinced'. Artic Ice then took the step of providing a test site and equipment to compare the performance of R-411 B with its mainstream refrigerant R-22.

Converted new system
Starting small and cautiously, Artic Ice tested R-411B on two ice merchandisers. Results were immediate. The R-411B merchandiser reached its desired temperature in a fraction of the time required for R-22. The compressor of R-411B unit also ran for less time.

With this successful test, R-411B's performance was further measured over a four-week period using two identical Turbo ice making systems: one charged with R-22, and the other with R-411B. Both machines were optimized for peak performance. Computer based control units were installed so that the cycles will be identical for both systems. Nothing else was required other than replacing R-22 refrigerant with Greencool R-411B. The results are indicated in the table below.

To eliminate the potential differences between the two systems, Arctic then compared System 1 against itself running first with R-22 and then with R-411B. The results are indicated in the table on the following page.

R-411B's superior performance increased ice production by 36.8 per

Test A	*Refrigerant*	*Ice produced (inches thick)*	*Change*
System 1	R-22	0.47	
System 2	R-411B	0.64	+36.2%

Test B	*Refrigerant*	*Ice production average (inches thick)*	*Power consumption average (Amps)*
System 1	R-22	0.475	53.6
System 1	R-411B	0.650	47.0
Difference		+36.8%	–12.3%

cent on average when using R-411B compared to R-22. Power consumption decreased with R-411B by 12.3 per cent. A number of large ice makers in Europe operate with ammonia, and initial comparisons of ice makers with similar capacity indicate that Greencool R-411B provides up to 20 per cent more ice for the same electricity cost and can be used in most applications ranging from +30 °C to –50 °C.

In this case, results have been exceptional. Greencool expected a 15 to 30 per cent increase. However, manufacturer and distributor agree that no two applications will be the same. The test results from Artic Ice may differ on other applications. Biggs encourages manufacturers to 'try R-411 B on one ice maker and do their own comparison. Buyers will be comfortable with their purchase, and the entire industry benefits when the results are publicised'.

Project duration (time)

Not available

Cost and economic considerations

Artic Ice now has four of its nine ice machines running with R-411 B. 'The new refrigerant' Bill Biggs, general manager of Artic Ice, notes, 'has enabled us to increase overall yield without investing in any new equipment'. Given their daily ice production of 200 tonnes, the additional 36 per cent production translates, in effect, to the addition of a new 60-tonne ice making system. Without requiring additional capital and installation costs, additional floor space or more energy usage, the increased production capacity was achieved.

Artic Ice assesses the higher purchase price of R-411B realistically. Biggs says that he 'looks at it in terms of an investment, for so much more per £; we can get more than 30 per cent and greater yield, somewhere near 60 tonnes'. Estimates vary, from two to four months, but the return on investment for converting to R-411B is a certainty according to the company.

Applicability to developing countries

This study is useful in encouraging conversion of R-22 or ammonia systems for operation with new refrigerant blends like R-411B which have potential for more energy efficiency. However, in most developing countries the technical staff would need special training for handling of refrigerant blends during repairs and maintenance.

Contact for further information

Mr Simon Foord
Managing Director
Greencool Refrigerants
12 Park Gate Business Centre
Chandlers Way, Park Gate
Southampton
Hampshire, S031 1 FQ
Great Britain
Tel: (44) 1489 583311
Fax: (44) 1489 583132
E-mail: R411B@greencool.co.uk

Ammonia cold store for Greenland's fishing industry

Type of facility

Prefabricated refrigeration machine room for the cold store

Location

Qasiiannhuit (Christianshab), Greenland

Project background

A new 10,000 m^3 cold store was to be installed at Qasiiannhuit (Christianshab) for Greenland's Homerule, the KTU, in only three weeks including the time required for cooling down the cold room temperature to –28 °C. The demand for quick installation and short construction time, along with special climatic conditions made it preferable to choose prefabricated machine rooms. It was decided to assemble the entire machine room in a 30-ft container specially insulated and made to withstand severe climatic conditions.

Old system

Not applicable (it is a new installation)

New system/installation

The new ammonia system employed 2 x two-stage piston compressors (type TSMC 108L), one driven by a diesel engine and the other by an electric motor of 55 kW, and three plate-finned evaporators with individual hot gas defrosting. Other components included:

- a R-717 (ammonia) pump station and a receiver for the refrigeration plant;
- an air-cooled condenser;
- a glycol cooler for cooling the diesel engine;
- a heat exchanger for heating glycol and to heat the cold store floor; and
- a switchboard and control system for monitoring the plant operation.

To ensure professional operation of the processing plant, Sabroe provided education and training of refrigeration system operating staff as well as management for a period of one year after commissioning.

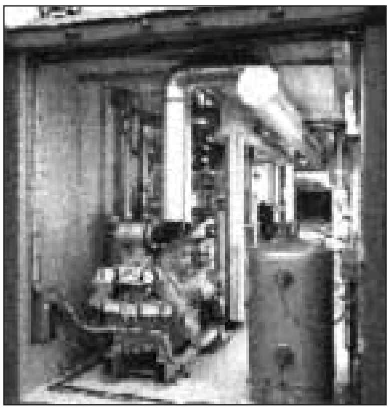
Project duration (time)

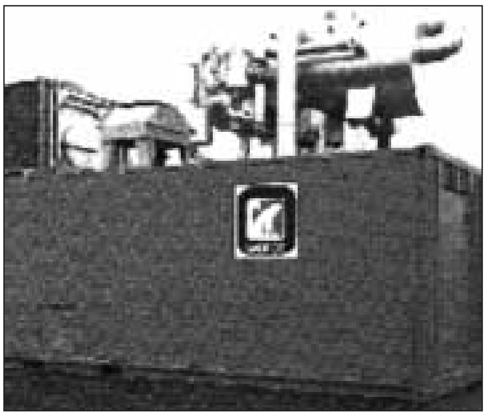
3 weeks

Cost and economic considerations

Not available

A view of the prefabricated machine room for the cold store





Applicability to developing countries

Many developing countries including Thailand, Indonesia, Philippines and Mexico already use ammonia systems and have trained technical manpower for their maintenance and repairs.

Ammonia is a zero ODP and zero GWP refrigerant. It has long been a refrigerant of choice in the fishery industry, particularly in the developing countries, because of its high refrigeration efficiency. Under the present scenario of phase out of ozone depleting substances, the option of ammonia refrigeration systems in new installations is very much obvious.

Contact for further information

York Refrigeration
Christian den X's Vej 201
8270 Hojbjerg, Arhus
Denmark
Tel: (45) 86 27 12 66
Fax: (45) 86 27 12 44
Telex: 68723
http://www.york.com

Transport refrigeration comparative conversions of R-12 and R-502 to R-409A and R-411B

Type of facility
Refrigerated transport

Location
Northern Ireland, UK

Project background
Refrigerated vehicles are used for transporting fish from offshore fishery cold storage facilities to regional cold storage and user cold storage facilities.

Ransome Group Services operates a variety of refrigerated transport units in the Northern Ireland.

Old system
R-502 and R-12 charged Thermo King transport refrigeration units

New system/installation
Comprehensive trials of Greencool R-411B (a blend of R-22/R-152a/R-1270) have been carried out by the Ransome Group Services in a variety of refrigerated transport units. The results have been compared with the new refrigerants R-409A and R-411B as the acceptable substitutes for R-12. It is to emphasize that R-409A is an acceptable substitute for R-12 only (not for R-502), while the R-411B is an acceptable substitute for both R-12 and R-502 in commercial refrigeration systems. These trials were carried out to compare the performance of both R-12 alternatives (i.e., R-411B and R-409A), as a part of the selection process.

Further, R-411B is a straight drop-in refrigerant and needs no oil and equipment change, while R-409A does not need oil change but needs a compatible filter drier.

Parameter	*Thermo King SNWD 50 R-12 vs R-409A*		*Thermo King SBI-50 R-12 vs R-411B*		*Thermo King RDII R-502 vs R-411B*	
Refrigerant charge	*6 kg*	*6kg*	*8.2kg*	*6.8kg*	*4.1kg*	*3.0kg*
air-on, air-off difference at:						
at 0 °C	5	5	5.5	5.4	4.9	6.8
–10 °C	3	3	4.2	5.8	4.4	6.8
–20 °C	2	1.5	3.1	4.4	3.8	5.8
pull-down time 0 °C to –20K °C (minutes)	104	114	68	45	46	40
typical defrost time (minutes)	40	40	39	26	36	38
running costs		plus 14%		18% less		33% less
pull-down time		plus 10 min		33% less		13% less
refrigerant charge		–		20% less		36% less

Conversion results and discussions
Trial results as given below show that Greencool R-411B can successfully be used for all R-502 and most R-l2 applications with greater benefits than any other alternative. Not only has it proved that Greencool R-411B could be used as a single refrigerant for most applications but with the additional benefits of reduced temperatures and shorter equipment running times, with less refrigerant charge.

R-411B application provided a significant reduction in global warming with each refrigerated unit and reduces global warming by up to 12 tonnes of CO_2 per annum compared with R-12 and R-502.

Mr Ransome, Managing Director of Ransome Group, said 'if all refrigerated transport in the UK used Greencool R-411B, the resultant annual CO_2 emissions could be reduced by approximately 1,000,000 tonnes of CO_2'. (However, if R-404A, another potential substitute, is used, the reduction would be 250,000 tonnes—only 25 per cent of that which R-411B can achieve.)

Project duration (time)

Not available

Cost and economic considerations

By conversion to R-411B, running cost savings of 20–28 per cent are normal.

Applicability to developing countries

Use of R-411B should be practicable in most developing countries as it does not involve oil and component or equipment change. However, since it is a blend (R-22/R-152a/R-1270), special training of technical staff would be necessary.

Contact for further information

Mr Simon Foord
Managing Director
Greencool Refrigerants
12 Park Gate Business Centre
Chandlers Way, Park Gate
Southampton
Hampshire, S031 1FQ
United Kingdom
Tel: (44) 1489 58331 1
Fax: (44) 1489 583132
E-mail: R411B@greencol.co.uk

Malaysia food retailer replaces R-502 with R-408A in a cold room

Type of facility

Cold room (freezer)

Location

Selangor, Malaysia

Project background

In many cities or town centres, fishery products are stored along with other food items in small cold rooms at retail centres or shops. Meat Packers SDN BHD, Malaysia decided to convert their –20 °C cold room in a shop in Selangor to operate with a new environmentally friendly refrigerant.

Old system

The refrigeration system of the cold room used R-502 as the refrigerant.

New system/installation

Conversion technology and equipment selection

After consultation with Elf Atochem and the refrigeration contractor Kong Chuen, R-408A (FORANE FX-10 produced by Elf Atochem) was chosen among other options for its simplicity in use and efficiency. R-408a is a blend of R-125, R-143 and R-22.

The project team decided for this operation to replace the original white mineral oil with PLANETELF (polyolester lubricant). This new polyester oil developed by Elf Lubricant is fully compatible with R-408A. It should be noted that it was not necessary to replace the mineral oil with a polyolester lubricant for retrofitting with R-408A. However, in the case described herein, polyester oil had been chosen to follow the manufacturer's recommendations.

Converted new system

- Condensing unit model: MANEUROP GM-56-FD
- Expansion device: Capillary tube
- Refrigeration power: 2.2 kW
- Refrigerant charge: 6 kg of R-408A
- Oil charge: 2 litres of PLANETELF 68
- Cold room size: 30 m^3

Kong Chuen refrigeration reported that the system with R-408A performed as smoothly as the system with R-502, showing excellent oil circulation, excellent refrigeration performances and very low energy consumption. The technical performance of the converted system with R-408A is shown below.

- Cold room temperature: –20 °C
- Evaporator temperature: –25 °C
- Condenser temperature: +47 °C
- Suction pressure: 2.95 bar (g)
- Discharge pressure: 18.9 bar (g)
- Motor electrical parameters:
  –Voltage: 415V
  –Current: 7.5A

This study confirmed that even with high equatorial outside temperature (up to 36 °C) and extreme humidity condition (up to 100 per cent), R-408A is a technically viable and cost-effective solution for replacing R-502.

Project duration (time)

Not available

Cost and economic considerations

Not available

Applicability to developing countries

Many developing countries like Thailand, Indonesia, the Philippines and Mexico have cold stores using CFCs like R-502. However, in most developing countries the technical staff would need special training for handling of refrigerant blends during repairs and maintenance.

Contact for further information

Elf Atochem
Centre d'application de Levallois (CAL)
95, rue Danton
92300 Levallois-Perret
France
Tel: (33) 1 47 58 1234
Fax: (33) 1 47 59 1441
http://www.elf-atochem.com/newelf/fluoro98/

Restaurant maximizes cold store efficiency and environmental performance with R-407A

Type of facility
Cold storage for frozen food

Location
'The Granary' Restaurant, Gatwick Airport, UK

Project background
In most hotels and large restaurants, cold room stores are used for storing fishery products along with other food items. The UK-based hotel, leisure and catering company Forte plc owns 'The Granary' restaurant at Gatwick Airport which was chosen to participate in a trial to convert to a new refrigerant. Forte plc also has a subsidiary refrigeration engineering company, Stangard, which conducted the conversion trial.

Old system
The restaurant's cold store is equipped with a duplex refrigeration system (having two independent refrigeration circuits), that employs two Prestcold MALQ 20X Bl-75 condensing units. These units are sited in a plant room with a 24-metre pipe run to the evaporators including a 6-metre suction riser. A single control thermostat maintains a cold room temperature of –22 °C. The refrigeration plant was originally commissioned with R-502 before retrofitting.

New system/installation
Conversion technology and equipment selection

The company carried out the trial to assess the performance of two new substitutes for R-502, namely R-404A (a blend of R-125, R-143a and R-134a produced by other leading companies e.g. Elf Atochem, DuPont and Allied Chemicals) and R-407A (a blend of R-32, R-125 and R-134a produced by ICI), in line with the company's policy of adopting refrigerants which combine the best operational and environmental performance.

Converted new system

The retrofit procedures for both substitutes consisted of a system performance and leakage check, followed by reclaim of the charge. The existing polyolester (EMKARATE RL 32S) lubricant had remained in good condition and did not require replacement. The only work required on the system was routine replacement of the dryer (with a dryer of the compatible type) and a check on the compressor oil level. The system was reassembled and thoroughly evacuated before recharging with R404A or R-407A. Once the system had reached a steady state the operating conditions were recorded.

The table opposite shows a comparison of measured data for both R-404A and R-407A operation. The results of the conversion show that the power consumption was lower using R-407A by approximately 5 per cent. Compressor running times were similar for both R-404A and R-407A. Ambient temperature was slightly higher when assessing the performance of R-407A. All other system parameters were comparable between the two refrigerants. Performance of the system after retrofit is comparable with previously reported values for both refrigerants. The retrofitted system is running smoothly since the conversion in December 1993.

Refrigerant	*Suction pressure (bar,g)*	*Suction temperature (˚C)*	*Discharge pressure (bar,g)*	*Discharge temperature (˚C)*	*Ambient air temperature (˚C)*	*Compressor power (kW)*
R-404A	0.76	13.6	10.38	61.2	14.3	1.90
R-407A	0.55	14.5	10.60	69.3	15.0	1.83

R-407A has been shown to be an ideal long-term replacement for R-502 with some advantages over R-404A in this application. Due to the lower direct global warming potential (GWP) and excellent energy efficiency, R-407A enables customers to achieve the lowest total equivalent warming impact (TEWI) available in this application field.

Project duration (time)
Changing from R-502 to R-407A required minimal time, and no system modifications were required.

Cost and economic considerations
Not available

Applicability to developing countries
In most developing countries the technical staff would need special training for handling of refrigerant blends during repairs and maintenance.

Contact for further information

ICI Klea
P.O. Box 14
The Heath
Runcorn
Cheshire WA7 4QG
United Kingdom
Tel: (44) 1928 511708
Fax: (44) 1928 513890
http://www.dircon.co.uk/klea/

Annex A: Glossary

Air blast freezer
A type of quick freezer (see also **Quick freezer**). In air blast freezers, the air is re-circulated around the packaged fish product at a very low temperature (-30 °C to -40 °C) and high velocity (2.5 to 7.5 m/s) in a tunnel. Freezing time varies from 3 to 8 hours depending upon the type of fish and size of fish package.

Article 5 Countries
Developing countries which are Party to the Montreal Protocol with an annual calculated level of consumption of less than 0.3 kg per capita of the controlled substances in Annex A, and less than 0.2 kg per capita of the controlled substances in Annex B, on the date of entry into force of the Montreal Protocol, or any time thereafter. These countries are permitted a ten-year grace period compared to the phaseout schedule in the Montreal Protocol for developed countries. Countries are commonly referred to as 'Article 5 countries' because their commitments under the Montreal Protocol are indicated in Article 5, paragraph 1 of the treaty.

Azeotrope
A blend consisting of one or more refrigerants of different volatilities and which does not change appreciably in composition or temperature as it evaporates (boils) or condenses (liquefies) under constant pressure (see also **Zeotrope**). Refrigerant blends assigned R-500 series number designations by ANSI/ASHRAE 34 are azeotropes.

Blends/mixtures
A blend is a mixture of two or more pure fluids. A ternary blend contains three fluids. Given the right composition, blends can achieve properties to fit almost any refrigeration purpose. For example, a mixture of flammable and non-flammable components can result in a non-flammable blend. Blends can be divided into three categories: azeotropic, non-azeotropic and near-azeotropic blends.

Blowing agent
A gas, a volatile liquid, or a chemical that, during the foaming process, generates gas. The gas creates bubbles or cells in the plastic structure of a foam.

Brine tank
A type of quick freezer (see also **Quick freezer**). Brine is a salt or glycol solution in water of up to about 20 per cent concentration and has freezing point temperature well below 0 °C. Calcium chloride ($CaCl_2$) brine solution is commonly used as a secondary refrigerant in fisheries refrigeration systems. Brine is chilled to low temperatures (-30 °C to -40 °C) in a compression refrigeration system and is used either to make ice in the cans placed in a brine tank or to freeze fish in a brine tunnel through which the brine is re-circulated.

Butane
A gaseous hydrocarbon of the alkane series (C_4H_{10}).

Carbon dioxide (CO_2)
A gaseous compound (CO_2) formed by, for example, combustion of carbon. Carbon dioxide contributes to the greenhouse effect.

CFCs
See **Chlorofluorocarbons**

Chlorofluorocarbons (CFCs)
A family of organic chemicals composed of chlorine, fluorine and carbon atoms, usually characterized by high stability contributing to a high ODP. These fully halogenated substances are commonly used in refrigeration, foam blowing, aerosols, sterilants, solvent cleaning, and a variety of other applications. CFCs have the potential to destroy ozone in the stratosphere.

CO_2
See **Carbon dioxide**

Contact or plate freezer
A type of quick freezer (see also **Quick freezer**). A plate freezer (also known as a 'contact freezer') consists of vertical or horizontal movable cold-plates having passageways for the primary or secondary refrigerant circulating at about -30 °C. Fishery products packaged in consumer cartons are placed between the cold-plates and slight pressure is applied for better contact between the fish package and the plate. Freezing time varies from 1 to 5 hours depending upon the thickness of fish package.

Containment
The application of service techniques or special equipment designed to preclude or reduce loss of refrigerant from equipment during installation, operation, service and/or disposal of refrigeration and air-conditioning equipment.

Controlled substance
Under the Montreal Protocol, any ozone depleting chemical that is subject to control measures, such as a phase-out requirement.

COP
See **Energy efficiency—coefficient of performance**

Cryogenic freezer (spray and immersion types)
A type of quick freezer (see also **Quick freezer**). In a cryogenic freezer, liquid nitrogen (boiling temperature of –195 °C) or carbon dioxide (boiling temperature of –79 °C) is sprayed directly over the fishery product to freeze it very quickly. Applications include individual quick frozen shrimp, prawns and crabs.

Cyclopentane
A cyclic hydrocarbon (C_5H_{10})

Drop-in replacement
The procedure when replacing CFC-refrigerants with non-CFC refrigerants in existing refrigerating, air conditioning and heat pump plants without doing any major plant modifications. However, the drop-in replacement process is normally referred to as 'retrofitting' (see **Retrofit**) because minor modifications are usually needed, such as a change of lubricant, replacement of expansion device and desiccant material.

Energy efficiency—coefficient of performance (COP)
The energy efficiency or coefficient of performance (COP) of a refrigerating system is defined as the ratio between the refrigerating capacity of the plant, Q0 (cooling/freezing capacity, kW) and the power/electricity consumption, P (kW) of the compressors and pumps. The COP is

primarily dependent on the working cycle and the temperature levels (evaporating/ condensing temperature) but also the properties of the refrigerant and system design and size. COP = (Q0/P).

Filter dryer
A device installed in the refrigerant loop of a system, containing a desiccant which removes moisture and other contaminants from the circulating refrigerant-lubricant mixture.

Global warming
The warming of the earth due to the heat-trapping action of natural and man-made greenhouse gases. Greenhouse gases emitted by human activities, including those involving the use of CFCs and HCFCs, are believed to warm the Earth's atmosphere, leading to climate change.

Global warming potential (GWP)
The relative contribution of certain substances (greenhouse gases), e.g. carbon dioxide, methane, CFCs, HCFCs and halons, to the global warming effect when the substances are released to the atmosphere by combustion of oil, gas and coal (CO_2), direct emission, leakage from refrigerating plants etc. The standard measure of GWP is relative to carbon dioxide (GWP=1.0), which is consistent with the Intergovernmental Panel on Climate Change (IPCC) indexing approach. The GWP can be given with 20, 100 or 500 years integration time horizon. There is no complete agreement within the scientific community on what is the proper time horizon, but 100 years is most commonly used.

Greenhouse gas
A gas, such as water vapour, carbon dioxide, methane, CFCs and HCFCs, that absorbs and re-emits infrared radiation, warming the earth's surface and contributing to climate change.

GWP
See **Global warming potential**

Halocarbons
Halocarbons are compounds derived from methane (CH_4) and ethane (C_2H_6), where one or several of the hydrogen atoms are substituted with chlorine (Cl), fluorine (F), and/or bromine (Br). These compounds are so called 'partly halogenated halocarbons'. When all the hydrogen atoms are substituted the compound is said to be fully halogenated. The ability of halocarbons to deplete ozone in the stratosphere is due to their content of chlorine and/or bromine and their chemical stability. Fully halogenated halocarbons have much higher chemical stability (atmospheric lifetime typically 100–500 years) than partly halogenated halocarbons (atmospheric lifetime typically 1–20 years). CFCs, HCFCs and HFCs are examples of halocarbons.

HBFCs
See **Hydrobromofluorocarbons**

HC
See **Hydrocarbon**

HCFCs
See **Hydrochlorofluorocarbons**

Hermetic compressors
Compressors whose motors are sealed within the refrigerant loop, and often

cooled by the flow of the refrigerant-lubricant mixture directly over the motor windings.

HFCs
See **Hydrofluorocarbons**

Hydrobromofluorocarbons (HBFCs)
A family of hydrogenated chemicals related to halons consisting of one or more carbon atoms surrounded by fluorine, bromine, at least one hydrogen atom, and sometimes chlorine. HBFCs have lower ODPs than halons.

Hydrocarbon (HC)
A chemical compound consisting of one or more carbon atoms surrounded only by hydrogen atoms. Examples of hydrocarbons are propane (C_3H_8, HC-290), propylene (C_3H_6, HC-1270) and butane (C_4H_{10}, HC-600). HCs are commonly used as a substitute for CFCs in aerosol propellants and refrigerant blends. The hydrocarbons have an ODP of zero. Hydrocarbons are volatile organic compounds, and their use may be restricted or prohibited in some areas. Although they are used as refrigerants, their highly flammable properties normally restrict their use as low concentration components in refrigerant blends.

Hydrochlorofluorocarbons (HCFCs)
A family of chemicals related to CFCs which contains hydrogen, chlorine, fluorine, and carbon atoms. HCFCs are partly halogenated and have much lower ODP than the CFCs. Examples of HCFC refrigerants are HCFC-22 ($CHClF_2$) and HCFC-123 ($CHCl_2CF_3$).

Hydrofluorocarbons (HFCs)
A family of chemicals related to CFCs which contains one or more carbon atoms surrounded by fluorine and hydrogen atoms. Since no chlorine or bromine is present, HFCs do not deplete the ozone layer. HFCs are widely used as refrigerants. Examples of HFC refrigerants are HFC-134a (CF_3CH_2F) and HFC-152a (CHF_2CH_3).

Immersion freezer
A type of quick freezer (see also **Quick freezer**). In the immersion freezer, fish is frozen aboard the fishing vessel by directly immersing the catch in low temperature brine (–15 °C to –18 °C) re-circulated in a tunnel. This type of freezer is used primarily for freezing tuna and, to lesser extent, for other products, i.e. shrimps, salmon and crabs.

Implementing Agency
Under the Montreal Protocol, four international organizations designated to implement the Multilateral Fund. They are UNDP, UNEP, UNIDO and the World Bank.

Liquefied petroleum gas (LPG)
A gas that occurs naturally as a constituent of wet natural gas or crude oil, or produced as a by-product of petroleum refining.

LPG
See **Liquefied petroleum gas**

Material compatibility
The abilities of materials to survive long-term exposure to substances without significant degradation of their physical or chemical properties.

Montreal Protocol
An international agreement limiting the production and consumption of chemicals that deplete the stratospheric ozone layer, including CFCs, halons, HCFCs, HBFCs, methyl bromide and others. Signed in 1987, the Protocol commits Parties to take measures to protect the ozone layer by freezing, reducing or ending production and consumption of controlled substances. This agreement is the Protocol to the Vienna convention.

Multilateral Fund
Part of the financial mechanism under the Montreal Protocol. The Multilateral Fund for Implementation of the Montreal Protocol has been established by the Parties to provide financial and technical assistance to Article 5 countries.

National Ozone Unit (NOU)
The government unit, in an Article 5 country, that is responsible for managing the national ODS phase-out strategy as specified in the Country Programme.

Natural refrigerants
Naturally existing substances which are already circulating in the biosphere which can be used as refrigerants. Examples of natural refrigerants are ammonia (NH_3), hydrocarbons (e.g. propane), carbon dioxide (CO_2), air and water.

Near-azeotropic blends/mixtures (NEARB/NEARM)
Near-azeotropic blends/mixtures (NEARB/NEARM) have properties very similar to azeotropic blends, and can be used as refrigerants in existing refrigeration equipment without any modification.

NOU
See **National Ozone Unit**

ODP
See **Ozone depletion potential**

ODS
See **Ozone depleting substance**

ODS Officer
A member of a National Ozone Unit.

Ozone
A reactive gas consisting of three oxygen atoms, formed naturally in the atmosphere by the association of molecular oxygen (O_2) and atomic oxygen (O). It has the property of blocking the passage of dangerous wavelengths of ultraviolet radiation in the upper atmosphere. Whereas it is a desirable gas in the stratosphere, it is toxic to living organisms in the proposphere.

OzonAction Programme
UNEP DTIE's OzonAction Programme, based in Paris, provides assistance to developing country parties under the Montreal Protocol through information exchange, training, networking, country programmes and institutional strengthening projects.

Ozone depleting substances (ODS)
Any substance with an ODP greater than 0 that can deplete the stratospheric ozone layer. Most ODS are controlled under the Montreal Protocol and its amendments, and include CFCs, HCFCs, halons and methyl bromide.

Ozone depletion
Accelerated chemical destruction of the stratospheric ozone layer by the presence of substances produced, for the most part, by human activities. The most depleting species for the ozone layer are the chlorine and bromine free radicals generated from relatively stable chlorinated, fluorinated, and brominated products by ultraviolet radiation.

Ozone depletion potential (ODP)
A relative index indicating the extent to which a chemical product may cause ozone depletion. The reference level of 1 is the potential of CFC-11 and CFC-12 to cause ozone depletion. If a product has an ozone depletion potential of 0.5, a given weight of the product in the atmosphere would, in time, deplete half the ozone that the same weight of CFC-11 would deplete. The ozone depletion potentials are calculated from mathematical models which take into account factors such as the stability of the product, the rate of diffusion, the quantity of depleting atoms per molecule, and the effect of ultraviolet light and other radiation on the molecules. The substances implicated generally contain chlorine or bromine.

Ozone layer
An area of the stratosphere, approximately 15 to 60 kilometres (9 to 38 miles) above the earth, where ozone is found as a trace gas (at higher concentrations than in other parts of the atmosphere). This relatively high concentration of ozone filters most ultraviolet radiation, preventing it from reaching the earth.

Ozone Secretariat
The secretariat to the Montreal Protocol and Vienna Convention, provided by UNEP and based in Nairobi, Kenya.

Party
A country that signs and/or ratifies an international legal instrument (e.g. a protocol or an amendment to a protocol), indicating that it agrees to be bound by the rules set out therein. Parties to the Montreal Protocol are countries that have signed and ratified the Protocol.

Phase out
The ending of all production and consumption of a chemical controlled under the Montreal Protocol.

POE
See **Polyolester**

Polyolester (POE)
A synthetic lubricant formed from one or more ester chains. Polyolester lubricants are typically more miscible with HFC refrigerants than traditional mineral oils.

Primary refrigerant
Primary refrigerant is the fluid medium used in the main vapour compression refrigeration cycle, e.g. ammonia, R-22 and R-134a, to extract heat from the heat source (e.g. air, water or brine) and transfer it to heat sink (e.g. outside air, sea water or cold water from cooling tower).

Propane
A gaseous hydrocarbon of the alkane series (C_3H_8).

Propylene
A member of the ethylene series (C_3H_6).

Quick freezer
In a quick freezer, the fish is frozen at a very fast rate, so as to retain its quality and appearance. Various methods of achieving fast cooling rate determine the type of quick freezer, namely immersion freezer, air blast freezer, contact or plate freezer and spray or cryogenic freezer.

Refrigerant
A heat transfer agent, usually a liquid, used in equipment such as refrigerators, freezers and air conditioners.

Refrigerant management plan (RMP)
The objective of a RMP at country level is to design and implement an integrated and overall strategy for cost-effective phase out of ODS refrigerants, which considers and evaluates all alternative technical and policy options. Projects previously implemented in isolation from one another are thus part of an overall approach synchronized for optimal results.The RMP concept may also be used as a management tool at the company level.

Refrigerated sea water (RSW)
A conventional mechanical refrigeration system is used to lower the temperature of sea water to that required for chilling fish, i.e. in the range from about 10 °C to a minimum possible temperature of –1.5 °C, (sea water freezes at about –2 °C). The fish catch is pre-cooled or chilled by re-circulating the refrigerated sea water in the fish tanks on board before the fish processing and freezing.

Retrofit
The upgrading or adjustment of equipment so that it can be used under altered conditions; for example, of refrigeration equipment to be able to use a non-ozone depleting refrigerant in place of a CFC.

Secondary refrigerant
Secondary refrigerant is the fluid that extracts heat from the product to be cooled and transfers it to the primary refrigerant through a heat exchanger.

Servicing
In the refrigeration sector, all kind of work which may be performed by a service technician, from installation, operations, inspection, repair, retrofitting, redesign and decommissioning of refrigeration systems to handling, storage, recovery and recycling of refrigerants, as well as record-keeping.

Stratosphere
The part of the earth's atmosphere above the troposphere, at about 15 to 60 kilometres (9 to 38 miles). The stratosphere contains the ozone layer.

Transitional substances
Under the Montreal Protocol, a chemical whose use is permitted as a replacement for ozone-depleting substances, but only temporarily due to the substance's ODP or toxicity.

United Nations Development Programme (UNDP)
One of the Multilateral Fund's implementing agencies.

United Nations Environment Programme (UNEP)
Through the UNEP DTIE OzonAction Programme, UNEP is one of the

Multilateral Fund's implementing agencies.

United Nations Industrial Development Organization (UNIDO)
One of the Multilateral Fund's implementing agencies.

UNDP
See **United Nations Development Programme**

UNEP
See **United Nations Environment Programme**

UNEP DTIE
United Nations Environment Programme Division of Technology, Industry and Economics (located in Paris, France) formerly called UNEP Industry and Environment Centre (UNEP IE).

UNIDO
See **United Nations Industrial Development Organization**

Venting
A service practice where the refrigerant vapour is allowed to escape into the atmosphere after the refrigerant liquid has been recovered. This practice is no longer acceptable.

Vienna Convention
The international agreement made in 1985 to set a framework for global action to protect the stratospheric ozone layer. This convention is implemented through the Montreal Protocol.

World Bank
Formally known as the International Bank for Reconstruction and Development, it is one of the Multilateral Fund's implementing agencies.

Zeotrope
A blend, consisting of several refrigerants of different volatilities, that changes appreciably in composition or temperature as it evaporates (boils) or condenses (liquefies) at a given pressure (see also **Azeotrope**). A refrigerant blend assigned a R-400 series number designation in ANSI/ASHRAE 34 is a zeotrope.

Annex B: Refrigerant Data

This *Annex* was adapted from the *1998 Report of the UNEP Technical Options Committee for refrigeration, air conditioning and heat pumps* (p. 264–274). It is intended to assist the reader in understanding the different chemical and environmental properties of the various refrigerant alternatives. For more details, please refer to the original report.

Data summary

The table on pages 47–51 provides summary data for refrigerants, both single compounds and blends, addressed in this report as well as those known to have been used historically or under consideration as candidates for future use. The table excludes proprietary blends for which the composition (components) and/or formulation (their proportions) have not been disclosed.

The data in this table were extracted from the ARTI Refrigerant Database /Cal98/, which provides further information on the refrigerants included and addresses additional refrigerants. This database identifies the source for the data presented in the table as well as, for some refrigerants, additional data where conflicting values have been identified by different investigators. The data and their limitations should be verified in the referenced source documents, particularly where use of the data would risk loss to life or property. REFPROP /McL98/ can be used to calculate additional properties for many of the refrigerants and additional blends.

The data presented, from left to right in the table are:

Refrigerant number: if assigned, in accordance with ASHRAE Standard 34 /ASH97/

Chemical formula: in accordance with the IUPAC convention /IUP79/ or, for blends, the blend composition in accordance with ASHRAE Standard 34 /ASH97/

Molecular mass

Normal boiling point (NBP) or, for blends, the bubble point temperature at 101.325 kPa

Critical temperature (Tc) in °C or, for blends, the calculated pseudo-critical temperature

Critical pressure (Pc) in kPa or, for blends, the calculated pseudo-critical pressure

Threshold limit value—time weighted average (TLV-TWA) in ppm v/v assigned by the American Conference of Governmental Industrial Hygienists (ACGIH) or a consistent measure

Lower flammability limit (LFL) in % concentration ambient air, determined in accordance with ASHRAE Standard 34 /ASH97/

Heat of combustion (HOC) in MJ/kg calculated assuming complete reaction to the most stable products in their vapour state, namely CO_2, HF (or F_2 if insufficient H), Cl_2, N_2, and H_2O: Negative values indicate endothermic

reactions while positive values indicate exothermic reactions

Safety classification: if assigned, in accordance with ASHRAE Standard 34 /ASH97/ or pending addenda thereto. Some of the classifications are followed by lower case letters, which indicate: 'd' signifies that the project committee responsible for ASHRAE Standard 34, SSPC 34, has recommended *deletion* of the classification, but final approval and/or publication is still pending; 'p' indicates that the classification was assigned on a *provisional* basis; 'r' signifies that SSPC 34 has recommended *revision* or *addition* of the classification as shown, but final approval and/or publication is still pending.

Atmospheric lifetime (τ_{atm}) in years

Ozone depletion potential (ODP) relative to R-11 based on the modelled values adopted in the Scientific Assessment /WMO95/ or, for blends, the mass-weighted average based on the IUPAC atomic weights /IUP97/ of the component ODPs.

Global warming potential (GWP) relative to CO_2 for 100-year integration based on the values adopted in the IPCC Assessment /IPC96/ or, for blends, the mass-weighted average based on the IUPAC atomic weights /Cop97/ of the component ODPs.

Status: refrigerants that are restricted (e.g. by production limitations, phase out, or measures to reduce releases) for environmental reasons are noted as follows:

M: controlled (or for blends one or more components is controlled) under the Montreal Protocol; or

K: controlled (or for blends one or more components is controlled) under the Kyoto Protocol

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		Physical Data				Safety Data				Environmental Data			
Refrigerant number	Chemical formula – common name	Molecular mass	NBP (°C)	Tc (°C)	Pc (MPa)	TLV-TWA (PPM)	LFL (%)	HOC MJ/kg	Std 34 safety group	Atmospheric life (yr)	ODP	GWP 100 yr	status
CFC-11	CCl_3F	137.37	23.7	198.0	4.41	C1000	none	0.9	A1	50	1.000	3800	M
BCFC-12B1	$CBrClF_2$ (halon 1211)	165.36	-4.0	154.0	4.10	1000	none			20	5.100		M
CFC-12	CCl_2F_2	120.91	-29.8	112.0	4.14	1000	none	-0.8	A1	102	0.820	8100	M
BFC-13B1	$CBrF_3$ (halon 1301)	148.91	-57.7	67.1	3.96	1000	none		A1	65	12.000	5400	M
CFC-13	$CClF_3$	104.46	-81.3	29.2	3.92	1000	none	-3.0	A1	640	1.000	11700	M
FIC-13I1	CF_3I	195.91	-22.5	122.0			none			<0.1		<1	
FC-14	CF_4 (carbon tetrafluoride)	88.00	-128.1	-45.6	3.75		none		A1	50000	0.000	6500	K
HCFC-21	$CHCl_2F$	102.92	8.9	178.3	5.18	10	none		B1		0.010		M
HCFC-22	$CHClF_2$	86.47	-40.8	96.2	4.99	1000	none	2.2	A1	12.1	0.040	1500	M
HFC-23	CHF_3 (fluoroform)	70.01	-82.1	25.9	4.84	1000	none	-12.5	A1	264	0.000	11700	K
HCC-30	CH_2Cl_2 (methylene chloride)	84.93	40.2	237.0	6.08	50	14.6		B2	0.46	0.000	9	
HCFC-31	CH_2ClF	68.48	-9.1			0.1					0.010		M
HFC-32	CH_2F_2 (methylene fluoride)	52.02	-51.7	78.1	5.78	1000	13.3	9.4	A2	5.6	0.000	650	K
HCC-40	CH_3Cl (methyl chloride)	50.49	-24.2	143.1	6.67	50	8.1		B2	1.5	0.020	8	
HFC-41	CH_3F (methyl fluoride)	34.03	-78.1	44.1	5.90					3.7	0.000	150	K
HC-50	CH_4 (methane)	16.04	-161.5	-82.5	4.64	1000	5		A3	12.2	0.000	21	
CFC-113	CCl_2FCClF_2	187.37	47.6	214.1	3.39	1000	none	0.1	A1	85	0.900	4800	M
CFC-114	$CClF_2CClF_2$	170.92	3.6	145.7	3.26	1000	none	-3.1	A1	300	0.850	9200	M
CFC-115	$CClF_2CF_3$	154.47	-38.9	80.0	3.12	1000	none	-2.1	A1	1700	0.400	9300	M
FC-116	CF_3CF_3 (perfluoroethane)	138.01	-78.2	19.9	3.04	1000	none		A1	10000	0.000	9200	K
HCFC-123	$CHCl_2CF_3$	152.93	27.8	183.8	3.66	50	none	2.1	B1	1.4	0.014	90	M
HCFC-124	$CHClFCF_3$	136.48	-12.0	122.3	3.62	1000	none	0.9	A1	6.1	0.030	470	M
HFC-125	CHF_2CF_3	120.02	-48.1	66.2	3.63	1000	none	-1.5	A1	32.6	0.000	2800	K
HFE-E125	CHF_2-O-CF_3	136.02	-42.0	81.3	3.35					82	0.000		
HFC-134	CHF_2CHF_2	102.03	-23.0	119.0	4.62	1000	none	4.3		10.6	0.000	1000	K
HFC-134a	CH_2FCF_3	102.03	-26.1	101.1	4.06	1000	none	4.2	A1	14.6	0.000	1300	K
HFE-E134	CHF_2-O-CHF_2	118.03	6.2	160.8	4.23		none			8	0.000		
HCFC-141b	CH_3CCl_2F	116.95	32.0	204.2	4.25	500	6.4	8.6		9.4	0.100	600	M
HCFC-142b	CH_3CClF_2	100.49	-9.0	137.1	4.12	1000	6.9	9.8	A2	18.4	0.050	1800	M
HFC-143	CH_2FCHF_2	84.04	5.0	156.7	4.52		5.8	10.9		3.8	0.020	300	K
HFC-143a	CH_3CF_3	84.04	-47.2	72.9	3.78	1000	7.1	10.3	A2	48.3	0.000	3800	K

Shaded areas denote substances or blends containing substances that are controlled under the Montreal Protocol.

Refrigerant number	Chemical formula – common name	Physical Data: Molecular mass	NBP (°C)	Tc (°C)	Pc (MPa)	Safety Data: TLV-TWA (PPM)	LFL (%)	HOC MJ/kg	Std 34 safety group	Environmental Data: Atmospheric life (yr)	ODP	GWP 100 yr	status
HFE-E143a	CH_3-O-CF_3	100.04	-24.1	104.9	3.59					5.1	0.000	450	
HFC-152a	CH_3CHF_2	66.05	-24.0	113.3	4.52	1000	3.1	17.4	A2	1.5	0.000	140	K
HCC-160	CH_3CH2Cl (ethyl chloride)	64.51	13.1	187.2	5.24	100	3.8	20.6		<1	0.000		
HFC-161	CH_3CH_2F (ethyl fluoride)	48.06	-37.1	102.2	4.70		3.8			<1	0.000	low	K
HC-170	CH_3CH_3 (ethane)	30.07	-88.6	32.2	4.87	1000	3.2		A3		0.000	~20	
HE-E170	CH_3-O-CH_3 (dimethyl ether)	46.07	24.8	128.8	5.32	1000	3.4				0.000	~20	
FC-218	$CF_3CF_2CF_3$ (perfluoropropane)	188.02	-36.6	71.9	2.68	1000	none		A1	2600	0.000	7000	K
HFC-227ea	CF_3CHFCF_3	170.03	-15.6	102.8	2.98	1000	none	3.3		36.5	0.000	2900	K
HFC-236ea	CHF_2CHFCF_3	152.04	6.2	139.3	3.50		none	5.4		7.8	0.000		K
HFC-236fa	$CF_3CH_2CF_3$	152.04	-1.4	124.9	3.20	1000	none			209	0.000	6300	K
HFC-245ca	$CH_2FCF_2CHF_2$	134.05	25.1	174.4	3.94		7.1	8.4		6.6	0.000	560	K
HFC-245cb	$CH_3CF_2CF_3$	134.05	-18.0	107.2	3.26					1.8	0.000		K
HFC-245fa	$CHF_2CH_2CF_3$	134.05	15.1	154.1	4.43	500 p	none	6.1	A1p r	8.8	0.000	820	K
HFE-E245fa1	CHF_2-O-CH_2-CF_3	150.05	29.2	170.9	3.42					6.1	0.000	640	
HFC-254cb	CH_3-CF_2-CHF_2	116.06	-0.8	146.2	3.75					1.6	0.000		K
HC-C270	CH_2-CH_2-CH_2- (cyclopropane)	42.08	-33.5	125.2	5.58		2.4				0.000		
HC-290	$CH_3CH_2CH_3$ (propane)	44.10	-42.1	96.7	4.25	2500	2.3	50.3	A3		0.000	~20	
FC-C318	CF_2-CF_2-CF_2-CF_2-	200.03	-6.0	115.2	2.78	1000	none		A1 d	3200	0.000	8700	K
HFE-E329mcc2	CHF_2-CF_2-O-CF_2-CF_3	236.04	22.0	139.5	2.26						0.000		
HFC-338mcc	$CH_2FCF_2CF_2CF_3$	202.05	27.8	158.8	2.73						0.000		K
HFC-338mee	$CF_3CHFCHFCF_3$	202.05	26.0	148.5	2.48		none				0.000		K
HFE-E347mcc3	CH_3-O-CF_2-CF_2-CF_3	200.05	34.2	164.6	2.48		none			6.4	0.000	485	
HFE-E347mmy1	CF_3-CF(OCH_3)-CF_3	200.05	29.4	160.2	2.55					4.9	0.000	368	
HFC-365mfc	$CH_3CF_2CH_2CF_3$	148.07	40.2	187.7	2.75		3.5			11	0.000	850	K
R-400(50/50)	R-12/114 (50/50)	141.63	-20.8	128.9	3.92		none		A1/A1		0.835	8650	M
R-400(60/40)	R-12/114 (60/40)	136.94	-23.2	125.4	3.99		none		A1/A1		0.832	8540	M
R-401A	R-22/152a/124 (53/13/34)	94.44	-34.4	105.3	4.61	1000	none		A1/A1		0.031	970	M
R-401B	R-22/152a/124 (61/11/28)	92.84	-35.7	103.5	4.68	1000	none	-2.7	A1/A1		0.033	1060	M
R-401C	R-22/152a/124 (33/15/52)	101.03	-30.5	109.9	4.40		none		A1/A1		0.029	760	M
	R-22/152a/124 (31/24/45)	95.09	-29.6	110.4	4.43						0.026	710	M
R-402A	R-125/290/22 (60/2/38)	101.55	-49.2	76.0	4.23		none	-1.4	A1/A1		0.015	2250	M

		Physical Data				Safety Data				Environmental Data			
Refrigerant number	Chemical formula – common name	Molecular mass	NBP (°C)	Tc (°C)	Pc (MPa)	TLV-TWA (PPM)	LFL (%)	HOC MJ/kg	Std 34 safety group	Atmospheric life (yr)	ODP	GWP 100 yr	status
R-402B	R-125/290/22 (38/2/60)	94.71	-47.2	83.0	4.53		none	-1.6	A1/A1		0.024	1960	M
R-403A	R-290/22/218 (5/75/20)	91.99	-44.0	91.2	4.69	1000	none		A1/A1		0.030	2530	M
R-403B	R-290/22/218 (5/56/39)	103.26	-43.8	88.7	4.40	1000	none		A1/A1		0.022	3570	M
R-404A	R-125/143a/134a (44/52/4)	97.60	-46.6	72.1	3.74	1000	none	-6.6	A1/A1		0.000	3260	K
R-405A	R-22/152a/142b/C318												
	(45.0/7.0/5.5/42.5)	111.91	-32.9	106.0	4.29	1000	none		A1/A1 d		0.021	4480	M
R-406A	R-22/600a/142b (55/4/41)	89.86	-32.7	116.5	4.88		wff		A1/A2		0.043	1560	M
	R-22/600a/142b (65/4/31)	88.57	-35.0	112.2	4.95		wff				0.042	1530	M
R-407A	R-32/125/134a (20/40/40)	90.11	-45.2	81.9	4.49	1000	none	-3.6	A1/A1		0.000	1770	K
R-407B	R-32/125/134a (10/70/20)	102.94	-46.8	74.4	4.08	1000	none	-1.8	A1/A1		0.000	2290	K
R-407C	R-32/125/134a (23/25/52)	86.20	-43.8	87.3	4.63	1000	none	-4.9	A1/A1		0.000	1530	K
R-407D	R-32/125/134a (15/15/70)	90.96	-39.4	91.6	4.48	1000	none	-4.3	A1/A1		0.000	1430	K
R-407E	R-32/125/134a (25/15/60)	83.78	-42.8	88.8	4.73	1000	none	-4.8			0.000	1360	K
	R-32/125/134a (30/10/60)	80.13	-43.4	89.1	4.87		wff				0.000	1260	K
R-408A	R-125/143a/22 (7/46/47)	87.01	-45.5	83.3	4.42		none	5.7	A1/A1		0.019	2650	M
R-409A	R-22/124/142b (60/25/15)	97.43	-35.4	106.9	4.69	1000	none	3.0	A1/A1		0.039	1290	M
R-409B	R-22/124/142b (65/25/10)	96.67	-36.5	104.4	4.71		none		A1/A1		0.039	1270	M
R-410A	R-32/125 (50/50)	72.58	-51.6	72.5	4.95	1000	none	-4.4	A1/A1		0.000	1730	K
R-410B	R-32/125 (45/55)	75.57	-51.5	71.0	4.78		none		A1/A1		0.000	1830	K
	R-32/125 (32/68)	84.63	-51.1	67.7	4.40						0.000	2110	K
	R-32/125 (48/52)	73.75	-51.6	69.9	4.73		none				0.000	1770	K
R-411A	R-1270/22/152a (1.5/87.5/11.0)	82.36	-39.7	99.1	4.95	1000	wff		A1/A2		0.035	1330	M
R-411B	R-1270/22/152a (3/94/3)	83.07	-41.6	96.0	4.95	1000	wff	6.5	A1/A2		0.038	1410	M
R-411C	R-1270/22/152a (3.0/95.5/1.5)	83.44	-41.8	95.5	4.95		none				0.038	1440	M
R-412A	R-22/218/142b (70/5/25)	92.17	-36.4	107.5	4.88	1000	wff		A1/A2		0.041	1850	M
R-413A	R-218/134a/600a (9/88/3)	103.95	-29.3	101.4	4.24		wff				0.000	1770	K
R-414A	R-22/124/600a/142b (51/28.5/4/16.5)	96.93	-34.0	110.7	4.70	1000		3.6			0.037	1200	M
R-414B	R-22/124/600a/142b (50/39/1.5/9.5)	101.59	-34.4	108.0	4.59		none				0.036	1100	M
	R-23/22/152a (5/80/15)	81.72	-47.0	97.2	5.04	1000	wff				0.032	1810	M
	R-23/22/152a (5/65/30)	78.29	-44.8	100.8	4.95						0.026	1600	M
	R-23/22/152a (5/90/5)	84.18	-48.4	94.4	5.10	1000	none				0.036	1940	M

Refrigerant number	Chemical formula – common name	Physical Data: Molecular mass	NBP (°C)	Tc (°C)	Pc (MPa)	Safety Data: TLV-TWA (PPM)	LFL (%)	HOC MJ/kg	Std 34 safety group	Environmental Data: Atmospheric life (yr)	ODP	GWP 100 yr	status
R-416A	R-134a/124/600 (59.0/39.5/1.5)	111.92	-23.4	108.2	4.02			7.8			0.012	950	M
	R-22/12/142b (25/15/60)	98.99	-26.6	129.4	5.10	1000	wff				0.163	2670	M
	R-22/124/600 (50/47/3)	102.64	-34.8	102.6	4.56	900	none				0.034	970	M
	R-22/134a/21 (65/15/20)	91.49	-35.9	111.0	5.10						0.034	1500	M
	R-22/142b (40/60)	94.37	-27.9	123.1	4.72		wff				0.046	1680	M
	R-22/142b/21 (65/20/15)	91.20	-34.5	116.0	5.07						0.042	1600	M
	R-22/227ea/600a/142b (41/40/4/15)	107.82	-32.4	108.2	4.37						0.024	2050	M
	R-23/125/143a (20/36/44)	90.16	-64.8	67.3	4.03						0.000	5020	K
	R-23/32/134a (4.5/21.5/74)	83.14	-42.2	89.0	4.90		none				0.000	1630	K
	R-32/125/143a (10/45/45)	90.69	-48.4	72.0	4.05		none				0.000	3040	K
	R-32/125/143a/134a (10/33/36/21)	90.80	-49.4	77.5	4.01		none				0.000	2630	K
	R-32/134a (25/75)	82.26	-40.3	93.7	4.83		wff				0.000	1140	K
	R-32/134a (30/70)	79.19	-41.8	92.4	4.94	1000	wff				0.000	1110	K
	R-32/134a (33.8/66.2)	77.03	-42.8	91.4	5.02						0.000	1080	K
	R-125/143a/290/22 (42/6/2/50)	95.70	-47.7	81.0	4.45	1000	none				0.020	2150	M
	R-134a/142b (80/20)	101.71	-24.1	107.5	4.12						0.010	1400	M
	R-134a/152a (20/80)	71.06	-24.1	384.2	4.40						0.000	370	K
	R-152a/227ea (25/75)	122.01	-20.7	107.8	2.83		none				0.000	2210	K
	R-170/290 (6/94)	42.90	-50.0	91.2	4.29		1.9				0.000	~21	
	R-218/134a/600 (32.7/62.8/4.5)	115.36	-31.4	99.8	4.15						0.000	3110	K
	R-290/22/124 (3/40/57)	105.45	-37.0	112.5	4.46	500	none				0.033	870	M
	R-290/600a (50/50)	50.15	-32.8	114.8	4.04		2				0.000	~20	
R-500	R-12/152a (73.8/26.2)	99.30	-33.6	102.1	4.17	1000	none		A1		0.605	6010	M
R-501	R-22/12 (75.0/25.0)	93.10	-40.5	96.2	4.76		none		A1		0.235	3150	M
R-502	R-22/115 (48.8/51.2)	111.63	-45.3	80.7	4.02	1000	none		A1		0.224	5490	M
R-503	R-23/13 (40.1/59.9)	87.25	-87.5	18.4	4.27	1000	none				0.599	11700	M
R-504	R-32/115 (48.2/51.8)	79.25	-57.7	62.1	4.44		none				0.207	5130	M
R-505	R-12/31 (78.0/22.0)	103.48	-30.0	117.8	4.73		none				0.642		M
R-506	R-31/114 (55.1/44.9)	93.69	-12.3	142.2	5.16		none				0.387		M
R-507A	R-125/143a (50/50)	98.86	-47.1	70.9	3.79		none	-5.5	A1		0.000	3300	K
R-508A	R-23/116 (39/61)	100.10	-87.4	11.0	3.70	1000	none		A1		0.000	10200	K

Refrigerant number	Chemical formula – common name	Physical Data: Molecular mass	Physical Data: NBP (°C)	Physical Data: Tc (°C)	Physical Data: Pc (MPa)	Safety Data: TLV-TWA (PPM)	Safety Data: LFL (%)	Safety Data: HOC MJ/kg	Safety Data: Std 34 safety group	Environmental Data: Atmospheric life (yr)	Environmental Data: ODP	Environmental Data: GWP 100 yr	status
R-508B	R-23/116 (46/54)	95.39	-87.4	14.0	3.93	1000	none		A1/A1		0.000	10400	K
R-509A	R-22/218 (44/56)	123.96	-40.4	87.2	4.03	1000	none		A1		0.018	4580	M
	R-134a/152a (85/15)	94.32	-25.4	102.9	4.08						0.000	1130	K
	R-152a/600a (70/30)	63.45	-26.5	120.3	4.93						0.000	100	K
	R-218/152a (83.5/16.5)	144.11	-34.8	86.8	3.38						0.000	5870	K
R-600	CH_3-CH_2-CH_2-CH_3 (butane)	58.12	-0.5	152.0	3.80	800	1.9	49.5	A3		0.000	~20	
R-600a	$CH(CH_3)_2$-CH_3 (isobutane)	58.12	-11.6	134.7	3.64	800	1.8	49.4	A3		0.000	~20	
R-610	CH_3-CH_2-O-CH_2-CH_3 (ethyl ether)	74.12	34.6	214.0	6.00	400	1.9				0.000		
R-611	HCOOCH3 (methyl formate)	60.05	31.8	214.0	5.99	100	5.1		B2		0.000		
R-630	$CH_3(NH_2)$ (methylamine)	31.06	-6.7	156.9	7.46	5	4.9				0.000		
R-631	CH_3-$CH_2(NH_2)$ (ethylamine)	45.08	16.6	183.0	5.62	5	3.5				0.000		
	$NCH_3(CF_3)_2$	167.05	10.4	142.6	2.92						0.000		
	$NCHF_2(CF_3)_2$	203.03	7.5	131.8	2.73					2.2	0.000		
R-704	He (helium)	4.00	-268.9	-267.9	0.23		none		A1		0.000		
R-717	NH_3 (ammonia)	17.03	-33.3	132.3	11.33	25	14.8	22.5	B2		0.000	<1	
R-718	H_2O (water)	18.02	100.0	374.2	22.10		none		A1		0.000	<1	
R-729	air	28.97	-194.4	-140.7	3.77		none				0.000	1	
R-744	CO_2 (carbon dioxide)	44.01	-78.4	31.1	7.38	5000	none		A1	>50	0.000	1	
R-764	SO_2 (sulphur dioxide)	64.06	-10.0	157.5	7.88	2	none		B1		0.000		
HCC-1130	CHCl=CHCl (dielene)	96.94	47.8	243.3	5.48	200	5.6						
HC-1150	CH_2=CH_2 (ethylene)	28.05	-109.4	9.3	5.11	1000	2.7		A3		0.000		
FC-1216	CF_2=$CFCF_3$	150.02	-29.4	94.9	2.90		none			5.8 d	0.000	2	K
HC-1270	CH_3CH=CH_2 (propylene)	42.08	-47.7	92.4	4.67	375	2.0		B3 r		0.000		

NBP = normal boiling point; Tc = critical temperature; Pc = critical pressure;
TLV-TWA = ACGIH Threshold Limit Value - Time Weighted Average, unless preceded by 'C' for Ceiling values, or consistent chronic exposure limit (e.g., OSHA Permissible Exposure Limit, PEL);
LFL = lower flammability limit (% volume in air), 'wff' signifies that the worst case of fractionation may be flammable; HOC = heat of combustion;
ODP = ozone depletion potential; GWP = global warming potential; STATUS codes of 'K' and 'M' indicate restricted by the Kyoto or Montreal Protocols

Suffixes to safety classifications indicate changes that are not final yet ('d' for deletion or 'r' for revision or addition) or classifications assigned as provisional ('p').
Data sources are identified in the ARTI Refrigerant Database; verify data and limitations in the source documents before use.

Annex C: Selected references and information sources for the replacement of CFCs and other ODS in the fishery refrigeration sector

The following is a selection of publications and organizations related to non-CFC alternatives in the fishery cold chain sector. These papers may be useful reference for companies wishing to avoid or replace CFCs in specific applications. Further information is available from UNEP DTIE's OzonAction Programme (see Annex D for contact officials).

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Tel: +1 506 858 4284
Fax: +1 506 858 4540
E-mail: Leblancdim@em.agr.ca

* available at: www.uneptie.org/ozonaction.html

** available at: www.teap.org

Annex D: Contacts for further information and assistance

Implementing Agencies

Mr Rajendra Shende
Chief, Energy and OzonAction Unit
United Nations Environment Programme
Division of Technology, Industry and Economics (UNEP DTIE)
39–43, quai Andre Citroën
75739 Paris Cedex 15
France
Tel: (33) 1 44 37 14 50
Fax: (33) 1 44 37 14 74
E-mail: ozonaction@unep.fr
Web: http://www.unepie.org/ozonaction.html

Mr Frank Pinto
Principal Technical Adviser and Chief
Montreal Protocol Unit
United Nations Development Programme (UNDP)
1 United Nations Plaza
United Nations
New York, N. Y. 10017
United States
Tel: (1) 212 906 5042
Fax: (1) 212 906 6947
E-mail: frank.pinto@undp.org
Web: http://www.undp.org/seed/eap/montreal

Mr Angelo D'Ambrosio
Managing Director
Industrial Sectors and Environment Division
United Nations Industrial Development Organization (UNIDO)
Vienna International Centre
P.O. Box 300
A-1400 Vienna
Austria
Tel: (43) 1 26026 3782
Fax: (43) 1 26026 6804
E-mail: adambrosio@unido.org
Web site: http://www.unido.org

Mr Steve Gorman
Unit Chief
Montreal Protocol Operations Unit
World Bank
1818 H Street N.W.
Washington, D. C. 20433
United States
Tel: (1) 202 473 5865
Fax: (1) 202 522 3258
E-mail: sgorman@worldbank.org
Web site: http://www.esd.worldbank.org/mp/home.cfm

Multilateral Fund Secretariat

Dr Omar El Arini
Chief Officer
Secretariat of the Multilateral Fund for the Montreal Protocol
27th Floor, Montreal Trust Building
1800 McGill College Avenue
Montreal, Quebec H3A 6J6
Canada
Tel: (1) 514 282 1122
Fax: (1) 514 282 0068
E-mail: secretariat@unmfs.org
Web site: http://www.unmfs.org

UNEP Ozone Secretariat

Executive Secretary
UNEP Ozone Secretariat
P. O. Box 30552
Nairobi
Kenya
Tel: (254 2) 623 855
Fax: (254 2) 623 913
Web site: http://www.unep.org/unep/secretar/ozone/home.htm

Other international organizations

Food and Agriculture Organization (FAO) Fisheries Department
Viale delle Terme di Caracalla
00100 Rome
Italy
Tel: (39) 0657051
Fax: (39) 0657053152
E-mail: FI-Inquiries@fao.org
Web site: www.fao.org/fi/default.asp

International Institute of Refrigeration (IIR)
177, Boulevard Malesherbes
F-75017,
Paris
France
Tel: (33) 1 42 273 235
Fax: (33) 1 47 631 798
E-mail: iifiir@iifiir.org
Web site: www.iifiir.org

About the UNEP DTIE OzonAction Programme

Nations around the world are taking concrete actions to reduce and eliminate production and consumption of CFCs, halons, carbon tetrachloride, methyl chloroform, methyl bromide and HCFCs. When released into the atmosphere these substances damage the stratospheric ozone layer—a shield that protects life on Earth from the dangerous effects of solar ultraviolet radiation. Nearly every country in the world—currently 175 countries—has committed itself under the Montreal Protocol to phase out the use and production of ODS. Recognizing that developing countries require special technical and financial assistance in order to meet their commitments under the Montreal Protocol, the Parties established the Multilateral Fund and requested UNEP, along with UNDP, UNIDO and the World Bank, to provide the necessary support. In addition, UNEP supports ozone protection activities in Countries with Economies in Transition (CEITs) as an implementing agency of the Global Environment Facility (GEF).

Since 1991, the UNEP DTIE OzonAction Programme has strengthened the capacity of governments (particularly National Ozone Units or 'NOUs') and industry in developing countries to make informed decisions about technology choices and to develop the policies required to implement the Montreal Protocol. By delivering the following services to developing countries, tailored to their individual needs, the OzonAction Programme has helped promote cost-effective phase-out activities at the national and regional levels:

- **Information Exchange**
  … provides information tools and services to encourage and enable decision makers to make informed decisions on policies and investments required to phase out ODS. Since 1991, the Programme has developed and disseminated to NOUs more than 100 individual publications, videos, and databases that include public awareness materials, a quarterly newsletter, a web site, sector-specific technical publications for identifying and selecting alternative technologies and guidelines to help governments establish policies and regulations.

- **Training**
  … builds the capacity of policy makers, customs officials and local industry to implement national ODS phase-out activities. The Programme promotes the involvement of local experts from industry and academia in training workshops and brings together local stakeholders with experts from the global ozone protection community. UNEP conducts training at the regional level and also supports national training activities (including providing training manuals and other materials).

- **Networking**
  … provides a regular forum for officers in NOUs to meet to exchange experiences, develop skills, and share knowledge and ideas with

counterparts from both developing and developed countries. Networking helps ensure that NOUs have the information, skills and contacts required for managing national ODS phase-out activities successfully. UNEP currently operates 8 regional/sub-regional Networks involving 109 developing and 8 developed countries, which have resulted in member countries taking early steps to implement the Montreal Protocol.

- **Refrigerant Management Plans (RMPs)**
  … provide countries with an integrated, cost-effective strategy for ODS phase-out in the refrigeration and air conditioning sectors. RMPs have to assist developing countries (especially those that consume low volumes of ODS) to overcome the numerous obstacles to phase out ODS in the critical refrigeration sector. UNEP DTIE is currently providing specific expertise, information and guidance to support the development of RMPs in 60 countries.

- **Country Programmes and Institutional Strengthening**
  … support the development and implementation of national ODS phase-out strategies especially for low-volume ODS-consuming countries. The Programme is currently assisting 90 countries to develop their Country Programmes and 76 countries to implement their Institutional-Strengthening projects.

For more information about these services please contact:

Mr Rajendra Shende,
Chief, Energy and OzonAction Unit
UNEP Division of Technology, Industry and Economics
OzonAction Programme
39–43, quai André Citroën
75739 Paris Cedex 15 France
Email: ozonaction@unep.fr
Tel: (33) 1 44 37 14 50
Fax: (33) 1 44 37 14 74
www.uneptie.org/ozonaction.html

About the UNEP Division of Technology, Industry and Economics

The mission of the UNEP Division of Technology, Industry and Economics (UNEP DTIE), is to help decision-makers in government, local authorities and industry develop and adopt policies and practices that:

- are cleaner and safer;
- make efficient use of natural resources;
- ensure adequate management of chemicals;
- incorporate environmental costs;
- reduce pollution and risks for humans and the environment.

UNEP DTIE, with its head office in Paris, is composed of one centre and four units:

- **The International Environmental Technology Centre (Osaka),** which promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins, in developing countries and countries in transition.

- **Production and Consumption (Paris),** which fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

- **Chemicals (Geneva),** which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety worldwide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).

- **Energy and OzonAction (Paris),** which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of the Unit.

- **Economics and Trade (Geneva),** which promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

UNEP DTIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

A Word from the Chief of UNEP DTIE's Energy and OzonAction Unit

Much of the Montreal Protocol's success can be attributed to its ability to evolve over time to reflect the latest environmental information and technological and scientific developments. Through this dynamic process, significant progress has been achieved globally in protecting the ozone layer.

As a key agency involved in the implementation of the Montreal Protocol, UNEP DTIE's OzonAction Programme promotes knowledge management in ozone layer protection through collective learning. There is much that we can learn from one another in adopting effective alternatives to ozone depleting substances.

I encourage you to share your experiences with the OzonAction Programme so that we can inform others involved in ozone protection in the fishery sector about the lessons you learned. Send us an e-mail, fax or letter about your experiences and successes. We will consider it as an important part of collective learning.

UNEP may use the feedback and information received for future updates or supplements to this publication. We will also disseminate your experiences and stories through a variety of channels, including the OzonAction Newsletter and the OzonAction Programme's website (www.uneptie.org/ozonaction.html).

If we use the information you provide, we will send you a free copy of one of our videos, publications, posters or CD-ROMs as thanks for your cooperation.

So take a pen and write to us. Let us learn collectively how to protect the ozone layer.

Rajendra M. Shende
Chief, UNEP DTIE Energy and OzonAction Unit

MAKING A GOOD CATCH:
NON-CFC TECHNOLOGIES IN THE FISHERY COLD CHAIN

Throughout the journey from catch to consumer, the fishing industry relies on a cold chain to ensure the commercial viability of its products. The safety of the food, its shelf life, taste and appearance all depend on reliable refrigeration to retard spoilage. This cold chain may take various forms including ice, refrigerated seawater, refrigerated compartments and cold stores, but a common feature in all of these applications has been the traditional use of CFC-based refrigeration technology.

With the commitment of developing and developed countries to phase out CFCs, HCFCs and other ozone depleting substances under the Montreal Protocol, the fishery industry must identify and adopt new non-CFC technologies. This publication provides examples of non-CFC technologies used in the fishery cold chain in nine countries, and includes an overview of refrigeration equipment used in the fishery industry, an introduction to alternative refrigerants, refrigerant data and sources of further information.

This document has been developed by the UNEP DTIE OzonAction Programme as part of UNEP's Work Programme under the Multilateral Fund.

UNEP DTIE OzonAction Programme
39–43, quai André Citroën
75739 Paris Cedex 15 France
Tel: (33) 1 44 37 14 59
Fax: (33) 1 44 37 14 74
E-mail: ozonaction@unep.fr
Web site: www.uneptie.org/ozonaction.html

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