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International Aspects of Restrictions on Ozone-Depleting Substances

S. C. McDonald

October 1989

Prepared for
the U.S. Department of Energy
Conservation and Renewable Energy
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Pacific Northwest Laboratory
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SUMMARY

The purpose of this report is to summarize international activities related to the protection of stratospheric ozone and implications for the United States. The report was prepared by Pacific Northwest Laboratory[a] in support of the Report to the Secretary of Energy on Ozone-Depleting Substances. The Report to the Secretary provides an analysis of the energy and economic implications for the United States of restrictions in chlorofluorocarbon (CFC) and halon use.

The United States is one of several countries seeking to protect stratospheric ozone through restrictions contained in the Montreal Protocol on Substances that Deplete the Ozone Layer. The Protocol places limits on production and consumption of CFCs and halons beginning in 1989. Other countries may be able to meet early cutbacks more easily than the United States simply by restricting aerosol uses. The United States banned most aerosol uses of CFCs in 1978 so this is not an option for the United States. The eventual success of the Protocol depends in large part on the number of participating countries. Most developing countries are given special consideration for their stage of development; however, before becoming formal parties to the Protocol, many are awaiting concrete measures of assistance to the transition to alternatives chemicals and technologies.

The Protocol restricts trade of CFCs and CFC-related goods between participating and non-participating countries. The Protocol has strong implications for U.S. trade in CFC-related goods such as air conditioners and refrigerators. The United States is also a major producer of CFCs and halons. Recently, foreign companies have acquired U.S. companies that manufacture these substances, gaining greater access to U.S. markets and adding further complexity to this issue.

As a member of the global community, the United States should 1) continue to take a leading role in international negotiations; 2) support

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cooperative research and development with other countries; and 3) assist developing nations in their efforts to adopt alternatives to the use of ozone-depleting substances.

Within its own boundaries, the United States must seek a policy that maximizes protection of the ozone layer but does not place U.S. industry at a disadvantage in the international marketplace.

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1.0 INTRODUCTION

This report summarizes international efforts to protect stratospheric ozone. Also included in this report is a discussion of activities in other countries to meet restrictions in the production and use of ozone-depleting substances. Finally, there is a brief presentation of trade and international competitiveness issues relating to the transition to alternatives for the regulated chlorofluorocarbons (CFCs) and halons.

The stratosphere knows no international borders. Just as the impact of reduced stratospheric ozone will be felt internationally, so protection of the ozone layer is properly an international effort. Unilateral action, even by a country that produces and uses large quantities of ozone-depleting substances, will not remedy the problem of ozone depletion if other countries do not follow suit.

The Montreal Protocol, an international treaty, is being implemented to reduce global production and consumption of ozone-depleting substances. Currently, 41 countries [including the European Economic Community (EEC) and two Soviet Socialist Republics within the USSR] have signed the Protocol. The terms of the Protocol call for an obligatory rollback, to 1986 levels, in the production and use of CFCs beginning July 1, 1989.

Each country may seek a unique path to CFC reductions within the confines of the broad restrictions in the Protocol. Some countries may choose to ban particular uses of these substances in order to meet these goals. Others may simply limit the supply and allow prices to determine the market. In any case, some type of regulation or fiscal incentive will be required.

There is a further role for government beyond simple regulation and fiscal incentives. Governments can ease the transition to new alternatives by keeping markets orderly and by minimizing the impact on affected industries. Governments can also accelerate the move to alternatives by supporting research, testing, and licensing of new chemicals, technologies, and management practices.

International competitiveness is an important consideration in the choices government and industry make in meeting the requirements of the Protocol. Billions of dollars in exports and hundreds of thousands of jobs depend upon a successful transition to alternatives for CFCs and halons. Technologies and industries that depend on these substances include air conditioning, refrigeration, food processing and transport, electronics, defense systems, and plastics. If the United States adopts less attractive or more costly technologies or alternatives than do foreign countries, U.S. firms could lose market share to foreign competition.

The following sections deal with many of the issues raised here. Chapter 2 details international efforts to protect the ozone layer. Chapter 3 contains descriptions of activities in other countries to regulate ozone-depleting substances. When available, data are also presented on use of the controlled substances in these countries. Chapter 4 contains a discussion of trade issues as they relate both to specific restrictions within the Montreal Protocol and to broader categories of products which use or contain CFCs. Information can also be found in this section on foreign chemical manufacturers with a discussion of the search for alternatives to the regulated substances. Finally, Chapter 5 contains recommendations.

2.0 PROTECTION OF THE OZONE LAYER

Stratospheric ozone loss is an incredibly complex process, as are international efforts to protect the ozone layer. No attempt is made here to provide comprehensive coverage of these areas. Some background information is provided on events leading up to international efforts to protect stratospheric ozone. There are also summaries of the Vienna Convention, Montreal Protocol, and recent international events related to the protection of the ozone layer.

2.1 BACKGROUND

It was first hypothesized that CFCs might be harmful to the ozone layer in 1974 (Roland and Molina 1975). At that time, over half the use of CFC-11 and CFC-12 in the United States was as an aerosol propellant. Since aerosol use constituted immediate release (emission), this use was the focus of early curtailment efforts.

Attempts were made, in the mid-1970s, to legislate a ban on use of CFCs as an aerosol propellant. A joint administrative ban on nearly all aerosol uses was issued by the U.S. Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) in 1978. A handful of other countries joined the United States, in whole or in part, in this action.

Though the U.S. aerosol ban was not implemented until 1978, industry foresaw the ban and began to phase in non-CFC propellants and technologies. The decrease in aerosol demand for these chemicals had a substantial impact on production of CFC-11 and CFC-12. Combined production of these two substances by companies reporting to the Chemical Manufacturers Association (CMA) peaked in 1974 at 812,522 metric tons (CMA 1988). Production of CFC-11 and CFC-12 decreased to less than 600,000 metric tons in 1982 but increased thereafter primarily because of increased use in other countries and applications. In fact, by 1987 production climbed to 806,476 metric tons, nearly reaching 1974 levels. The figure for 1987 production would probably exceed that of even 1974 if data from non-reporting countries such as the USSR and

China could be included. Meanwhile, production of other ozone-depleting substances continued to grow throughout this period (HSIA 1989, and Hammitt et al. 1985).

In 1985, an international conference on the status of the ozone layer was held in Vienna, Austria. The Vienna Convention for the Protection of the Ozone Layer was adopted by this conference. The Montreal Protocol grew out of the Convention process.

Also in 1985, there was a startling announcement of a substantial loss of stratospheric ozone over Antarctica (Farman et al. 1985). This loss occurred during the Austral Spring and had been recorded each year from 1977 to 1984. The Antarctic "Ozone Hole" is not actually a total loss of ozone, but a significant reduction in concentration levels of stratospheric ozone.

In September 1987, a number of countries met in Montreal, Canada, to sign the Montreal Protocol on Substances that Deplete the Ozone Layer. The United States had participated in early negotiations leading to the Protocol and was present to sign in September. The Protocol did not take effect immediately, however, because at least 11 countries representing at least two-thirds of world consumption were required to ratify.

Late in 1987, an international scientific team mounted an expedition to study the stratosphere above Antarctica. The expedition confirmed ozone losses while also reporting high concentrations of chlorine (Stolarski 1988, and Shell 1988). Small concentrations of bromine were also found. Manmade CFCs and halons (which contain bromines) were implicated in the loss.

In March 1988, the Ozone Trends Panel, an international panel of experts, reported global losses of stratospheric ozone. These losses could not be explained solely by natural phenomena (Ozone Trends Panel 1988). Another scientific expedition, this time to the Arctic, reported conditions there were "primed" for ozone loss because of abnormally high concentrations of chlorine (C&EN 3/89).

Towards the end of 1988, a sufficient number of countries had signed the Vienna Convention and Montreal Protocol to allow them to enter into force.

These two documents provide the current framework for the international effort to protect the ozone layer.

2.2 THE VIENNA CONVENTION

The process leading to the Vienna Convention actually began in the early 1980s as countries sought to learn more information about the production, use, and impact of ozone-depleting substances (WMO 1985). These efforts culminated in an international conference in Vienna, Austria, on March 18-22, 1985. The purpose of the conference was to discuss the status of the ozone layer.

The conference adopted, as its Final Act, a Convention for the Protection of the Ozone Layer (Vienna Convention 1985). The United States was present at the conference and is a party to the Vienna Convention. Although the parties to the Convention proceeded to implement the Final Act, the Convention did not actually enter into force until September 22, 1988 (when at least 20 countries had ratified). Currently, there are 46 parties to the Vienna Convention (see Appendix A). Parties include the EEC and two Soviet Socialist Republics within the USSR.

The Convention provides a framework for international cooperation with regard to the ozone layer. Among the provisions in the Convention are cooperative scientific evaluation of the status of the ozone layer, voting rights of Convention members, the adoption of protocols, and the exchange of information.

Among the resolutions adopted by the conference and appended to the Vienna Convention were

- the resolution on institutional and financial arrangements
- the resolution on a protocol concerning CFCs.

The first resolution provided for the needed institutional and financial arrangements to continue the international process through the auspices of the United Nations Environmental Program (UNEP). The second resolution called for a protocol, or treaty, to protect the ozone layer. This second resolution ultimately led to the Montreal Protocol.

2.3 THE MONTREAL PROTOCOL

In September 1987, a conference was convened in Montreal, Canada, for the purpose of obtaining signatures to a Protocol to the Vienna Convention. The Montreal Protocol, as it has come to be known, is an international treaty regulating the consumption and production of substances which deplete the ozone layer. The United States was present in Montreal to sign the Protocol. The U.S. Senate voted unanimously to ratify the treaty on March 14, 1988, and the President later signed it into law. On August 1, 1988, EPA issued regulations (40 CFR Part 82) to implement the terms of the treaty when the Protocol eventually entered into force.

The Protocol entered into force on January 1, 1989. According to the terms of the treaty, this could not have happened until ratification by at least 11 countries, representing at least two-thirds of global consumption (Montreal Protocol 1987). Late in 1988, a sufficient number of countries had ratified (become parties to) the agreement to allow the Protocol to enter into force on schedule (see Appendix A).

2.3.1 Limits on Production, Consumption, and Trade

At the heart of the effort to mitigate destruction of stratospheric ozone is the attempt to limit introduction of manmade sources of chlorine (from CFCs) and bromine (from halons) into the stratosphere. While a small portion (<2%) of CFCs and halons are emitted to the atmosphere during production, primary emissions occur during use, testing, and disposal. CFC and halon end-users are widely dispersed and are extremely difficult to monitor and control. For this reason, it was decided to instead regulate overall country production, consumption, and trade of these compounds as a more effective control measure.

Production and consumption are defined in the Protocol (Montreal Protocol) as:

> "Production means the amount of controlled substances produced minus the amount destroyed by technologies approved by the Parties"
>
> "Consumption means production plus imports minus exports of controlled substances."

Absolute levels of production, consumption, and trade of each substance are not controlled directly. Instead, "calculated" levels of production, consumption, imports, and exports are used. Calculated levels are determined as the product of the ozone depletion potential (ODP) number for each substance multipled by the level of production, consumption, or trade. The calculated level for each substance is then summed to form a control total for the entire group (Group I or II). Production, consumption, and trade levels of individual substances are allowed to vary within these control totals.

Currently, eight chemicals are controlled through the Protocol (see Table 2.1). Included in Table 2.1 is the ODP of each of these substances. The ODP is a measure of the destructive potential (towards ozone) of a substance. It is a relative scale, with CFC-11 arbitrarily set equal to 1. The ODP of a particular substance is largely a factor of the number of chlorine (Cl) or bromine (Br) atoms it contains and its ability to reach the stratosphere intact (atmospheric lifetime). Both the list of controlled substances and their ODPs must be agreed upon by the participating countries to the Protocol.

The regulated substances are divided into two groups. Beginning July 1, 1989, six months after the Protocol entered into force, annual production and

TABLE 2.1. Controlled Substances

Group I (Chlorofluorocarbons)	ODP	Group II (Halons)	ODP
CFC-11	1.0	Halon-1211	3.0
CFC-12	1.0	Halon-1301	10.0
CFC-113	0.8	Halon-2402	6.0[a]
CFC-114	1.0		
CFC-115	0.6		

(a) Listed as "to be determined" in the Protocol. Later agreed to at the First Meeting of the Parties to the Montreal Protocol, May 1989.

Source: Montreal Protocol 1987.

consumption of Group I compounds must be curtailed to 1986 levels. By July 1, 1993, production and consumption of Group I compounds is to be decreased to 80% of 1986 levels. Finally, by July 1, 1998, production and consumption must be reduced to just 50% of 1986 levels.

Group II compounds are treated somewhat differently. Calculated production or consumption of Group II compounds is frozen at 1986 levels 3 years after the agreement enters into force (January 1, 1992). No further constraints are placed on Group II substances.

2.3.2 Exceptions to Production Limits

There are two major exceptions to limits on production of substances regulated by the Protocol. First, ". . . all or a portion of the calculated level of production . . ." may be transferred from one Party to another for purposes of "industrial rationalization." As constraints take hold and production falls, some plants may become uneconomical to operate. Rather than lose this production outright, production rights may be transferred across borders thereby allowing multinational firms to rationalize their production lines.

A second exception is for production facilities which were under construction before September 16, 1987. As long as such facilities are completed by the end of 1990, the capacity of these facilities may be included in production limits specified by the Protocol (i.e., included in the 1986 level of production). However, this addition cannot exceed 0.5 kilograms per capita.

2.3.3 Developing Countries

CFCs and halons are used primarily in developed countries. However, use is growing in developing countries. Therefore, participation by developing countries in the Protocol is essential if international efforts to protect the ozone layer are to succeed (OTA 1987).

Special provisions have been made in the Protocol for developing countries (Montreal Protocol, Article 5). Any developing country which has a (calculated) consumption of the controlled substances of less than 0.3 kilograms per capita per year may delay compliance with controls in the Protocol

for up to 10 years from each controlling date. However, during this time, consumption must remain below 0.3 kilograms per capita.

The Protocol also calls for developed countries to make environmentally-safe alternatives and technologies available to developing countries. Developed countries are asked to provide subsidies, credits, or aid to facilitate this transfer. These provisions are intended to entice developing countries to join the Protocol.

2.3.4 Other Conditions

The Protocol contains a number of other conditions. These include specific trade restrictions which are addressed in detail in Chapter 4. In addition to trade, production, and consumption limits, parties are also discouraged from transferring technologies to produce or use the controlled substances to non-party countries. Loans, subsidies, and credits to construct such facilities are also discouraged. Such restrictions do not apply to technologies to recycle or reduce the use of the controlled substances, however.

Article 9 of the Protocol calls for cooperative research and development, and information exchange. This includes technologies, for example, for recovery and recycling, and information on potential alternatives and products which are produced or used with these alternatives. Parties are required to document these activities and submit this information to the Secretariat of the Vienna Convention every 2 years.

2.3.5 Reassessment of Protocol Limits

The Montreal Protocol allows for revisions in control measures based upon the degree to which protection is afforded the ozone layer. Other factors must also be considered in this review, including the technical and economic capability to respond to further tightening in the terms of the treaty. Currently, four separate reviews are taking place:

- Scientific
- Technological

- Environmental
- Economic.

The scientific assessment will examine the current concentration levels of the regulated compounds and the status of the ozone layer. The technological review will determine the technically feasible levels for further reductions in the use of the regulated substances and the timetable for implementation of candidate technologies. The environmental review will consider the impact of further loss of stratospheric ozone on the biosphere. Finally, the economic review will analyze the cost of further restrictions in the use of these compounds and, the switch to alternatives.

These reviews were completed during the summer of 1989. A working group of the parties to the Montreal Protocol will convene in the fall of 1989 to consider the results. The parties will act based on the conclusions and recommendations in these reports.

2.4 RECENT INTERNATIONAL ACTIVITIES

On March 5-7, 1989, the British government sponsored a conference on saving the ozone layer. This meeting was outside the formal Vienna Convention and Montreal Protocol process. At the meeting, EPA Administrator William K. Reilly restated the U.S. government's position that the United States would support a phase-out of production of ozone-depleting substances by the year 2000, provided safe substitutes are available.

The parties to the Montreal Protocol and Vienna Convention met last April and May in Helsinki, Finland. A non-binding resolution was issued, but not voted upon, by the parties at the conclusion of the Helsinki meetings. The resolution called upon parties to ". . . phase out the production and the consumption of CFC's controlled by the Montreal Protocol as soon as possible but not later than the year 2000 and for that purpose to tighten the timetable agreed upon in the Montreal Protocol. . . ." (See Appendix B.)

At Helsinki, discussion also included proposals to broaden the list of controlled substances to include methyl chloroform. Methyl chloroform is used primarily as a cleaning and degreasing agent, at least in the United

States. Another ozone-depleting substance, carbon tetrachloride, is used as feedstock in producing fully halogenated CFCs. While feedstock use is not, and probably will not, come under control, use of this chemical in solvent applications is of concern. Carbon tetrachloride is not used in the United States for this purpose, but there is information to suggest that it is used in developing countries in solvent applications.

The draft declaration also made mention once again of the special situation of developing countries. Although a central fund was proposed to, among other things, support the transition to environmentally safe alternatives; this issue was not resolved. A working group will meet in the fall of 1989 to deliberate on the modalities to provide this support to developing countries.

3.0 FOREIGN RESPONSES

While most countries use at least some amount of the regulated substances, few are producers. In addition, the degree to which these substances are used in one application versus another (e.g., solvents versus refrigerants) also varies from one country to the next. Therefore, the impact of restrictions on availability of these substances will likely affect countries differently.

The method used to implement the terms of the Montreal Protocol is left to individual countries. The ease with which a particular country limits production and/or consumption of these substances will depend not only on the absolute level of production and consumption, but also on current use patterns and choice of control mechanisms. The most salient example of this is the use of CFCs as aerosol propellants, a use for which there are known, relatively low-cost, technological alternatives.

The United States may be able to learn from other countries participating in the Montreal Protocol. This is true not only of alternative regulatory methods to meet Protocol limits to production and consumption levels, but also of support for research into alternatives, policies towards private industry (tax incentives, anti-trust), and environment, health, and safety standards for substitute technologies.

An investigation of foreign country responses should also include an examination of the production and use of CFCs and halons in foreign countries. However, these data are difficult to obtain. One excellent source of data is the Chemical Manufacturers Association (CMA), but this is limited to CFC-11 and -12 and to reporting companies (primarily U.S., Japanese, and European firms).

Article 7 of the Protocol does require all participating countries to supply data on production and consumption of the regulated substances. The data are to be submitted to the UNEP in Nairobi, Kenya. However, these data are held in absolute confidence and are not available for dissemination.

Much of the data obtained for countries presented in the following subsections are uneven in terms of coverage and definition. As a consequence,

it was not possible to provide much comparative analysis using this data. No information was obtainable for halons.

3.1 EUROPEAN ECONOMIC COMMUNITY (EEC)

Article 2 of the Protocol allows regional economic organizations to act as a single entity in responding to the Protocol, provided certain conditions are met. The overall limits to production and consumption are equal to the sum of individual states, but production and consumption constraints may shift freely among the countries. The EEC qualifies as such an organization. The countries which are members of the EEC are listed below.

United Kingdom	France	Spain
Portugal	Greece	Ireland
Italy	Belgium	Germany, Federal Republic
The Netherlands	Denmark	Luxembourg

3.1.1 EEC Regulations

The Council of the European Communities is the governing body of the EEC. On October 14, 1988, the Council issued a decision to become a party to the Protocol (CEC 1988b). Formal approval, however, was not given until December 16, 1988, after all members of the EEC had agreed to ratify.

Simultaneous with the Council decision, regulations were issued which restricted the production and consumption of CFCs and halons in member states (CEC 1988a). These regulations are similar to U.S. EPA regulations in that they control production of CFCs and halons by manufacturers and restrict consumption in member states. Restrictions are also placed on trade outside the EEC, as called for in the Protocol (see Section 4.1).

Later, the EEC Council resolved to go beyond the terms of the Protocol (CEC 1988c). The resolution called for voluntary restraint agreements with CFC and halon users. One such agreement was negotiated with the Federation of European Aerosol (FEA) producers to reduce aerosol use by 90% by the end of 1990. An agreement was also reached with the European Isocyanate Producers Association to reduce CFCs "in urethanes by an average of 60% over the

next 5 years" (C&EN 4/89). The Council has also made calls for further reductions of up to 85% in production and consumption of the regulated substances "as soon as possible . . . with a view to their being eliminated towards the end of the century . . ." (CEC 1989).

3.1.2 Production and Use of Controlled Substances

The United States is the single largest national producer of CFCs and halons. However, the EEC countries, when considered as a whole, exceed U.S. production of CFC-11 and CFC-12 (see Table 3.1). It is interesting to note the small amount of recent growth in production of CFC-11 and CFC-12 in the EEC and United States in comparison with the rest of the world.

The primary use of CFC-11 and CFC-12 in the EEC countries is as aerosol propellants (see Table 3.2). Aerosol usages accounted for over 50% of the combined consumption of CFC-11 and CFC-12 in 1987. Since this usage was banned by some countries in the 1970s, alternative technologies for aerosols are well known.

It appears from these data that the EEC may be able to reach current limits on consumption (50% reduction relative to 1986, by 1998) with relative ease simply by eliminating aerosol uses. However, in all likelihood, there will be further tightening in the timetable for the reductions, the amount of the reductions, or the list of restricted compounds (or all three). Furthermore, the EEC supports, as do many countries, a total ban of these substances

TABLE 3.1. Production of CFC-11 and CFC-12 in CMA-Reporting Companies (thousands of metric tons)

	1986	1987	Percent Growth
EEC	372	376	1.1
USA	238	242	1.7
Other	139	189	36.0
Total	749	807	7.7

Source: CEC 1989.

TABLE 3.2. Consumption and Production of CFC-11 and CFC-12 in EEC Countries (metric tons)

	1986	1987	Percent Growth
Production	371,795	376,065	1.1
Final Consumption (Percent)			
Aerosols	136,248 (52.6)	137,299 (50.6)	+0.8
Refrigeration	26,780 (10.3)	27,299 (10.1)	+1.9
Foam Plastics	82,761 (31.9)	93,342 (34.4)	+12.8
Solvents and Other Uses	13,461 (5.2)	13,455 (5.0)	0.0
Total	259,250 (100.0)	271,395 (100.0)	+4.7
Exports	111,449	110,056	-1.3

Note: Totals may not sum because of rounding errors.
Source: CEC 1989.

by 2000. Therefore, like the United States, EEC countries will be searching for substitutes in all applications. Still, EEC countries may enjoy an advantage in timing in that they can meet early control dates through bans on aerosol uses. This will allow them more time, versus U.S. manufacturers, to find alternatives for more complex applications such as refrigeration, air conditioning, and foam blowing.

3.2 JAPAN

Japan became a party to the Vienna Convention and the Montreal Protocol in late 1988. Since that time it has moved quickly to address the CFC issue. The Japanese approach also appears to be unique in terms of both policy and technology responses.

3.2.1 Japanese Regulations

On March 11, 1988, the Japanese Cabinet completed work on the Ozone Layer Protection Bill which implements the terms of the Protocol (Environment Agency 1988). Like U.S. EPA regulations, the bill imposes limits on import, export, and production of CFCs and provides for licensing of these activities. However, the bill goes further in that it obligates CFC users to reduce emissions and rationalize use of CFCs. Preferential tax treatment is given to businesses which establish facilities to reduce CFC emissions.

3.2.2 Use of Controlled Substances

Japan announced at the Helsinki meeting that it had a combined production of CFC-11 and CFC-12 of about 73,000 metric tons in 1986. Detailed data on shipments (production plus changes in inventory) of all regulated CFCs are available (see Table 3.3). Using either source of information, it appears that Japan probably ranked third after the United States and the EEC in 1986.

The overwhelming use of CFCs in Japan is CFC-113 for cleaning. This is understandable given Japan's large manufacturing capabilities in electronic components. CFC-113 is used as a degreaser to remove flux and other contaminants from circuit boards and other electronic parts. The term "blowing" as listed in Table 3.3 is believed to be aerosol usage while "foaming" refers to foam blowing.

TABLE 3.3. Shipment of CFCs by Use in Japan, 1986 (metric tons)

	CFC-11	CFC-12	CFC-113	CFC-114	CFC-115	Total
Refrigerant	2,573	21,439	144	134	119	24,209
Blowing	4,439	7,157	159	150	0	11,905
Foaming	21,211	9,292	176	1,318	0	31,997
Cleaning	305	0	62,182	0	0	62,487
Other	873	315	917	11	11	2,127
Total	29,401	38,203	63,578	1,613	130	132,925

Source: ARI/JRAIA 1988.

3.2.3 Destruction Technologies

Japan has placed a large emphasis on developing destruction technologies for CFCs (Chemical Product Council, 1989). On March 20, 1989, Japan established the Destruction Technology Subcommittee, under the Ozone Protection Committee of the Chemical Substances Council [an advisory group to the Ministry of International Trade and Industry (MITI)]. A preliminary report has been issued which describes five alternative generic destruction techniques:

Technique	Developer
Thermal plane reaction	National Research Institute for Pollution and Resources
Catalytic method	National Research Institute for Pollution and Resources
Efficient incineration	National Chemical Laboratory for Industry
Reactive destruction by sodium naphthalenide method	Kyoto Institute of Technology
Destruction of CFCs using supercritical water	National Chemical Laboratory for Industry

According to the terms of the Protocol, destruction can be used as a credit against production. The Japanese are pursuing destruction techniques in order to maximize this credit and therefore have more CFCs for domestic consumption and export. There may also be a market for destruction technology; particularly if one, or a small set, of techniques become formally sanctioned methods of destruction according to the terms of the Protocol.

3.3 CANADA

Canada was host to the diplomatic signing of the Montreal Protocol in September 1987. There are similarities to the United States in both federal regulations and in the local responses. However, use of the regulated substances differs between the two countries.

3.3.1 Canadian Regulations

As a first step towards implementation of the Montreal Protocol, Canada has taken measures similar to other countries by freezing production and consumption at 1986 levels. However, Canada has since made it national policy to go beyond the terms of the Protocol (Environment Canada 1989). The Minister of the Environment for Canada announced, on February 20, 1989, an objective to totally eliminate controlled CFCs within 10 years. A further call was made for all countries to reduce usage to no more than 15% of 1986 levels by 1999.

Canada has proposed a number of specific end-use restrictions. Among these are bans on aerosol uses, except for certain medical applications and industrial uses where alternatives are not available and where flammability is of particular concern. Also banned would be the use of CFCs to produce food and beverage containers and the use of halons for small portable fire extinguishers. These proposed bans are scheduled to take effect on January 1, 1990 (Environment Canada 1989).

As in the United States, there are non-federal government actions to reduce or ban CFC use. In February of this year, the province of Ontario announced its intention to ban all products destructive to the ozone layer. The ban will be instituted in stages, beginning with elimination of aerosol (except prescription drugs) and packaging uses on July 1, 1989. Likewise, the Province of British Columbia has announced an intent to issue a ban on certain uses (not specified).

3.3.2 Use of Controlled Substances

Canada's use of CFCs by application is detailed in Table 3.4. As can be seen from this table, refrigeration (36.1%) represents the number one use of CFCs in Canada followed closely by rigid foams (33.2%). Flexible foam production, solvents, and aerosol uses are about equal in consumption of CFCs.

TABLE 3.4. CFC Usage in Canada

	Total Estimated Usage (Kilotonnes)	Percent of Total Usage
Refrigeration	7.5	36.1
Rigid Foams	6.9	33.2
Flexible Foams	1.7	8.2
Aerosol Products	1.9	9.1
Solvents	2.0	9.6
Other	0.8	3.8
Total	20.8	100.0

Source: Fontaine and Fletcher 1988.

3.4 THE SOVIET UNION

The Soviet Union (USSR) is a party to the Protocol, as are the individual Republics of Byelorussia and the Ukraine. Due to the closed nature of Communist economies, it is difficult to obtain data on CFC production and use.

Although not current, some data are available (see Table 3.5). As can be seen from this table, the USSR was a significant producer and consumer of CFCs in 1975. The USSR experienced a rapid growth in production and consumption of CFC-11 and CFC-12 in the early 1970s (CMA 1988). Use of these chemicals in the USSR is likely greater today.

Approximately half the usage of CFCs listed in Table 3.5 is as an aerosol propellant. Not included in Table 3.5 are other CFCs such as CFC-113. If CFC-113 usage in the United States is any indication, use of CFC-113 in the USSR for military electronic needs may be very large. There is also the possibility that the USSR relies upon the use of methyl chloroform or carbon tetrachloride for use as a solvent, although the USSR has put forth a proposal to include methyl chloroform on the list of controlled substances.

TABLE 3.5. Estimated Production and Consumption of CFC-11 and CFC-12 in the USSR, 1975 (metric tons)

	CFC-11	CFC-12	Total
Production	7,500	9,800	17,300
Consumption			
Refrigeration			18,290
Foam for Refrigerators			300
Aerosol Propellants			18,240
Other			1,680
Total			38,510

Source: CMA 1989.

3.5 DEVELOPING COUNTRIES

Many developing countries are not parties to the Protocol. Two major examples are the Peoples Republic of China (PRC) and India. It is believed that one of the reasons these countries have not yet signed the Protocol is that they are waiting to see what provisions will be made for assistance to developing countries in moving to the non-CFC technologies.

As mentioned earlier, the Protocol requires developed countries to assist developing countries in seeking "alternative technologies and substitute products" (see Section 2.3.1). Use of CFCs can be broadly associated with a higher standard of living (refrigerators, air conditioners, consumer electronics, etc.). Allowing developing countries to expand use of CFCs is an equity consideration between developed and developing countries. Developing countries, which may not be able to afford non-CFC technologies, will be able to increase production and consumption, at least domestically, of some CFC-using goods.

Several developing countries appear to be moving toward adoption of the Protocol[a]. In February 1989, the Turkish Environmental Directorate

(a) U.S. Department of State. 1989. Reporting Cables. Washington, D.C.

indicated a willingness to sign both the Vienna Convention and the Montreal Protocol. Likewise, the Malaysian Department of Environment is recommending ratification of the Protocol.

There have been individual responses by developing countries which are not yet parties to the Protocol. For instance, on November 21, 1987, Taiwan removed eight CFCs from a list of substances which domestic industries were being encouraged to produce. Although Taiwan does not produce any CFCs currently, Formosa Plastic Company has plans to begin production in 1989.

4.0 TRADE ISSUES

In addition to restricting production and consumption of substances which deplete the ozone layer, the Protocol also potentially restricts trade. There are strong implications for trade even beyond the limits imposed by the Protocol. Billions of dollars worth of products and perhaps hundreds of thousands of jobs depend on the use of CFCs here in the United States (Fay 1988). With the switch to alternatives comes change, and with change, opportunity. However, there is also the possibility of substantial loss of both jobs and market share to foreign competitors should U.S. companies adopt the wrong technology, too fast, too soon--or the right technology too late.

4.1 PROTOCOL TRADE RESTRICTIONS

The Protocol itself contains trade restrictions (Article 4). These trade restrictions apply to import and export of goods from countries not party to the Protocol. An exception is made for countries in compliance with major provisions of the Protocol (specifically Articles 2 and 7).

Within 1 year of entry into force of the Protocol, (i.e., January 1, 1990) all parties are to ban import of the controlled substances from any State not party to the Protocol. Furthermore, exports of controlled substances to non-participating countries are banned beginning January 1, 1993.

The trade restrictions are not limited to the ozone-depleting substances themselves. Within 3 years after the Protocol enters into force, the parties are to adopt a list of goods which "contain" these substances. This list of products would certainly include, but not be limited to, foam-blown plastics, air conditioners, heat pumps, chillers, refrigerators, and freezers (both domestic and commercial). Import, but not export, of these products from non-participating countries would be banned 1 year after the adoption of this list.

Within 5 years after the Protocol enters into force (January 1, 1994), the Parties are to determine the feasibility of banning goods "produced with, but not containing, controlled substances." If feasible, a list of such products will be drawn and agreed upon (according to voting rules of the

Protocol). Examples of such products might include television sets, VCRs, computers and many other electronic devices. Once again, imports from countries not party to the Protocol would be banned.

4.2 TRADE IN CFCs AND HALONS

Several firms produce CFCs and halons in the United States:

Racon	Kaiser Chemicals
Pennwalt Corporation	Allied Signal
DuPont Corporation	Great Lakes Chemical Corporation
ICI Americas	

Not all of these firms are U.S.-owned and -operated, however. For example, Racon has recently been purchased by Atochem, a subsidiary of the French firm Elf Aquitaine. In turn, 58% of Elf Aquitaine is owned by the French government.

Although Racon is the smallest producer of CFCs in the United States, it is an important producer of HCFC-22. HCFC-22 is believed to be a major alternative to fully halogenated CFCs in many applications. Production of HCFC-22 will probably grow substantially over the next several years. Atochem may be positioning itself for growth in the HCFC-22 market. Atochem is looking to use Racon's distribution network for the alternative HCFC-142b. Atochem also will be marketing HFC-134a, HCFC-123, and HCFC-141b in Europe and North America (ACH&R News 1989).

Elf Aquitaine also recently extended an offer to purchase Pennwalt, the third largest domestic producer of CFCs after DuPont and Allied Signal. The proposed purchase of Pennwalt is currently under review by the Federal Trade Commission (FTC). More than half of Pennwalt's outstanding shares have been tendered as a result of Elf Aquitaine's offer (C&EN 5/89).

Other foreign firms are also in the race to introduce alternatives to the fully halogenated CFCs. For instance, the U.K. firm, ICI, has announced plans to construct a plant to produce HFC-134a (WSJ 1988). HFC-134a is an important substitute for CFC-12, particularly in mobile air conditioning.

A Dutch firm, AKZO, has also patented a "drop-in" substitute for CFC-12. The mixture, Demeon 13/87, is a blend of approximately 80 percent CFC-12 and 20 percent dimethyl ether (C&EN 1988). While not a long-term substitute, the mixture would offer a lower ODP and may be used in the interim to service existing equipment.

There have been a number of announcements in Japan. Showa Denko K.K. has developed a mass production process for HFC-134a and plans to be able to produce 5000 tons per year by July 1993 (Nihon Reito 1988). Likewise, Daikin Industries, a major air conditioner manufacturer, is prepared to supply up to 2000 tons per year of HCFC-142b (another CFC-12 substitute). A third firm, Asahi Glass Co., is in the process of developing HCFC-225 as a substitute for CFC-113 in grease-cutting applications in the electronics industry (NTIS 1989).

4.3 TRADE IN GOODS MANUFACTURED USING CFCs and HALONS

In addition to the global competition to find substitutes for the regulated compounds, there is a parallel race to adapt these substitutes to current manufacturing processes and products. Large segments of our economy currently depend on the use of CFCs. The operation of over $100 billion worth of installed equipment relies upon CFCs or suitable alternatives (Fay 1988).

Choosing the right alternative and the right manufacturing technique is critical to the future competitiveness of U.S. manufacturers of these products. There is also the potential outright ban on some CFC-containing products by countries that move faster than Protocol limits. The U.S. government should seek a policy that maximizes protection of the stratospheric ozone but does not place U.S. industry at a comparative disadvantage vis-a-vis its foreign competitors.

5.0 RECOMMENDATIONS

The United States should study foreign countries for lessons that it can apply internally. These lessons include not only methods of regulating CFC and halon production and use, but also means of supporting the transition to safe alternatives. This will require study of foreign regulations, research programs, and institutions that support the development of alternatives. An attempt should also be made to obtain and understand data on the pattern of use of CFCs and halons in foreign countries. Currently, these data are not available from UNEP.

The United States should continue to support international efforts to protect stratospheric ozone. The primary vehicles for this effort are the Vienna Convention and the Montreal Protocol. (The Montreal Protocol is included as Appendix C to this document.) By playing an active role in international negotiations, the United States can help shape future global responses to stratospheric ozone depletion. These responses should maximize protection but should not be overly burdensome to the U.S. economy, particularly in relation to foreign competitors.

The United States should support cooperative R&D and exchange of information. Mechanisms are already in place for cooperative R&D. One example is the International Energy Agency (IEA), which has cooperative research programs in alternative working fluids in heat pumps. IEA membership, however, is not broad enough to include many of the parties to the Protocol.

The United States should also seek to fulfill its commitment to developing countries in the transition to alternative technologies. Modalities already exist for providing assistance to developing countries [e.g., U.S. Agency for International Development (AID), World Bank, United Nations]. However, this is still a point for discussion among the parties.

6.0 REFERENCES

Air Conditioning and Refrigeration Institute (ARI)/Japanese Refrigeration Air Conditioning Industrial Association (JRAIA) Forum. Fall 1988. Chicago, Illinois.

Chemical and Engineering News (C&EN). July 18, 1988. "Akzo Offers Chlorofluorocarbon Alternative." Chemical and Engineering News.

Chemical and Engineering News (C&EN). March 6, 1989. "Arctic Ozone Loss: Fact-Finding Mission Concludes Outlook is Bleak." Chemical and Engineering News, pp. 29-31.

Chemical and Engineering News (C&EN). April 24, 1989. "Europe to Reduce CFCs in Urethane Foams." Chemical and Engineering News p. 14.

Chemical and Engineering News (C&EN). May 22, 1989. "Elf Aquitaine Extends Pennwalt Offer." Chemical and Engineering News, p. 21.

Chemical Product Council. April 1989. "Destruction Technologies of CFCs (Interim Report)." Ozone Layer Protection Committee, Destruction Technology Subcommittee, CFCs Policy Office, Basic Industries Bureau, Ministry of Trade and Industry, Japan.

Chemical Manufacturers Association (CMA). 1988. Production, Sales, and Calculated Release of CFC-11 and CFC-12 Through 1987. Chemical Manufacturers Association, Washington, D.C.

Chemical Product Council. April 1989. "Destruction Technologies of CFCs (Interim Report)." Ozone Layer Protection Committee, Destruction Technology Subcommittee, CFCs Policy Office, Basic Industries Bureau, MITI, Japan.

Council of the European Communities (CEC). October 14, 1988a. "Certain Chlorofluorocarbons and Halons Which Deplete the Ozone Layer." Regulation 3322/88, Official Journal of the European Communities, 31(L297), October 31, 1988.

Council of the European Communities (CEC). October 14, 1988b. "Council Decision of October 14, 1988 Concerning the Conclusion of the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer." Decision 88/540/EEC, Official Journal of the European Communities, 31(L297), October 31, 1988.

Council of the European Communities (CEC). October 14, 1988c. "Council Resolution of October 14, 1988 for the Limitation of Use of Chlorofluorocarbons and Halons." Resolution 88/C 285/01, Official Journal of the European Communities, 1:C285, November 11, 1989.

Council of the European Communities (CEC). February 21, 1989. "Chlorofluorocarbons 11 and 12: Production and Sales Within and Outside the EEC." METRA Consulting Group Limited, Brussels, Belgium.

Council of the European Communities (CEC). April 7, 1989. Conclusion. Brussels, Belgium

Environment Agency, Government of Japan. March 10, 1988. "Ozone Layer Protection in Japan." Japan Environment Summary 16(3).

Environment Canada. April 1989. "Preserving the Ozone Layer: A Step Beyond." Cat. No. EN40-374/1989E, Commercial Chemicals Branch, Ottawa, Ontario.

Farman, J. C., B. G. Garner, and J. D. Shaklin. May 16, 1985. "Large Losses of Total Ozone in Antarctica Reveal Seasonal ClOx/NOx." Nature Vol. 315.

Fay, K. 1988, "Chlorofluorocarbons: The Case for Responsible Policy." Alliance for Responsible CFC Policy, Rosslyn, Virginia.

Fontaine P., and D. Fletcher. 1988. Commercial Analysis of Chlorofluorocarbon Applications in Canada. 6541/90/DF/6deb, Stevenson, Kellog, Ernst, and Whitney, Management Consultants for Commercial Chemicals Branch, Environment Canada, Dttawa, Ontario.

Halogenated Solvents Industry Alliance (HSIA). June 1987. 1,1,1,-Trichloroethane White Paper. Halogenated Solvents Industry Alliance, Washington, D.C.

Hammitt, J. K., K. A. Wolf, F. Camm, W. E. Mooz, T. H. Quinn, and A. Bameza. 1985. "Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985-2000." R-3386-EPA, Rand Corporation, Santa Monica, California.

National Technical Information Service (NTIS). April 11, 1989. "CFC-Substitute Development Underway in Japanese Firms." Foreign Broadcast Information Source (FBIS), JPRS-JST-89. National Technical Information Service, Springfield, Virginia.

Nihon Reito Reibo Shinbun (Japan Air Conditioning and Refrigeration News, in Japanese). June 23, 1988. "Technology Established for Mass Production of CFC Substitute."

Ozone Trends Panel, Draft. 1988. Executive Summary. NASA, Washington, D.C.

Roland, F. S., and M. J. Molina. 1975. "Chlorofluoromethanes in the Environment." Review of Geophys. Space Phys. 13:1-36.

Shell, E. R. February 1988. "Solo Flights into the Ozone Hole Reveal Its Causes." Smithsonian pp. 142-155.

Stolarski, R. S. January 1988. "The Antarctic Ozone Hole." Scientific American 258(1).

The Air Conditioning Heating and Refrigeration (ACH&R) News. April 24, 1989. "Elf Aquitaine Unit Purchases Racon." The Air Conditioning Heating and Refrigeration News, p. 1.

U.S. Congress, Office of Technology Assessment (OTA). December 10, 1987 (revised February 1, 1988). "An Analysis of the Montreal Protocol on Substances that Deplete the Ozone Layer." Office of Technology Assessment, Washington, D.C.

Vienna Convention. October 15, 1987. The Montreal Protocol on Substances that Deplete the Ozone Layer. United Nations Environmental Program, New York.

Vienna Convention. March 22, 1985. Final Act of the Vienna Convention for the Protection of the Ozone Layer. United Nations Environmental Program, New York.

Wall Street Journal. November 23, 1988. "U.S. Unit to Build Plant for Refrigerant Substitute." Wall Street Journal, p. 83.

World Meteorological Organization (WMO). 1985. Atmospheric Ozone, 1985. Report No. 16, Global Ozone Research and Monitoring Project, World Meteorological Organization, Case Postale No. 5, CH 1211 Geneva 20, Switzerland.

APPENDIX A

PARTICIPANTS IN VIENNA CONVENTION AND MONTREAL PROTOCOL (as of June 1, 1989)

APPENDIX A

PARTICIPANTS IN VIENNA CONVENTION AND MONTREAL PROTOCOL (as of June 1, 1989)[a]

	Vienna Convention		Montreal Protocol	
	Signed	Party	Signed	Party
Argentina	5/85	--	6/88	--
Australia	--	9/87	6/88	5/89
Austria	9/85	8/87	8/88	5/89
Belgium	5/85	10/88	9/87	12/88
Burkina Faso (formerly Upper Volta)	12/85	3/89	9/88	--
Byelorussian Soviet Socialist Republic	5/85	6/86	1/88	10/88
Canada	5/85	6/86	9/87	6/88
Chad	--	5/89	--	--
Chile	5/85	--	6/88	--
Congo	--	--	9/88	--
Denmark	5/85	9/88	9/87	12/88
Egypt	5/85	5/88	9/87	8/88
Equatorial Guinea	--	8/88	--	--
European Economic Community	5/85	10/88	9/87	12/88
Finland	5/85	9/86	9/87	12/88
France	5/85	12/87	9/87	12/88
Germany, Democratic Republic of	--	1/89	--	1/89
Germany, Federal Republic of	5/85	9/88	9/87	12/88
Ghana	--	--	9/87	3/89[b]
Greece	5/85	12/88	10/87	12/88
Guatemala	--	9/87	--	--
Hungary	--	5/89	--	4/89
Indonesia	--	--	7/88	--
Ireland	--	9/88	9/88	12/88
Israel	--	--	1/88	--
Italy	5/85	9/88	9/87	12/88
Japan	--	9/88	9/87	9/88
Jordan	--	5/89	5/89	5/89
Kenya	--	11/88	9/87	11/88
Liechtenstein	--	2/89	--	2/89
Luxembourg	5/85	10/88	1/88	10/88
Maldives	--	4/88	7/88	5/89
Malta	--	9/88	9/88	12/88
Mexico	4/85	9/87	9/87	3/88
Morocco	2/86	--	1/88	--
Netherlands	3/85	9/88	9/87	12/88
New Zealand	3/86	6/87	9/87	7/88
Nigeria	--	10/88	--	10/88
Norway	5/85	9/86	9/87	6/88

	Vienna Convention		Montreal Protocol	
	Signed	Party	Signed	Party
Panama	--	2/89	9/87	3/89
Peru	5/85	4/89	--	--
Philippines	--	--	9/88	--
Portugal	--	10/88	9/87	10/88
Senegal	--	--	9/87	--
Singapore	--	1/89	--	1/89
Spain	--	7/88	7/88	12/88
Sweden	5/85	11/86	9/87	6/88
Switzerland	5/85	12/87	9/87	12/88
Thailand	--	--	9/88	--
Togo	--	--	9/87	--
Uganda	--	6/88	9/88	9/88
Ukrainian Soviet Socialist Republic	5/85	6/86	2/88	9/88
Union of Soviet Socialist Republics	5/85	6/86	12/87	11/88
United States of America	5/85	8/86	9/87	4/88
United Kingdom	5/87	5/87	9/87	12/88
Uruguay	--	2/89	--	--
Venezuela	--	9/88	9/87	2/89
Total		46		41

(a) The first step in becoming a party to either the Convention or the Protocol is to sign the document. In most countries, this signature (willingness to participate) has to be formally ratified. In the United States, this requires a two-thirds majority of the Senate and the signature of the President. Terms used in other countries which are essentially equivalent to ratification are: acceptance, approval, or accession. It can be assumed that countries which are parties to either the Convention or the Protocol have also signed the document, although that specific information was not available in some cases.

(b) Ghana's participation in the Montreal Protocol is in temporary abeyance.

APPENDIX B

DRAFT DECLARATION

APPENDIX B

DRAFT DECLARATION

The Governments and the EEC represented at the First Meetings of the Parties to the Vienna Convention and the Montreal Protocol

- Aware of the wide agreement among scientists that depletion of the ozone layer will threaten present and future generations unless more stringent control measures are adopted;

- Mindful that some ozone depleting substances are powerful greenhouse gases leading to global warming;

- Aware also of the extensive and rapid technological development of environmentally acceptable substitutes for the substances that deplete the ozone layer and the urgent need to facilitate the transfer of technologies of such substitutes especially to developing countries;

  - Encourage all states that have not done so to join the Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol

  - Agree to phase out the production and the consumption of CFCs controlled by the Montreal Protocol as soon as possible but not later than the year 2000 and for that purpose to tighten the timetable agreed upon in the Montreal Protocol (due account taken of the special situation of developing countries)

  - Agree to both phase out halons and control and reduce other ozone-depleting substances which contribute significantly to ozone depletion as soon as feasible

  - Agree to commit themselves in proportion to their means and resources to accelerate the development of environmentally acceptable substituting chemicals, products and technologies

  - Agree to facilitate the access of developing countries to relevant scientific information, research results and training and to seek to develop appropriate funding mechanisms to facilitate the transfer of technology and replacement of equipment at minimum cost to developing countries.

APPENDIX C

MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, 1987

APPENDIX C

MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, 1987

The parties to this Protocol,

Being Parties to the Vienna Convention for the Protection of the Ozone Layer,

Mindful of their obligation under that Convention to take appropriate measures to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer,

Recognizing that world-wide emission of certain substances can significantly deplete and otherwise modify the ozone layer in a manner that is likely to result in adverse effects on human health and the environment,

Conscious of the potential climatic effects of emissions of these substances,

Aware that measures taken to protect the ozone layer from depletion should be based on relevant scientific knowledge, taking into account technical and economic considerations,

Determined to protect the ozone layer by taking precautionary measures to control equitably total global emissions of substances that deplete it, with the ultimate objective of their elimination on the basis of developments in scientific knowledge, taking into account technical and economic considerations,

Acknowledging that special provision is required to meet the needs of developing countries for these substances,

Noting the precautionary measures for controlling emissions of certain chlorofluorocarbons that have already been taken at national and regional levels,

Considering the importance of promoting international co-operation in the research and development of science and technology relating to the control and reduction of emission of substances that deplete the ozone layer, bearing in mind in particular the needs of developing countries,

HAVE AGREED AS FOLLOWS:

ARTICLE 1: DEFINITIONS

For the purposes of this Protocol:

1. "Convention" means the Vienna Convention for the Protection of the Ozone Layer, adopted on 22 March 1989,

2. "parties" means, unless the text otherwise indicates, parties to this Protocol,

3. "Secretariat" means the Secretariat of the Convention,

4. "Controlled substance" means a substance listed in Annex A to this Protocol, whether existing alone or in a mixture. It excludes, however, any such substance or mixture which is in a manufactured product other than a container used for the transportation or storage of the substance listed,

5. "Production" means the amount of controlled substances produced minus the amount destroyed by technologies to be approved by the parties,

6. "Consumption" means production plus imports minus exports of controlled substances,

7. "Calculated levels" of production, imports, exports and consumption means levels determined in accordance with Article 3,

8. "Industrial rationalization" means the transfer of all or a portion of the calculated level of production of one party to another, for the purpose of achieving economic efficiencies or responding to anticipated shortfalls in supply as a result of plant closures,

ARTICLE 2: CONTROL MEASURES

1. Each party shall ensure that for the twelve-month period commencing on the first day of the seventh month following the date of the entry into force of this Protocol, and in each twelve-month period thereafter, its calculated level of consumption of the controlled substances in Group 1 of Annex A does not exceed its calculated level of consumption in 1986. By the end of the same period, each party producing one or more of these substances shall ensure that its calculated level of production of the substances does not exceed its calculated level of production in 1986, except that such level may have increased by no more than ten per cent based on the 1986 level. Such increase shall be permitted only so as to satisfy the basic domestic needs of the parties operating under Article a and for the purposes of industrial rationalization between parties.

2. Each party shall ensure that for the twelve-month period commencing on the first day of the thirty-seventh month following the date of the entry into force of this Protocol, and in each twelve month period thereafter, its calculated level of consumption of the controlled substances listed in Group II of Annex A does not exceed its calculated level of consumption in 1986. Each Party producing one or more of these substances shall ensure that its calculated level of production of the substances does not exceed its calculated level of production in 1986, except that such level may have increased by no more than ten per cent based on the 1986 level. Such increase shall be permitted only so as to satisfy the basic domestic needs of the parties operating under Article 5 and for the purposes of industrial rationalization between parties. The mechanisms for implementing these measures shall be decided by the parties at their first meeting following the first scientific review.

3. Each party shall ensure that for the period 1 July 1993 to 30 June 1994 and in each twelve-month period thereafter, its calculated level of consumption of the controlled substances in Group I of Annex A does not exceed, annually, eighty per cent of its calculated level of consumption in 1986. Each party producing one or more of these substances shall, for the same periods, ensure that its calculated level of production of the substances does not exceed, annually, eighty per cent of its calculated level of production in 1986. However, in order to satisfy the basic domestic needs of the parties operating under Article 5 and for the purposes of industrial rationalization between parties, its calculated level of production may exceed that limit by up to ten per cent of its calculated level of production in 1986.

4. Each Party shall ensure that for the period 1 July 1998 to 30 June 1999, and in each twelve-month period thereafter, its calculated level of consumption of the controlled substances in Group 1 of Annex A does not exceed, annually, fifty per cent of its calculated level of consumption in 1986, Each party producing one or more of these substances shall, for the same periods, ensure that its calculated level of production of the substances does not exceed, annually, eighty per cent of its calculated level of production in 1986. However, in order to satisfy the basic domestic needs of the parties

operating under Article 5 and for the purposed of industrial rationalization between parties, its calculated level of production may exceed that limit by up to fifteen per cent of its calculated level of production in 1986. This paragraph will apply unless the parties decide otherwise at a meeting by a two-thirds majority of parties present and voting, representing at least two-thirds of the total calculated level of consumption of these substances of the parties. This decision shall be considered and made in the light of the assessments referred to in Article 6.

5. Any party whose calculated level of production in 1986 of the controlled substances in Group I of Annex A was less than twenty-five kilotonnes may, for the purposes of industrial rationalization, transfer to or receive from any other party, production in excess of the limits set out in paragraphs 1, 3 and a provided that the total combined calculated levels of production of the Parties concerned does not exceed the production limits set out in this Article. Any transfer of such production shall be notified to the secretariat, no later than the time of the transfer.

6. Any party not operating under Article a, that has facilities for the production of controlled substances under construction, or contracted for, prior to 16 September 1987, and provided for in national legislation prior to 1 January 1987, may add the production from such facilities to its 1986 production of such substances for the purposes of determining its calculated level of production for 1986, provided that such facilities are completed by 31 December 1990 and that such production does not raise that party's annual calculated level of consumption of the controlled substances above 0,5 kilograms per capita.

7. Any transfer of production pursuant to paragraph 5 or any addition of production pursuant to paragraph 6 shall be notified to the secretariat, no later than the time of the transfer or addition.

8. (a) Any parties which are Member states of a regional economic integration organization as defined in Article 1(6) of the Convention may agree that they shall jointly fulfil their obligations respecting consumption under this Article provided that their total combined calculated level of consumption does not exceed the levels required by this Article.

   (b) The parties to any such agreement shall inform the secretariat of the terms of the agreement before the date of the reduction in consumption with which the agreement is concerned.

   (c) Such agreement will become operative only if all Member states of the regional economic integration organization and the organization concerned are Parties to the Protocol and have notified the secretariat of their manner of implementation.

9. (a) Based on the assessments made pursuant to Article 6, the parties may decide whether:

(i) adjustments to the ozone depleting potentials pacified in Annex A should be made and, if so, what the adjustments should be; and

(ii) further adjustments and reduction of production or consumption of the controlled substances from 1986 levels should be undertaken and,if so, what the scope, amount and timing of any such adjustments and reductions should be.

(b) Proposals for such adjustments shall be communicated to the parties by the secretariat at least six months before the meeting of the parties at which they are proposed for adoption.

(c) In taking such decisions, the parties shall awake every effort to reach agreement by consensus. If all efforts at consensus have been exhausted, and no agreement reached, such decisions shall, as a last resort, be adopted by a two-thirds majority vote of the Parties present and voting representing at least fifty per cent of the total consumption of the controlled substances of the parties.

(d) The decisions, which shall be binding on all parties, shall forthwith be communicated to the parties by the Depositary. unless otherwise provided in the decisions, they shall enter into force on the expiry of Six months from the date of the circulation of the communication by the Depositary.

10. (a) Based on the assessments made pursuant to Article 6 of this Protocol and in accordance with the procedure at out in Article 9 of the Convention, the parties may decide:

(i) whether any substances, and if so which, should be added to or removed from any annex to this Protocol; and

(ii) the mechanism, scope and timing of the control measures that should apply to those substances;

(b) Any such decision shall become effective, provided that it has been accepted by a two-thirds majority vote of the parties present and voting.

11. Notwithstanding the provisions contained in this Article, Parties may take more stringent measures than those required by this Article.

ARTICLE 3: CALCULATION OF CONTROL LEVELS

For the purposes of Articles 2 and a, each Party shall, for each Group of substances in Annex A, determine its calculated levels of:

(a) production by:

(i) multiplying its annual production of each controlled substance by the ozone depleting potential specified in respect of it in Annex A; and

(ii) adding together, for each such Group, the resulting figures;

(b) imports and exports, respectively, by following, mutatis mutandis,the procedure set out in subparagraph (a); and

(c) consumption by adding together its calculated levels of production and imports and subtracting its calculated level of exports as determined in accordance with subparagraphs (a) and (b). However, beginning on 1 January 1993, any export of controlled substances to non-parties shall not be subtracted in calculating the consumption level of the exporting party.

ARTICLE 4: CONTROL OF TRADE WITH NON-PARTIES

1. Within one year of the entry into force of this Protocol, each Party shall ban the import of controlled substances from any State not party to this Protocol.

2. Beginning on 1 January 1993, no party operating under paragraph 1 of Article 5 may export any controlled substance to any state not party to this Protocol.

3. Within three years of the date of the entry into force of t.his Protocol, the parties shall, following the procedures in Article 10 of the Convention, elaborate in an annex a list of products containing controlled substances. Parties that have not objected to the annex in accordance with those procedures shall ban, within one year of the annex having become effective, the import of those products from any State not party to this Protocol.

4. Within five years of the entry into force of thís Protocol, the Parties shall determine the feasibility of banning or restricting, from States not party to this Protocol, the import of products produced with, but not containing, controlled substances. If determined feasible, the parties shall, following the procedures in Article 10 of the Convention, elaborate in an annex a list of such products. Parties that have not objected to it ia accordance with those procedures shall ban or restrict, within one year of

the annex having become effective, the import of those products from any state not party to this Protocol.

5. Each Party shall discourage the export, to any state not party to this Protocol, of technology for producing and for utilizing controlled substances.

6. Each party shall refrain from providing new Subsidies, aid, credits, guarantees or insurance programmes for the export to states not party to this Protocol of products, equipment, plants or technology that would facilitate the production of controlled substances.

7. Paragraphs 5 and 6 shall not apply to products, equipment, plants or technology that improve the containment, recovery, recycling or destruction of controlled substances, promote the development of alternative substances, or otherwise contribute to the reduction of emissions of controlled substances.

8. Notwithstanding the provisions of this Article, imports referred to in paragraphs 1, 3 and 4 may be permitted from any state not party to this Protocol if that state is determined, by a meeting of the parties, to be in full compliance with Article Z and this Article, and has submitted data to that effect as specified in Article 7.

ARTICLE 5: SPECIAL SITUATION OF DEVELOPING COUNTRIES

1. Any party that is a developing country and whose annual calculated level of consumption of the controlled substances is less than 0.3 kilograms per capita on the date of the entry into force of the Protocol for it, or any time thereafter within ten years of the date of entry into force of the Protocol shall, in order to meet its basic domestic needs, be entitled to delay its compliance with the control measures set out in paragraphs 1 to 4 of Article 2 by ten years after that specified in those paragraphs. However, such Party shall not exceed an annual calculated level of consumption of 0.3 kilograms per capita. Any such party shall be entitled to use either the average of its annual calculated level of consumption for the period 1995 to 1997 inclusive or a calculated level of consumption of 0.3 kilograms per capita, whichever is the lower, as the basis for its compliance with the control measures.

2. The Parties undertake to facilitate access to environmentally safe alternative substances and technology for parties that are developing countries and assist them to make expeditious use of such alternatives.

3. The Parties undertake to facilitate bilaterally or multilaterally the provision of subsidies, aid, credits, guarantees or insurance programmes to Parties that are developing countries for the use of alternative technology and for substitute products.

ARTICLE 6: ASSESSMENT AND REVIEW OF CONTROL MEASURES

Beginning in 1990, and at least every four years thereafter, the parties shall assess the control measures provided for in Article Z on the basis of available scientific, environmental, technical and economic information. At least one year before each assessment, the parties shall convene appropriate panels of experts qualified in the fields mentioned and determine the computation and terms of reference of any such panels. Within one year of being convened, the panels will report their conclusions, through the secretariat, to the Parties.

ARTICLE 7 : REPORTING OF DATA

1. Each Party shall provide to the secretariat, within three months of becoming a party, statistical data on its production, imports and exports of each of the controlled substances for the year 1986, or the best possible estimates of such data where actual data are now available.

2. Each party shall provide statistical data to the secretariat on its annual production (with separate data on amounts destroyed by technologies to be approved by the parties), imports, and exports to parties and non-parties, respectively, of such substances for the year during which it becomes a party and for each year thereafter. It shall forward the data no later than nine months after the end of the year to which the data relate.

ARTICLE 8: NON-COMPLIANCE

The parties, at their first meeting, shall consider and approve procedures and institutional mechanisms for determining non-compliance with the provisions of this Protocol and for treatment of Parties found to be in non-compliance.

ARTICLE 9: RESEARCH, DEVELOPMENT, PUBLIC AWARENESS AND EXCHANGE OF INFORMATION

1. The Parties shall co-operate, consistent with their national laws, regulations and practices and taking into account in particular the needs of developing countries, in promoting, directly or through competent international bodies, research, development and exchange of information on:

(a) best technologies for improving the containment, recovery, recycling or destruction of controlled substances or otherwise reducing their emissions;

(b) possible alternatives to controlled substances, to products

containing such substances, and to products manufactured with them; and

(c) costs and benefits of relevant control strategies.

2. The Parties, individually, jointly or through competent international bodies, shall co-operate in promoting public awareness of the environmental effects of the emissions of controlled substances and other substances that deplete the ozone layer.

3. Within two years of the entry into force of this Protocol and every two years thereafter, each party shall submit to the secretariat a summary of the activities it has conducted pursuant to this Article.

ARTICLE 10: TECHNICAL ASSISTANCE

1. The Parties shall, in the context of the provisions of Article 4 of the Convention, and taking into account in particular the needs of developing countries, co-operate in promoting technical assistance to facilitate participation in and implementation of this Protocol.

2. Any Party or Signatory to this Protocol may submit a request to the secretariat for technical assistance for the proposal of implementing or participating in the Protocol.

3. The Parties, at their first meeting, shall begin deliberations on the means of fulfilling the obligations see out in Article 9, and paragraphs 1 and 2 of this Article, including the preparation of workplans. Such work-plans shall pay special attention to the needs and circumstances of the developing countries. States and regional economic integration organizations not party to the Protocol should be encouraged to participate in activities specified in such workplans.

ARTICLE 11 : MEETINGS OF THE PARTIES

1. The parties shall hold meetings at regular intervals. The secretariat shall convene the first meeting of the Parties not later than one year after the date of the entry into force of this Protocol and in conjunction with a meeting of the Conference of the Parties to the Convention, if a meeting of the latter is scheduled within that period.

2. Subsequent ordinary meetings of the Parties shall be held, unless the Parties otherwise decide, in conjunction with meetings of the Conference of the Parties to the Convention. Extraordinary meetings of the Parties shall be held at such other times as may be deemed necessary by a meeting of the parties, or at the written request of any party, provided that, within six months of such a request being communicated to them by the secretariat, it is

supported by at least one third of the Parties.

3. The parties, at their first meeting, shall:

(a) adopt by consensus rules of procedure for their meetings;

(b) adopt by consensus the financial rules referred to in paragraph 2 of Article 13;

(c) establish the panels and determine the terms of reference referred to in Article 6;

(d) consider and approve the procedures and institutional mechanisms specified in Article 8; and

(e) begin preparation of workplans pursuant to paragraph 3 of Article 10.

4. The functions of the meetings of the parties shall be to:

(a) review the implementation of this Protocol;

(b) decide on any adjustments or reductions referred to in paragraph 9 of Article 2;

(c) decide on any addition to, insertion in or removal from any annex of substances and on related control measures in accordance with paragraph 10 of Article 2;

(d) notify the parties of any request for technical assistance received pursuant to Article 10 so as to facilitate the provision of such assistance;

(e) encourage non-Parties to attend the meetings of the parties as observers and to act in accordance with the provisions of this Protocol;

(f) provide, as appropriate, the information and requests referred to in subparagraphs (c) and (d) to such non-party observers; and

(g) perform such other functions for the achievement of the purposes of this Protocol as may be assigned to it by the parties.

ARTICLE 13: FINANCIAL PROVISIONS

1. The funds required for the operation of this Protocol, including those for the functioning of the secretariat related to this Protocol, shall be charged exclusively against contributions from the parties.

2. The Parties, at their first meeting, shall adopt by consensus financial rules for the operation of this Protocol.

ARTICLE 14: RELATIONSHIP OF THIS PROTOCOL TO THE CONVENTION

Except as otherwise provided in this Protocol, the provisions of the Convention relating to its protocols shall apply to this Protocol.

ARTICLE 15: SIGNATURE

This Protocol shall be open for signature by States and by regional economic integration organizations in Montreal on 16 September 1987, in Ottawa from 17 September 1987 to 16 January 1988, and at United Nations Headquarters in New York from 17 January 1988 to 15 September 1988.

ARTICLE 16: ENTRY INTO FORCE

1. This Protocol shall enter into force on 1 January 1989, provided that at least eleven instruments of ratification, acceptance, approval of the Protocol or accession thereto have been deposited by states or regional economic integration organizations representing at least two-thirds of 1986 estimated global consumption of the controlled substances, and the provisions of paragraph 1 of Article 17 of the Convention have been fulfilled. In the event that these conditions have not been fulfilled by that date, the Protocol shall enter into force on the ninetieth day following the date on which the conditions have been fulfilled.

2. For the purposes of paragraph 1, any such instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by number states of such organization.

3. After the entry into force of this Protocol, any State or regional economic integration organization shall become a party to it on the ninetieth day following the date of deposit of its instrument of ratification, acceptance, approval or accession.

ARTICLE 17 : PARTIES JOINING AFTER ENTRY INTO FORCE

Subject to Article 5, any state or regional economic integration organization which becomes a party to this Protocol after the date of its entry into force, shall fulfil forthwith the sum of the obligations under Article 2, as well as under Article 4, that apply at that date to the states and regional economic integration organization that became parties on the date the Protocol entered into force.

ARTICLE 18: RESERVATIONS

No reservations may be made to this Protocol.

ARTICLE 19: WITHDRAWAL

For the purposes of this Protocol, the provisions of Article 19 of the Convention relating to withdrawal shall apply, except with respect to parties referred to in paragraph 1 of Article a. Any such Party may withdraw from this Protocol by giving written notification to the Depositary at any time after four years of assuming the obligations specified in paragraphs 1 to 4 of Article 2. Any such withdrawal shall take effect upon expiry of one year after the date of its receipt by the Depositary, or on such later date as may be specified in the notification of the withdrawal.

ARTICLE 20: AUTHENTIC TEXTS

The original of this Protocol, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

IN WITNESS WHEREOF THE UNDERSIGNED, BEING DULY AUTHORIZED TO THAT EFFECT, HAVE SIGNED THIS PROTOCOL.

DONE AT MONTREAL THIS SIXTEENTH DAY OF SEPTEMBER, ONE THOUSAND NINE HUNDRED AND EIGHTY SEVEN

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ANNEX A

CONTROLLED SUBSTANCES

Group	Substance		Ozone Depleting Potential *
Group I			
	$CFCl_3$	(CFC-11)	1.0
	CF_2Cl_2	(CFC-12)	1.0
	$C_2F_3Cl_3$	(CFC-113)	0.8
	$C_2F_4Cl_2$	(CFC-114)	1.0
	C_2F_5Cl	(CFC-115)	0.6
Group II	CF_2BrCl	(halon-1211)	3.0
	CF_3Br	(halon-1301)	10.0
	$C_2F_4Br_2$	(halon-2402)	(to be determined)

* These ozone-depleting potentials are estimates based on existing knowledge and will be reviewed and revised periodically.

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