CFCs

THE ROYAL NAVY AND THE OZONE LAYER

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ABSTRACT

Public, political and media interest in the protection of the environment, particularly the ozone layer, has been developing rapidly since the mid 1980s. Ozone-friendly aerosols are almost universally available and now the Montreal Protocol has further extended boundaries of study. It comes as no surprise that the Ministry of Defence and the Royal Navy have aligned themselves with current thinking, undertaking investigations into methods of managing and eliminating CFCs and Halons. This article chronicles the background and history to the Protocol, documents the progress made within the Royal Navy, and indicates the potential of future environmental measures.

Introduction

CFC (Chlorofluorocarbon) and Halon chemicals are perceived as a threat to the earth's stratospheric ozone layer. The Royal Navy's viewpoint on this emotive issue is considered here, but not the greenhouse effect and global warming problems. These atmospheric phenomena are related to increasing energy consumption levels, the corresponding excess production of carbon dioxide, and the earth's diminishing ability to absorb this and other 'warming' gases such as methane produced as a result of more intensive farming methods. The ozone layer problem contributes less than 5% to the greenhouse effect. The solution to the CFC and Halon problem alone is relatively straightforward compared to the logistics required to reduce the greenhouse effect.

In March 1985, the Vienna Convention for the Protection of the Ozone Layer was adopted at a diplomatic conference in Austria. This led to a meeting in Montreal at which the Protocol was endorsed. The Montreal Protocol[1], signed in September 1987 by 24 countries including the U.K. and the European Commission, is designed to limit the impact of CFCs and Halons on the ozone layer. Political pressure is building internationally to eliminate completely the production and use of these and other chemicals.

CFCs are widely used in the Royal Navy as refrigerants and as blowing agents for insulating foams, whilst Halons are exclusively used as fire-fighting reagents. In response to the Montreal Protocol agreement, the Ministry of Defence is involved in the production of a 'Policy and Programmes' document to manage and ultimately eliminate CFCs and Halons.

The Environment Under Study

The earth's atmosphere is subdivided into a number of regions (FIG. 1). The lowest of these, the troposphere, is between five and ten miles thick and contains 90% of all the air and almost all the water vapour. Air temperature falls through the troposphere. The stratosphere extends from the troposphere to a height of approximately 30 miles above the earth's surface. The air thins and, surprisingly, the temperature rises through the stratosphere. Above the stratosphere comes another zone of falling temperature, the mesosphere. Above the mesosphere (50 miles and beyond) is a region called the ionosphere. The temperature rises quickly in the ionosphere until, at a height of 300 to 400 miles, the ionosphere thins away into the emptiness of space.

The Ozone Layer

In the upper part of the stratosphere is a gaseous layer containing ozone. This ozone layer absorbs most of the ultra-violet rays that emanate from the sun. Ultra-violet light attacks germinating crops and photo-plankton in the oceans, and can also cause skin cancer in fair-skinned humans. Ozone (chemical symbol O_3), is a condensed, very active form of oxygen with a peculiar, pungent odour. The name originates from the Greeek word ozein, to smell.

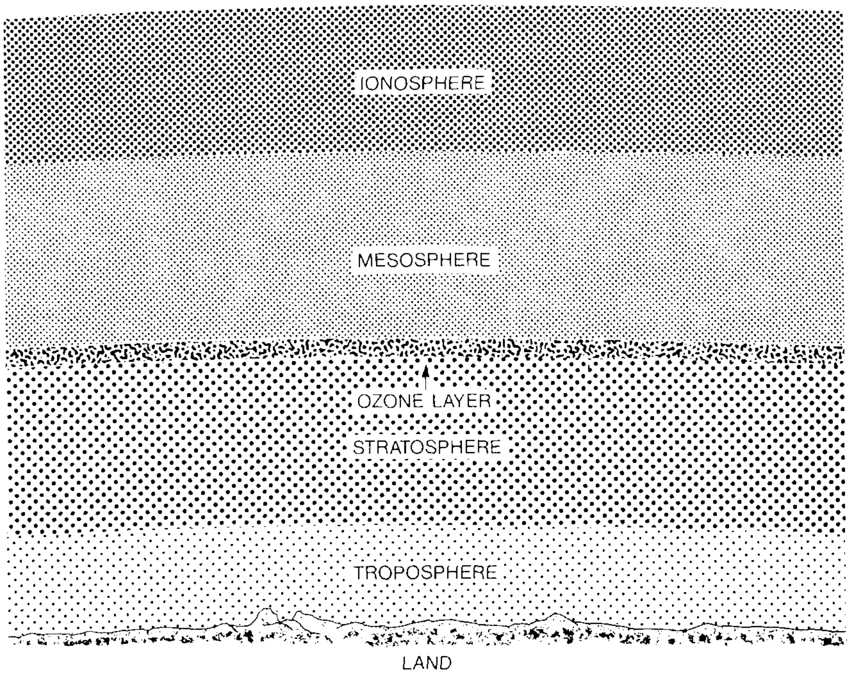

FIG. 1—REGIONS OF THE EARTH'S ATMOSPHERE

CFCs

CFCs belong to a chemical class called halogenated hydrocarbons. Halogen covers a group of elements identified as fluorine, chlorine, bromine and iodine. Hydrocarbons are compounds of carbon and hydrogen. Halogenation is a process whereby some or all of the hydrogens of the hydrocarbon are replaced by halogens.

CFCs have a number of important properties:

- Low toxicity
- Non flammable
- Solvent properties
- Chemical and thermal stability
- Low thermal conductivity

Although odourless and of low toxicity, CFC compounds are heavier than air and will exclude oxygen as the air is displaced by CFC gas. More importantly, the decomposition of CFCs in the presence of an open flame yields a percentage of phosgene, hydrogen fluoride and hydrogen chloride. These products of combustion are very poisonous.

Development of CFCs

In 1930, the development of fluorocarbon refrigerants (CFCs) was announced by T. Midgley and A. L. Henne. The commercial production of Refrigerant (R) 12 started in 1931, followed by R11 (1932), R114 (1933), R113 (1934) and R22 in 1936. Other uses for CFCs were found after World War II, such as aerosol propellants (1943), foaming agents (1960) and cleaning compounds (1970s).

Effects on the Environment

The claim that CFCs are a threat to the earth's stratospheric ozone layer was first mooted in 1974 by M. J. Molina and F. S. Rowland. This was based on three factors: firstly, their stability (CFCs have atmospheric lifetimes of up to 400 years); secondly, there is no obvious sink in the atmosphere for their disposal; and thirdly, under the influence of solar radiation CFCs are able to release a chlorine radical which catalyses the decomposition of ozone to oxygen.

The Montreal Protocol

The Protocol[1] restrictions affect two groups of compounds shown in TABLE 1:

TABLE I—*Montreal Protocol controlled substances*

Group	*Substance*	*Ozone Depletion Potential*
Group 1	R11	1·0
	R12	1·0
	R113	0·8
	R114	1·0
	R115	0·6
Group 2	Halon 1211	3·0
	Halon 1301	10·0
	Halon 2402	6·0

R11 is the most common blowing agent used in the production of phenolic foam insulations for cold and cool rooms. Although the manufacture of such foams is not carried out by MOD, the disposal of the materal is a MOD responsibility.

R12 is used extensively as a refrigerant in ships, submarines and in shore bases. The Royal Navy uses more of this than any other regulated chemical, but is still only a minor consumer (less than 5% of U.K. commercial production levels).

R113 is used as a solvent and cleaning agent throughout the Navy. Commercial manufacturers are phasing out the production of CFC-based solvents.

R114 is a relatively new Royal Navy refrigerant used in submarines in centrifugal chilled water plants. Problems may arise with R114 because the Navy is a specialist user. Commercial production levels are much lower than for other proprietary CFCs. Alternatives may not be available before the production of R114 ceases.

R115 is not used in isolation. This refrigerant is combined with others to form mixtures such as R502, (see below), which is used for specific cooling applications.

Halon 1211 is used exclusively for fire-fighting, primarily in portable extinguishers. *Halon 1301* is more widely used for fire-fighting and is the preferred agent for room flooding systems. *Halon 2402* appears to have no use in the Royal Navy.

The degree of threat posed by individual CFC and Halon chemicals is indicated by the ozone depletion potential (ODP). This factor is based on the chemical reactivity of the material and its lifetime in the stratosphere. A figure of 1·0 is given to R11.

The restrictions on Group 1 substances came into force on the 1st of January 1989 and have returned production and consumption levels to those of 1986. Production and consumption will be further cut from the 1st of July 1993 to 80% of the 1986 level and finally to 50% of the 1986 level in the 12 months following the 1st of July 1998.

Group 2 restrictions come into force later, probably from the 1st of February 1992, and return production and consumption levels to those of 1986.

Azeotropic Mixtures

In addition to the two groups of substances controlled specifically under the Montreal Protocol, some mixtures are also controlled by virtue of their composition. These refrigerant combinations, known as azeotropic mixtures are not widely used. Three main variants warrant mention, as detailed in TABLE II. An azeotrope is a liquid which has a definite boiling point and a vapour composition the same as that of the liquid. The mixture acts as a new single refrigerant.

TABLE II—*Azeotropic mixture compositions*

Refrigerant	*Mixture*	*Proportion %*	*Ozone Depletion Potential*
R500	R12/R152A	(73·8/26·2)	0·74
R501	R22/R12	(75/25)	0·25
R502	R22/R115	(48·8/51·2)	0·30

Policy and Programmes Strategy

The requirement is for a comprehensive, long-term programme to eliminate the Royal Navy's dependence on restricted CFC and Halon chemicals. In order to determine a complete solution, it is necessary to investigate three areas: the chemical of concern; its application and use; and the activities involved in controlling its use. The resulting 'Policy and Programmes' document will establish policies and assign responsibilities and actions for the management of CFCs and Halons throughout the Royal Navy and MOD.

Until the elimination of CFCs and Halons can be achieved, conservation measures must be taken to ensure that unnecessary releases of CFCs and Halons are minimized and that there are sufficient reserves to meet future needs.

Elimination of CFCs and Halons—that is the development and introduction of substitute chemicals and new equipment/systems that do not use ozone-depleting substances—is reliant upon the activities of the international chemical industry. The Royal Navy is only able to conduct limited suitability testing.

At all stages throughout the programme, operational, training and testing practices will be modified to take account of alternative techniques. Disposal of ozone-depleting substances will become an increasingly difficult problem, demanding a more responsible method. Effective CFC and Halon disposal is carried out by high temperature incineration. Existing facilities in the U.K. consist of two furnace sites, one in Wales and one in the North of England. More furnaces are likely to be required in the near future.

The success of the project is dependent upon maintaining a balance between conservation, management of reserves, search for substitutes and the development of alternative technologies. A balance must be also struck between operational requirements, costs and effectiveness. Long term costing estimates (including manpower) will be made by all organizations involved.

Short-Term Measures

Short-term activities depend upon a sound method of accountability. Essential elements include management of stock, conservation and improved husbandry.

Management of Stock

The better management of stock during all stages of the programme is essential towards the goal of improved CFC and Halon control. Director General Supply and Transport (Navy) (DGST(N)) is involved in a procurement data gathering and control exercise which will identify CFC and Halon uses, and allot priorities.

A centrally coordinated chemical use inventory will ensure that initial data is kept up to date annually and that conservation efforts are accurately monitored. The analysis of this inventory will ensure that adequate supplies of Montreal Protocol controlled substances are available to meet Royal Navy requirements.

Conservation

CFC and Halon management problems centre around the ease of release to atmosphere and relative difficulty with which gases are recovered and transported.

The conservation programme focuses on emission control and equipment modification activities. Director General Marine Engineering (DGME) is actively pursuing methods of recovering and recycling refrigerant gases. ICI and British Oxygen operate a recycling service whereby used bottled refrigerant is collected and re-processed. This facility is used by the Royal Navy but not extensively. Some ships and shore establishments have portable freon recovery units which allow a plant charge to be bottled. FIG. 2 shows the operation of a refrigerant recovery unit. The intention is to provide a fleet-wide removal capability in order to make best use of a commercial recycling contract. Recovery units transfer volumes of liquid CFCs (typically refrigerants) from a liquid receiver on the equipment to an external storage bottle or they can be re-used to charge a system before commissioning. A pump is used to effect the transfer and may be motor-driven, air-driven or manual.

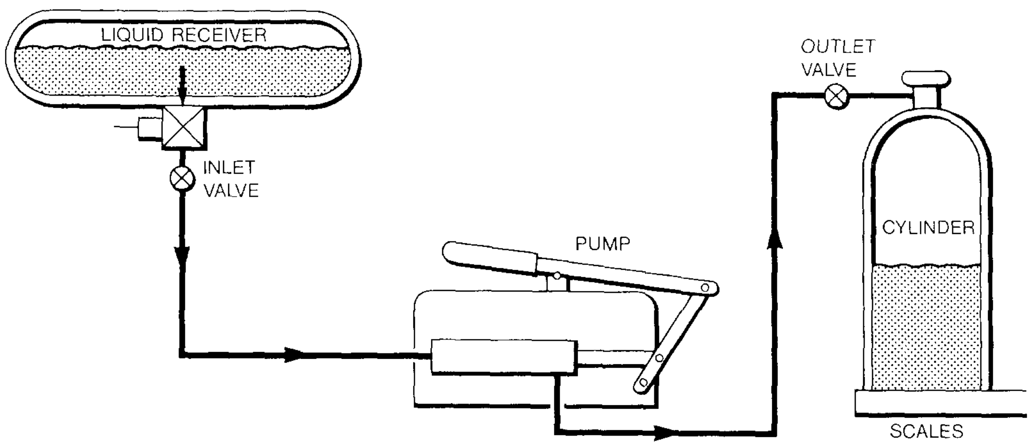

FIG. 2—REFRIGERANT RECOVERY UNIT

Most units are portable, cheap and easy to use, as long as basic safety precautions are observed. Weighing scales must be employed in order to avoid over-filling bottles. FIG. 3 shows a typical CFC recovery unit. The logistic difficulties involved in recovering, recycling and re-using CFCs will depend on the substance and its specific application.

Halon recycling services are offered by industry, but the application is limited. Conservation efforts should be very successful as most Halon emissions to the atmosphere are controllable. Fire-fighting system test procedures are being investigated. It is hoped that the use of an alternative test gas (SF_6) will stop the unnecessary release of Halon.

Short-term equipment modifications are being concentrated on the re-design of plant for product substitution. Initially, this will involve the use of refrigerants not on the Montreal Protocol controlled list, such as R22. The Royal Navy already uses R22 in some surface ships, but it is banned in submarines due to carcinogenic worries.

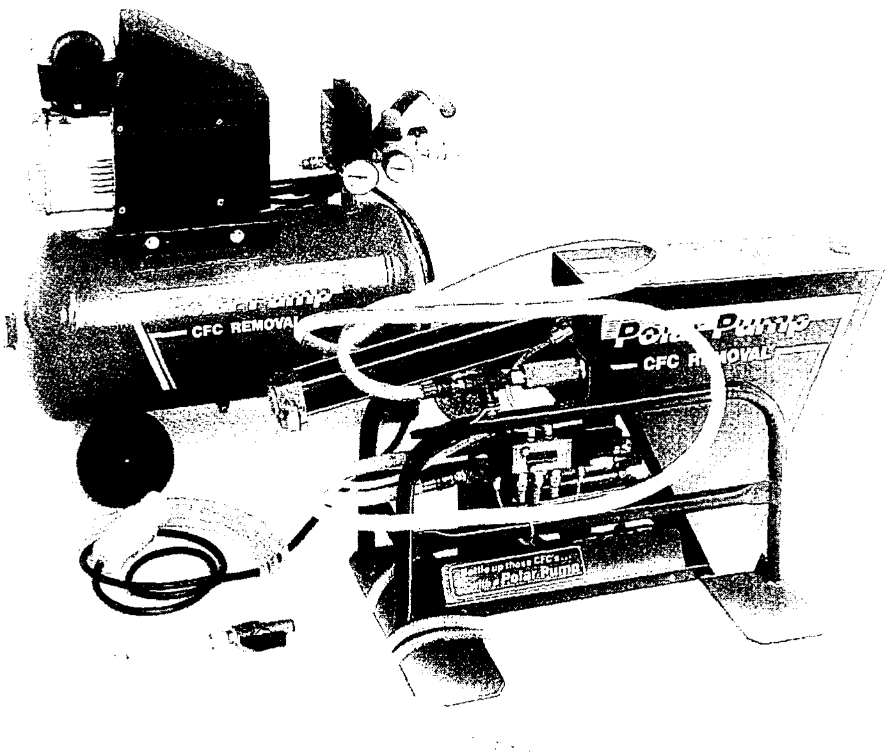

FIG. 3—A TYPICAL CFC RECOVERY UNIT. THE AIR-DRIVEN PUMP IS ON THE RIGHT WITH THE AIR COMPRESSOR TO POWER IT BEHIND

Improved Husbandry

Designers, plant manufacturers, installers, instructors, end users and maintainers are all obliged to protect the environment under the auspices of the Montreal Protocol. Significant emission reductions are possible by making changes in working practices, operator training and handbooks. The E.E.C. refrigeration industry has produced a comprehensive code of practice entitled CECOMAF GT1[2], which has been adopted by U.K. manufacturers. Many sections of this document are applicable to Royal Navy operations.

DGME is involved in a number of husbandry-related projects including plant modifications to assist containment, revised maintenance procedures and personnel training methods, and redesigned gas-tight bottle valves.

Due to the nature of CFC and Halon chemicals, leak detection is difficult and it is possible that a significant proportion of a system's charge may escape unnoticed. Certain atmosphere monitoring systems are in service, but the general situation is unacceptable under the Montreal Protocol. A more reliable and effective method is needed to detect leaks from equipment containing CFCs and Halons.

Other Royal Navy applications for Montreal Protocol controlled substances, such as solvents, aerosol propellants and cleaning agents, will diminish progressively as industry changes to alternative ozone-friendly products.

Long Term Measures

The longer-term elimination programme is likely to be organized into four project areas: refrigerants, fire-fighting, solvents and insulation foams. Each project will govern the procedure for adopting alternative chemicals and processes when they become available, including internal research and development programmes to optimize their use.

Several 'new' refrigerants are undergoing toxicity testing at ICI and Du Pont. U.K. manufacturers are investigating the implications of using such gases in Royal Navy equipment. The introduction of these refrigerants commercially will be no earlier than 1994. Replacements for Halons are not envisaged before the turn of the century.

DGME is studying the feasibility of alternative processes particularly thermoelectric cooling[3]. This heating and cooling principle, based on the Peltier effect, does not use CFCs. The French are leading the development process and intend to fit centralized thermoelectric cooling plant.

The complete programme of replacement may take 25 to 30 years, depending on the availability of suitable alternative chemicals or processes. The Halon and refrigerant projects will be the most manpower-intensive and time-consuming.

Conclusion

A first projection of costs indicates that the whole CFC and Halon elimination process will require finance in the region of £25M. Funding is likely to be a problem throughout the programme.

Benefit could be gained by ensuring that NATO navies freely share information on an exchange basis, collaborate on aspects of research and development, and communicate military requirements to that country's treaty negotiators.

A recent heads of government meeting held in Toronto to discuss atmospheric pollution problems will have wide-ranging implications. The inclusion of the greenhouse effect in future policies would ensure a much wider scope for study and certainly increase the public, political and media interest in defence pollution control activities.

References

1. *Montreal Protocol on Substances that deplete the Ozone Layer, final act;* United Nations Environmental Programme (UNEP), 1987.
2. *CECOMAF GT1-001, Reduction of CFC emissions from refrigerating systems;* European Committee of Manufacturers of Refrigeration Equipment, Dec. 1988.
3. Tillin, A. J.: Thermoelectric Cooling; *Journal of Naval Engineering*, vol. 32, no. 1, Dec. 1989, pp.117-125.