



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

20991

Distr.
LIMITED

ISED.1(SPEC.)
2 February 1994

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ORIGINAL: ENGLISH

ALTERNATIVE ODS-FREE TECHNOLOGIES APPLICABLE TO
SMALL AND MEDIUM SIZE METAL/PRECISION
CLEANING INDUSTRIAL UNITS*

Prepared by

Dr. Husamuddin Ahmadzai**

* The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

** Based on the work of Dr. Husamuddin Ahmadzai, Technology Dr., C.E., Mensa Milieu, Solna, Sweden.

**ALTERNATIVE ODS-FREE TECHNOLOGIES APPLICABLE
TO SMALL AND MEDIUM SIZE METAL/PRECISION CLEANING
INDUSTRIAL UNITS**

CONTENTS	PAGE
1. Introduction	1
2. Requirement of the Montreal Protocol Against Ozone Depleting Substance Use in Metal/Precision Cleaning Sub-sector	3
3. State of Art ODS-free Technologies	14
4. Phasing-out Problems Related to Small and Medium Size Industrial Units	33
5. Cost of Phasing-out	34
6. Methodology of Transfer to ODS-free Processes in Relation to Small and Medium Size Enterprises	41
7. Training Needs	43
8. References	44
Appendix 1 Status of ratification of the Montreal Protocol and list of countries eligible for funding	
Appendix 2 CFC trade names and CFC-113 content of selected products	
Appendix 3 1,1,1-trichloroethane trade names and content of selected products	
Appendix 4 Sources of information on the Montreal Protocol	
Appendix 5 Contact addresses for obtaining funding assistance	
Appendix 6: Guidelines regarding to best available technology for solvent-based cleaning	
I General	
II Design of the cleaning equipment	
III Operation of the cleaning equipment	

1.0 INTRODUCTION

Historically the problem of the depletion of the ozone layer has been in focus since the 70's when the major role played by the CFCs (fully halogenated ChloroFluoroCarbons) in the depletion process was established. Concern for the protection of the ozone layer led to action whereby USA, Canada, along with Sweden and Norway banned the use of CFCs in aerosol applications. Aerosol applications accounted for virtually half of the consumption of CFCs at that time.

The discovery of the ozone hole over the Antarctic in the mid-eighties led to the realization that the problem was more acute than what some previous studies had indicated. Matters were aggravated by the fact that despite the knowledge of the detrimental effect of CFCs on the ozone layer and the ban imposed on aerosols, the global CFC consumption had continued to increase and was in fact greater in 1986 than it had been 10 years ago. The major growth areas were the refrigeration, insulation and foam manufacturing, and the solvent cleaning sectors.

In 1987 the Montreal Protocol was signed whereby a 50% reduction of CFCs by 1998 was prescribed. The use of Halons was to be frozen at the 1986 year level.

The scientific community, however, warned that the stipulated measures were insufficient to mitigate the damage to the ozone layer. A depletion of the ozone layer had been detected outside the polar regions. The rate of degradation of the ozone layer is estimated to be around 1% per 10 years. During the winter, the degradation over the northern latitudes is much greater. Above Northern Europe, the decrease is estimated to be about 3-5% per 10 years during the winter months.

Due to continuous depletion of the ozone layer, it is evident that further actions must be taken internationally in order to minimize the damage to the stratosphere. A decision has now been made within the context of the Montreal Protocol to the phase-out of ODS (CFCs and 1,1,1-trichloroethane) by the year 1997 in the developed countries with a ten year grace for developing countries. A forceful decision on HCFCs has not been successful. However, there are provisions in the Protocol for a revision at least every fourth year.

In light of this, actions taken by individual countries to enable a more rapid phase-out of the ozone depleting substances are essential and welcome. Demonstrated practice that the substitution of ozone depleting substances is possible is a strong argument and an example for industry and governments. Another reason is to promote the development of new technologies.

The list of Ozone Depleting Substances (ODS) that are being addressed under the Montreal Protocol are as follows

- chlorofluorocarbons (CFC), CFC-11, 12, 113, 114, 115 as well as mixtures of these substances.
- Halons 1211, 1301 and 2402
- 1,1,1-trichloroethane (methyl chloroform)
- Carbon tetrachloride (CTC)
- HCFC, HBFC

- Methyl Bromide

Major use of the controlled substances are in:

1. Aerosol manufacturing Sector (CFC, 1,1,1-trichloroethane, HCFC)
2. Sterilization Sector (CFC, HCFC)
3. Packaging Sector (CFC, HCFC)
4. Flexible Foam Sector (CFC)
5. Rigid Foam Sector (CFC, 1,1,1-trichloroethane, HCFC)
6. Extruded polystyrene manufacturing Sector (CFC, HCFC)
7. Refrigeration and Heat exchanger Sector (CFC, HCFC)
8. Solvent cleaning and degreasing including Dry cleaning (CFC, HCFC, 1,1,1-trichloroethane, Carbon tetrachloride (CTC))
9. Fire Suppression Sector (Halons, HBFC, HCFC)
10. Miscellaneous (CFC, 1,1,1-trichloroethane, CTC, HCFC)

The present report describes the various alternatives to CFCs for cleaning and degreasing purposes and presents guidelines for best available technology for cleaning with alternative solvents. The report also addresses the costs for replacing ODS solvents and how to access the Multilateral Fund for assistance to implement alternative technologies.

The intention of the report is to provide guidance to small and medium sized companies, regulators and implementors.

2.0 REQUIREMENT OF THE MONTREAL PROTOCOL AGAINST OZONE DEPLETING SUBSTANCE USE IN METAL/PRECISION CLEANING SUB-SECTOR

2.1 The Montreal Protocol

In September 1987, 24 nations met to negotiate the final text and sign the Montreal Protocol (MP) on Substances that Deplete the Ozone Layer (ODS)(1). The agreed Montreal Protocol, which entered into force on January 1, 1989, limited production of most commonly used ODSs, i.e. ChloroFluoroCarbons (CFCs)s and halons. MP required each party's production of chlorofluorocarbons (CFC-11,-12,-112,-113, -114 and -115) first to be frozen at 1986 levels and ultimately reduced to 50 percent of 1986 levels by 1998. Production of halons 1211, 1301 and 2402 were to be restricted to 1986 levels. The MP called for a freeze in production of halons at 1986 levels beginning in 1992

2.1.1 The London Amendment

Shortly after the 1987 MP was negotiated, new scientific evidence showed that ozone depletion was occurring at rate significantly faster than previously assumed. In June 1990, the Parties to the MP met in London and agreed to MP amendments that required more stringent controls on ODSs included in the original agreement. The London Agreement added further controls on other important ODSs such as carbon tetrachloride (CTC) and 1,1,1-trichloroethane (1,1,1-TCE) also known as methyl chloroform (MC). The aforementioned substances are particularly of significance to the solvents sub-sector. The London Amendment limit production of commonly used CFCs to 50 percent of 1986 levels by 1995 and 15% by 1997. Under the amended agreement, CFCs, halons, and CTC production is to be phased out by the year 2000. 1,1,1-TCE is to be phased out by 2005. The 1990 MP amendment also introduced the concept of transitional substances, such as the hydrochlorofluorocarbons (HCFCs). These are envisaged to be chemical replacement for CFCs and other controlled substances and have a relatively small ozone depletion potential. A nonbinding resolution by the parties calls for a phase-out of hydrochlorofluorocarbons (HCFCs) by the year 2020 if possible but no later than 2040. The London Amendment to the MP entered into force in August 1992. In addition to setting phase-out dates, Article 4 of the London Amendments also include restrictions governing trade with non-Party countries:

- **Import and Export of Controlled Substances.** Paragraphs 1 and 2 mandate that Parties to the MP are required to ban trade in controlled substances with any nation that is not a Party to the Protocol.
- **Products Containing Controlled Substances.** Paragraph 3 requires that Parties prepare a list of products containing controlled substances in Annex A and take steps to ban the import of those products from any State not a Party to the Protocol.
- **Products Produced with Controlled Substances.** Paragraph 4 requires the Parties to examine the feasibility of banning the import from non-Party countries of products produced with but not containing controlled substances.

As of June 1993, 117 countries had ratified the Montreal Protocol (Appendix 1). By 31 July 1993, 65 countries including EEC had ratified the London Amendment of the MP. These countries represent over 95 percent of the world's production of CFCs and halons (2).

2.1.2 The Copenhagen Amendment

Scientific data on depletion of the ozone layer presented to the Parties at their November meeting in Copenhagen revealed that depletion has been occurring at a rate twice as fast as originally observed. For example, at latitudes where 2% depletion had been observed over the last decade, new evidence showed that actual depletion is closer to 3 or 5 %. The Copenhagen Amendment calls for an accelerated phase-out of ODSs for the developed countries (CFCs, CTC, and MC by 1996; HCFCs by 2030). Additionally the Copenhagen Amendment calls for measures against hydrobromofluorocarbons (HBFCs) and methyl bromide. The Copenhagen Amendment to the MP was adopted in November 1992 and shall enter into force on 1 January 1994, provided that at least twenty countries have ratified the Amendment. As of July 1993, 4 had done so.

The 1992 Copenhagen amendments can be summarized as follows:

	<u>Percent phase-out</u>	<u>Year</u>
CFCs	75	1994
	100	1996
Halons	100	1994
CTC	100	1994
MC	85	1994
	100	1996

HCFCs¹ The phase-out of HCFCs shall be as follows:

35	2005
65	2010
90	2015
99.5	2020
100	2030

HBFC² 100 1996

Methyl Bromide Resolution to include methyl bromide into the Protocol. Freeze by 1995 at 1991 year's consumption level.

¹Total use of HCFC allowed is 3.1 percent of the total 1989 consumption of CFC and HCFC (weighted ozone depletion potential).

²HBFC = HydroBromoFluoroCarbons

The developed country signatories of the Montreal Protocol (MP) are thus committed by the Copenhagen Amendment to a freeze of CFC production and consumption at 1986 levels from mid-1989 through 1993 followed by phased reductions of both production and consumption [defined as production plus imports minus export of bulk chemicals] leading to a complete phase-out of CFC and halons by 1996 (under November 1992 revised reduction schedule).

The Protocol grants a 10-year grace period on all phase out dates and interim reduction deadlines for developing countries whose per capita consumption of Annex A chemicals is less than 0.3 kg/year. Annex A chemicals include the five main CFCs: CFC-11, CFC-12, CFC-113, CFC-114, CFC-115; and halons. For most developing countries this allows considerable leeway to expand CFC consumption over the next several years. However, by the terms of the MP, such expansion is allowed only to "meet....basic domestic needs". Production for export has been clearly excluded from the definition of domestic needs.

The list of Ozone Depleting Substances (ODS) that are regulated by the Montreal Protocol are thus

- chlorofluorocarbons (CFC), CFC-11, 12, 113, 114, 115 as well as mixtures of these substances.
- Halons 1211, 1301 and 2402
- 1,1,1-trichloroethane (methyl chloroform)
- Carbon tetrachloride (CTC)
- HCFC, HBFC
- Methyl Bromide

Major use of the controlled substances are in:

1. Aerosol manufacturing Sector (CFC, 1,1,1-trichloroethane, HCFC)
2. Sterilization Sector (CFC, HCFC)
3. Packaging Sector (CFC, HCFC)
4. Flexible Foam Sector (CFC)
5. Rigid Foam Sector (CFC, 1,1,1-trichloroethane, HCFC)
6. Extruded polystyrene manufacturing Sector (CFC, HCFC)
7. Refrigeration and Heat exchanger Sector (CFC, HCFC)
8. Solvent cleaning and degreasing including Dry cleaning (CFC, HCFC, 1,1,1-trichloroethane, Carbon tetrachloride (CTC))
9. Fire Suppression Sector (Halons, HBFC, HCFC)
10. Miscellaneous (CFC, 1,1,1-trichloroethane, CTC, HCFC)

2.2 The Current Status of the Montreal Protocol

For the solvent sector, the controlled Ozone Depleting Substances with respect to the current London Amendment are (3):

- Chlorofluorocarbons - CFC, i.e. CFC-113
- Carbon tetrachloride
- Methyl chloroform, i.e. 1,1,1-trichloromethane
- Hydrochlorofluorocarbons - HCFCs; among the HCFCs, HCFC-225, HCFC-

123 and HCFC-141b are commercial candidate solvents. HCFCs are termed transitional substances.

Appendices 2 and 3 lists some of the common trade names, contents of selected products, and the major manufacturers of CFC-113 and methyl chloroform respectively (2).

Their nomenclature, grouping and annexures with respect to the Montreal Protocol are reproduced in Table 2.1 below. The controlled substances are the listed substances in Annex A, B, C or E to the Protocol, whether existing alone or in a mixture. Controlled substance listing includes the isomers of any such a substance.

Table 2.1 Ozone Depleting Substance of Relevance to the Solvent Sub-sector

Annex	Group	Substance	Formula	Ozone Depleting Potential
A	I	CFC-113	$C_2F_3Cl_3$	1.0
B	II	Carbon tetrachloride	CCl_4	1.1
B	III	1,1,1-trichloroethane	$C_2H_3Cl_3$	0.1
C	I	HCFC-123	$CHCl_2CF_3$	0.02
C	I	HCFC-225	$C_3HF_2Cl_2$	0.02 - 0.07
C	I	HCFC-141b	CH_2CFCl_2	0.11

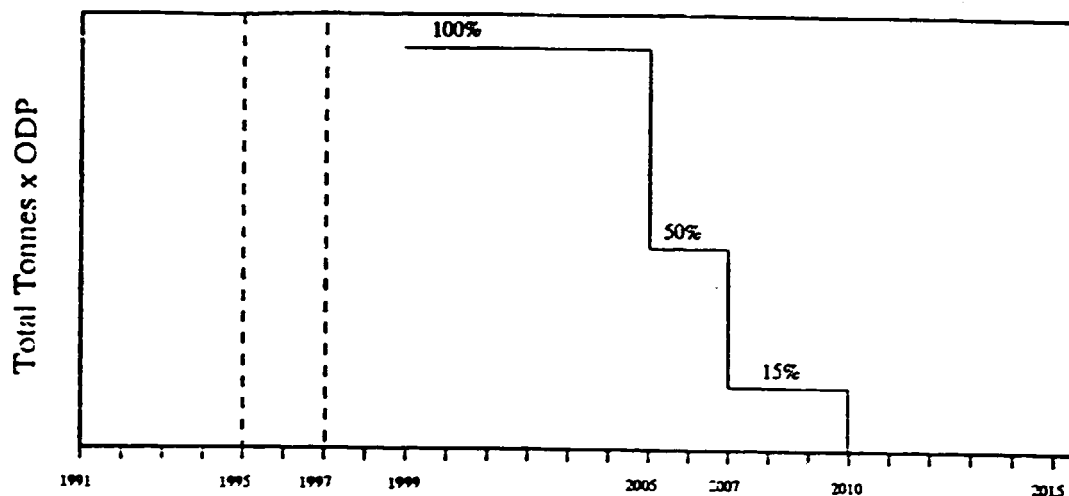
The current 1990 London amendment calls for a phase-out of CFC and halon production and consumption (but not use) by the year 2000 with exemptions for production of halons if agreed by the parties to be necessary for essential uses. An intermediate cut of 50 percent of 1986 levels by 1995 has also been agreed upon for CFCs and halons, together with an 85 percent cut for CFCs, but not halons, by 1997. These adjustments entered into force early in 1991. Additionally carbon tetrachloride (CTC (CCl_4)) is to be phased out by 2000 with an intermediate cut of 85 percent of 1989 levels by 1995. 1,1,1-trichloroethane is to be frozen at 1989 levels from 1993, cut by 30 percent by 1995, 70 percent by 2000 and phased-out by 2005. Other fully halogenated CFCs are to be phased out by 2000, with intermediate cuts, from 1989 levels, of 20 percent by 1993 and 85 percent by 1997.

The current requirement of the Protocol for the developing countries (Article 5 countries³) phase-out of ODS are graphically depicted in Figures 2.1 - 2.5. The phase-out of ODS-solvents are graphically depicted in Figures 2.1, 2.4 and 2.5 (4).

³Article 5 countries are any party that is a developing country and whose annual consumption of controlled substances is less than 0.3 kg per capita

Figure 2.1

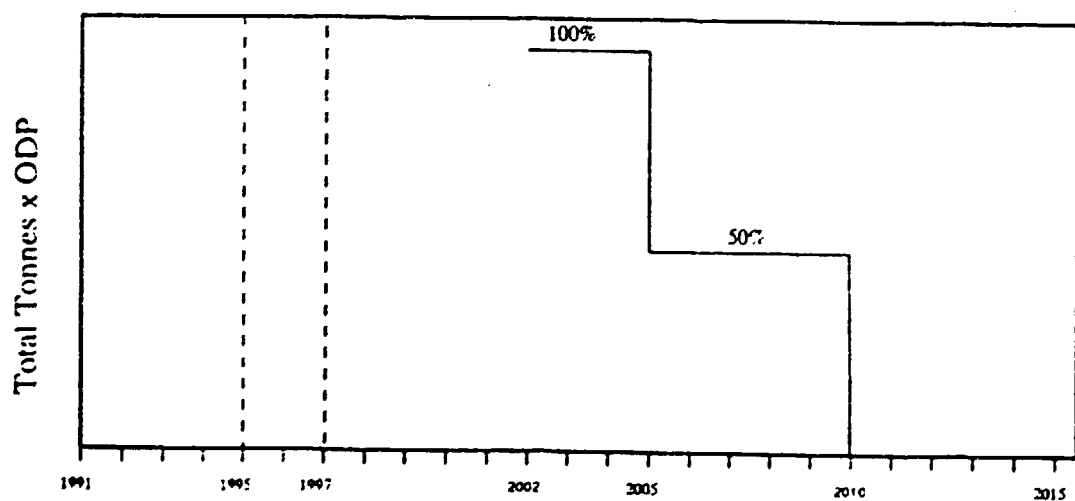
Protocol Phase-Out Profile CFCs in ANNEX A Group I



Percentages are based on average consumption in the years 1995 to 1997
 Dates apply to countries operating under Paragraph 1 of Article 5

Figure 2.2

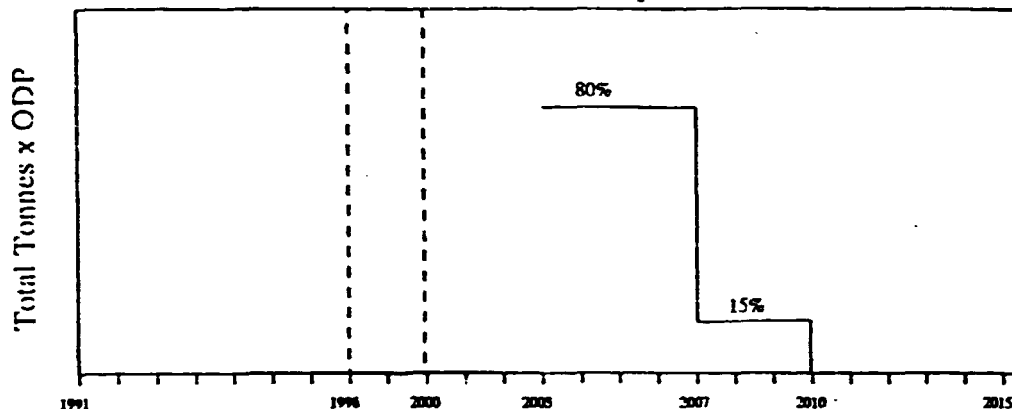
Protocol Phase-Out Profile HALONS in ANNEX A Group II



Percentages are based on average consumption in the years 1995 to 1997
 Dates apply to countries operating under Paragraph 1 of Article 5

Figure 2.3

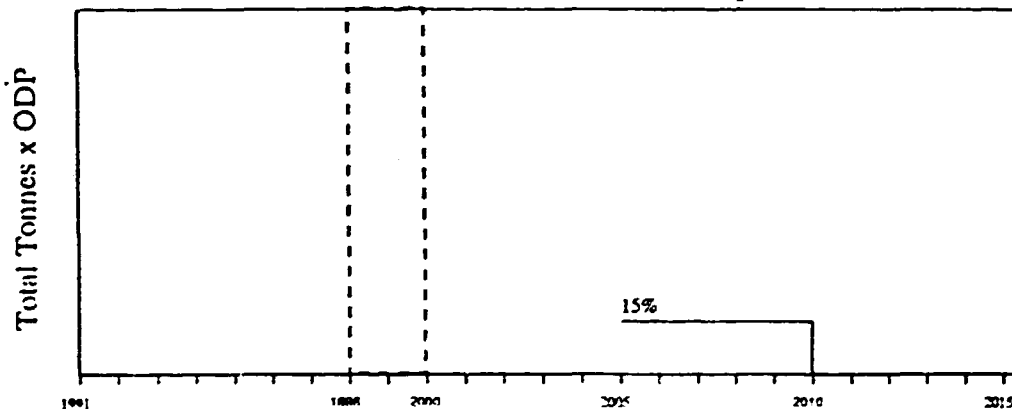
**Protocol Phase-Out Profile
CFCs in ANNEX B Group I**



Percentages are based on average consumption in the years 1998 to 2000
Dates apply to countries operating under Paragraph 1 of Article 5

Figure 2.4

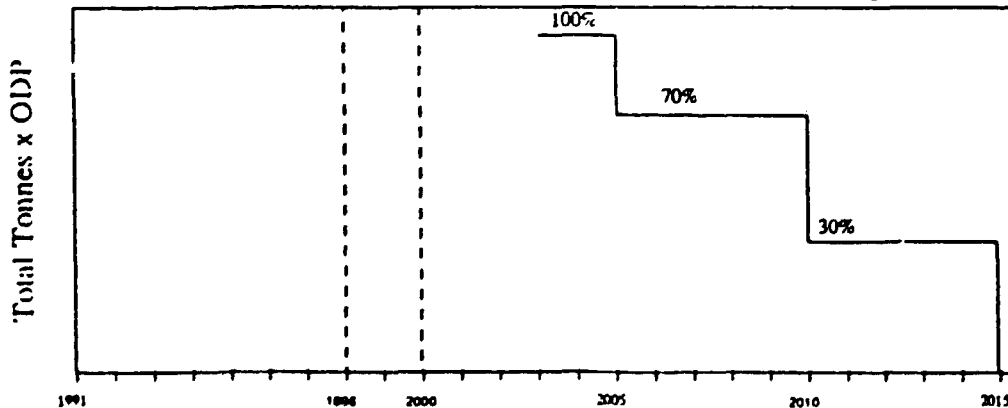
**Protocol Phase-Out Profile
Carbon Tetrachloride in ANNEX B Group II**



Percentages are based on average consumption in the years 1998 to 2000
Dates apply to countries operating under Paragraph 1 of Article 5

Figure 2.5

**Protocol Phase-Out Profile
1,1,1 - Trichloroethane (Methyl Chloroform) in ANNEX B Group III**



Percentages are based on average consumption in the years 1998 to 2000
Dates apply to countries operating under Paragraph 1 of Article 5

2.3 The Multilateral Fund for the Implementation of the Montreal Protocol

The MP also calls on the developed countries to provide financial and technical assistance to developing countries. This has resulted in the establishment of the "Multilateral Fund" (MF) for the implementation of the Montreal Protocol (5). The Fund offers assistance to developing countries to acquire technologies to substitute ODSs with alternative technology that does not harm the ozone layer.

The MF, established by the Parties to the MP, had a USD 240 M interim capital for 1991-1993 to assist developing countries in meeting the control measures of the MP. Contributions to the MF are made by the industrialized countries. The contributions for the period 1994-1996 is expected to be between USD 340M and USD 500 M (6).

The MF is managed by an Executive Committee which is assisted by a Secretariat. The Executive Committee, composed of 14 members with equal representation from developing and developed Parties, approves funding and develops guidelines for administration of the Fund.

The Fund assisted activities are implemented through four implementation agencies:

- 1) the United Nations Environment Programme (UNEP IE/PAC in Paris)
- 2) the United Nations Development Programme (UNDP in New York)
- 3) the United Nations Industrial Development Organization (UNIDO in Vienna)
- 4) the World Bank (in Washington).

Provisions also exist for direct bilateral assistance between the Parties. Bilateral assistance can be adjusted up to 20% of the contribution obligations of the donors. Bilateral assistance, however, has to be consistent with the criteria established by the Executive Committee.

UNEP (Nairobi Headquarters) also provides the organizational umbrella for the Fund's Secretariat, and serves as the treasurer receiving all contributions to the MF and disburses monies according to the decisions of the Executive Committee. The organization of MP activities and mandate for the implementing agencies is summarized in Figure 2.6 below.

THE STRUCTURE OF THE MULTILATERAL FUND

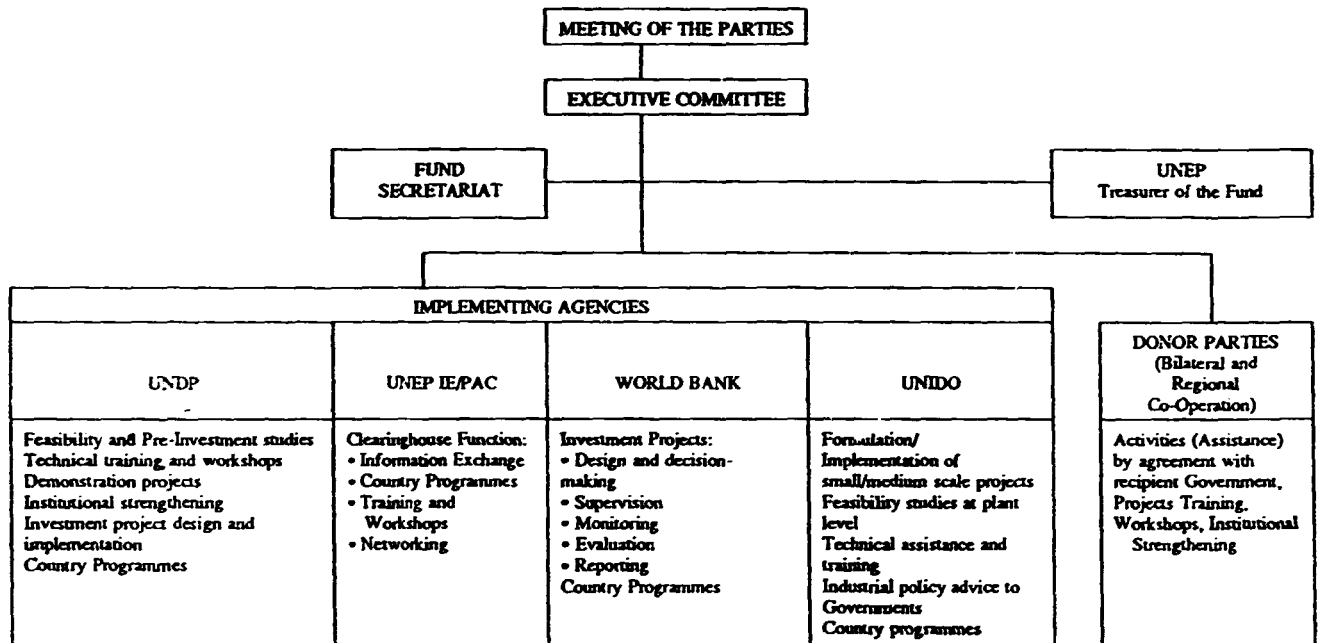


Figure 2.6 The structure of the Multilateral Fund of the Montreal Protocol.

2.3.1 Eligibility to the Multilateral Fund

Only developing countries which are Parties to the Protocol and with a annual per capita consumption less than 0.3 kg are eligible for assistance from MF. The Article 5 countries as of June 1993 are listed in Appendix 1.

2.3.2 Assistance from the Fund

The MF gives assistance in the following areas:

1. Identifying a Countries Needs: The status of production and consumption of ODS and how they are to be phased out are determined through the

development of the Country Programme (CP). The cost of developing the CP is met by MF and may be prepared with assistance from one of its Implementing Agencies in collaboration with the concerned Government. Elements contained in the CP are reproduced in point 6 below.

2. **Projects:** Individual Project Proposals (PP) eliminating the use of ODS may be developed and funded in all sub-sectors including solvents, aerosols, foams, refrigeration and air conditioning and halons. Area of activity may include improved maintenance, retrofitting of existing equipment, conservation and recycling of ODS, strengthening of institutional structures for implementing the CP, training and demonstration in the use of new technologies. Major elements of Project Proposals exceeding USD 500 000 are summarized in Point 7 below. Appendix 4 contains the main sources of further information and a sample of Executive Project Summary for the MF describing the elements in greater detail. Point 8 Summarizes documentation requirements for MP Projects under USD 500 000.
3. **Training and Networking:** These activities target: decision-making groups to strengthen their capabilities in designing programmes, technical personnel in the various industry sectors to enhance their skills in the use of ODS free alternative technologies, conservation and recycling techniques. A regional well informed network of government, industry and non-governmental organization (NGO) representatives can also be developed.
4. **Information:** MF assists in formulation and distribution of information on policies, technologies, alternatives and control strategies useful in reduction of ODSs. (See Appendix 4 for further information)
5. **Institutional Strengthening:** To ensure effective action at the country level, a National Focal Point (NFP) is commonly designated. The NFP liaises with industry, institutions and the implementing agencies. Where necessary, support for institutional strengthening can be obtained from the MF to help strengthen the NFP and allow it to carry out the country's responsibility effectively.
6. **Country Programme:** A CP describes the ODS situation in a country and reproduces the relevant data. It also contains an action plan to phase-out ODS and outlines the various project areas. The CP identifies the following main components:
 - a) Data on unconstrained demand, production and consumption of ODS
 - b) Action Plan; how and when the ODSs are to be phased out.
 - c) Strategies that support the Action Plan, e.g. new taxes, creation of industrial zone panels, task forces, import monitoring, licensing procedures, financial assistance, legislation and policy formulations etc.
 - d) Project Identification; here Project Proposals are outlined and support the Action consistent with the suggested strategy. Details of PP can be worked out at a later stage.
 - e) Costs, stating the incremental cost of implementing the Action Plan
 - f) Prioritization of projects.
7. **Project Proposals:** Project Proposals (exceeding USD 500 000) should contain

all the details of a specific project in a specific sector or a group of projects and should contain the following main components:

- Project Cover Sheet. Provides a summary of basic data, including ownership of the enterprise concerned, consumption, time frame, impact, budget, implementing agency and national coordinating agency (NFP) and brief summary of technical, institutional and policy issues;
- Project title
- Sector data
- Project description; the project's short and long term objectives and their relationship with the CP or the national strategy is described along with the activities required to accomplish the project objectives
- Project time frame
- Outputs
- Budget; the budget should clearly describe how the incremental cost figures are calculated
- Institutional framework
- Technical appraisal

8. Project Proposals for Investment Projects under USD 500 000: Documentation that is needed on investment projects submitted to the Executive Committee for final approval within a work programme should cover the following information:

- Country or Region
- Sector(s) covered
- Project Title
- Technology to be used (where applicable)
- Project Impact (ODS phased-out/year, beginning in where applicable)
- Project duration
- Total Cost
- Ownership of enterprise
- Incremental cost
- Cost effectiveness
- Implementation Agency
- National Coordinating Agency/NFP
- Technical review

In general, the MF is designed for payment only for eligible costs of national enterprises or corresponding shares of joint ventures and not for any part owned by transnational companies.

2.3.3 Accessing the Fund

All applications requesting MP funding should be made via the National Government and submitted for approval to the Executive Committee through the Fund Secretariat. Interested countries can apply through three channels:

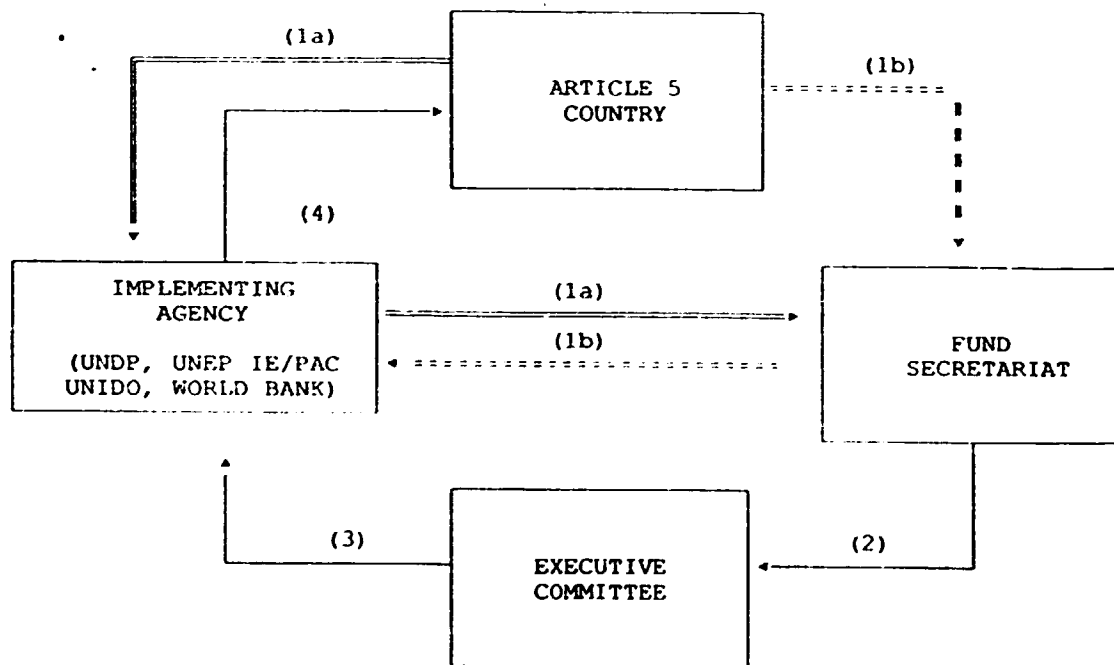
- 1) By contacting the MF Secretariat (MFS): The MFS can assist a country in identifying a relevant Implementing Agency that can help prepare a CP or PP; and supply information necessary to develop a CP or PP. The MFS also

provides liaison with recipient countries, the Implementing Agencies and the Executive Committee.

- 2) By contacting one of the Implementing Agencies (IA): Countries can contact one of the IA to develop CP and/or PPs. Appendix 5 describes areas where the IA can assist and contact address for the four IAs: UNEP, UNDP, UNIDO and World Bank.
- 3) By contacting a bilateral Donor Agency: A country can also seek direct bilateral assistance from one of the donor Parties. The assistance is limited to a maximum of 20% and the assistance activities should comply with the guidelines set by the Executive Committee.

All PPs and CPs requiring funding from MF must be submitted and approved by the Executive Committee. They should also include the designated IA(s). The Committee holds three meetings a year at which action on requests for funding and other issues is taken. Figure 2.7 summarizes the Project submission and Approval Process.

Figure 2.7 PROJECT SUBMISSION AND APPROVAL PROCESS



Notes

- 1(a) Project submitted by an Article 5 country through an implementing agency.
- 1(b) Project submitted directly by Article 5 country to the Secretariat and referred to an Implementing Agency.
- 2) Project reviewed by Fund Secretariat and submitted to the Executive Committee.
- 3) Project approved by the Executive Committee. Funds disbursed to Implementing Agency.
- 4) Project implementation.

Projects that are not approved by the Executive Committee are referred back to the Implementing Agency concerned for further elaboration and resubmission. Projects that are not eligible for funding cannot be resubmitted.

- Project submission process.
- Project approval and implementation process.

3.0 STATE OF ART ODS-FREE TECHNOLOGIES

3.1 Uses of ODSs

The primary uses of ODSs (mainly CFC-113, MC) within industry are as follows (7):

- dry-cleaning/spot removal
- cleaning of electronics assemblies
- cleaning of precision/optical components
- cleaning of certain other metal components

as well as, to a lesser extent, for the following (non-exhaustive) purposes:

- drying of components
- carriage of special lubricants
- leak and crack detection for checking of e.g. fuel tanks, non destructive testing
- decontamination in the nuclear industry
- dissolving of greases in laboratory testing
- protection of the primary vapour in vapour phase soldering
- as a coolant in radars
- mould release agent carriage
- skin cleaner

CTC is mainly used a reaction medium because of its inertness (it is however toxic) and excellent solubilization of resinous materials. In some regions where regulations may permit, it is commonly used as a solvent in metal cleaning, textile spot removal etc. It is moreover used as a carrier solvent in the manufacture of chlorinated rubber, chlorinated polyethylene, pesticides, pharmaceuticals. Usage of CTC is there in some paints, adhesives, printing ink, laboratory analyses etc.

3.2 Use of ODS in metal and precision cleaning

Materials cleaned in the context of metal cleaning are usually made from stainless steel, mild steels, bimetal, galvanized sheets/steel, hard metal (e.g. Ti, W), copper, aluminium. Precision cleaning are typically, inertial systems, gyroscopes, accelerometers, etc., and related gaskets, bearings, and housings: these may include new parts and a significant number of refurbished parts, hydraulic systems, miniature bearings, and disc-drives. The materials may be composites (i.e of various plastics and metal, powder metallurgical forms and reactive metals like beryllium, magnesium). CFC-113 and 1,1,1-trichloroethane have been commonly used in the cleaning of the above and additionally in the context of manufacture and maintenance of equipment used in optical systems, aerospace applications, and the offshore oil industry.

3.3 Conservation and Recovery

In general, conservation of and recovery practice for ODSs, while not being an

alternative per se, can enable up to 90 percent capture. A summary of measures, engineering as well as house-keeping, for control of alternative volatile organics, is reproduced in Appendix 6.

3.4 Alternatives

There is no single universal alternative for ODS-solvents. Some common alternatives that are being applied as substitutes for ODSs in principal applications within the metal and precision cleaning industry may be summarised as follows:

- a) Technology that eliminates the need for subsequent cleaning with chemicals ("no-clean" technology). In the cleaning of precision components, particles can be removed by blowing with clean compressed air or atomized frozen carbon dioxide. Thermal vacuum de-oiling can be used with a heated vacuum chamber to remove oil from parts by vaporizing the oil. The vapours are then pumped through a cold trap where they are condensed and drained for recycle or disposal. Typical applications are for parts of simple or complex design that are soiled with low- to mid-viscosity oils. The technology can be used to clean parts following cutting, machining, quenching and stamping operations. Vacuum de-oiling is also used to clean parts in preparation for brazing, coating, plating and heat treating operations. Advantages of the no clean system are typically elimination of solvents and pollution emanating from their emissions, provision of ultraclean parts, relatively simple operation of equipment, reclamation of oils, floor space requirement similar to that of existing degreasing equipment.

The primary disadvantage of no clean system is that it may be very soil specific. Especially for the case of clean compressed air blowing and vacuum de-oiling systems. Vacuum cleaning is only capable of removing oils that can be volatilized within certain temperature, time and pressure ranges. The systems may be constrained to manufacturing applications that have consistent part size and soil loadings. For example, heat exchangers of domestic refrigeration units, made of aluminium fins and copper tubes with a number of machining oils and forming lubricants are being cleaned by the method. Traditionally large amounts of MC were used for this application.

A typical thermal vacuum de-oiling equipment, with inner working dimensions of 91 cm W x 91 cm H x 122 cm L incurs a capital cost of approximately USD 100,000 and about USD 10,000 annual operating costs (8).

- b) Aqueous cleaning (includes partially water-based systems: emulsions/microemulsions). Aqueous systems cover a range of methods using ultra pure water cleaning to emulsion based systems. Choice of systems is dependant on the characteristics of contamination to be removed. Aqueous emulsion systems can be used for contaminants that are difficult to dissolve in water. Some of these water-based emulsions can consist of up to 15-25 tensides and 20-30% organic solvents. Additives e.g. surfactants, complexing agents, dispersion agents, inhibitors and buffering chemicals are commonly added to aqueous formulations. In emulsion systems, the organic phase is either dispersed in the aqueous phase or vice versa. Typical droplet size of dispersions in micro-emulsion systems are

of the order of 2-10 nm. Droplet size in emulsions are 1000 times larger. Alkaline degreasing baths usually consists of about 10% tensides and 10% alkali and complexing agents. Commercial alkaline systems are usually classified according to the formulation hydrogen ion concentrations (pH) (9, 10):

- Acidic (pH 1.5-5)
- Neutral (pH 6-8)
- Mildly alkaline (pH 9-11)
- Alkaline (pH 11-13.5)

Conversion to aqueous cleaning requires treatment and recycling of the waste water. This entails an initial capital expenditure for small companies without such facilities. Aqueous system usually range between 0.25 - 1.5 m³/h capacity. While payback on direct substitution of aqueous cleaner for solvent degreasers may appear attractive, the annual operating costs are considerably higher than the annual operating costs using a recycling/recovery system. An aqueous cleaner without recovery practice can be prohibitively expensive. As illuminated below, annual operating costs for a typical 0.45 m³/h, two stage aqueous, stand alone operation (offsetting a 0.61 kg/h, m² consumption of halogenated solvent) is assessed at USD 30 000/y if no recirculation is practised. Recirculation practice reduces the operation costs by about 40% to USD 17 000/y. The requirement for drying is a function of what subsequent treatment is to be carried out. One ball bearing manufacturer is utilising the SKF Washing Principle (Figure 3.1). This is a close loop system with respect to the cleaning agent and applicable for mass production lines for cleaning of delicate surfaces. The system operates with an aqueous cleaner (2-5 percent "Careclean E88") in conjunction a low content aromatic hydrocarbon (Castrol Rustilo DWX 88) as a dewatering media. The system is suitable for cleaning of delicate surfaces such as bearing or composite (metal/plastic/glass) components.

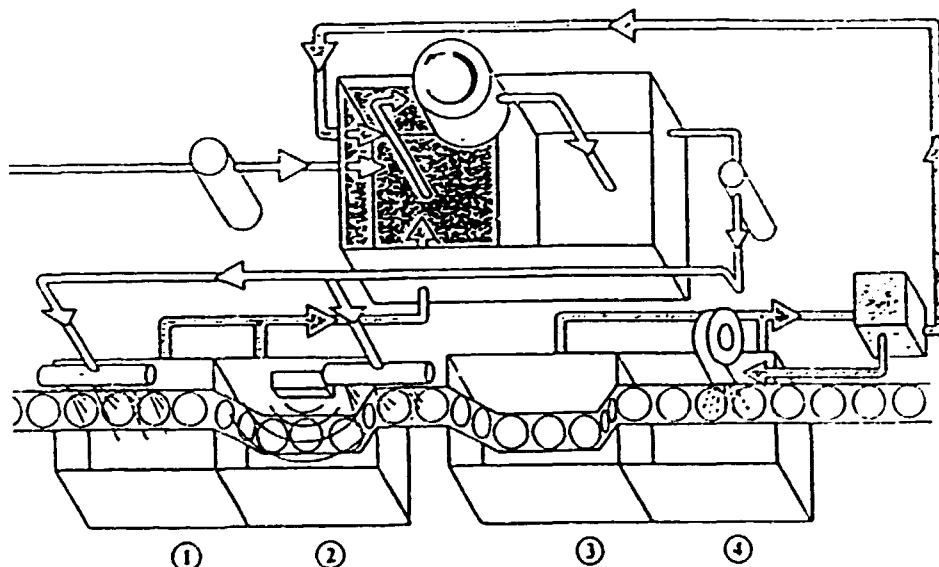


Fig. 3.1 The SKF Washing Principle. The rings are washed in four stages: 1) Pre-wash and flush; 2) Ultra-sonic cleaning plus rinsing; 3) Dewatering; 4) Drying.

c) Cleaning with organic solvents, such as alcohols (e.g. isopropanol, ethanol), ketones (e.g. acetone), terpenes (e.g. d-limonene), esters, lactates (e.g. ethyl lactate), dearomatized hydrocarbons, glycols, methyl siloxanes and other organic compounds. Organic solvents usually associated with flammability problems. Conversion to flammable solvents requires investments to prevent fire and explosion. The problems can be overcome, however. In some cases perfluorocarbons (C₂F₆; perfluorohexane, perfluoropentane etc) are being introduced for speciality applications (see HCFCs below) and as a fire suppressant. Much concern has been expressed about the introduction of FCs, primarily because of their extreme stability 1000 -50000 years lifetimes and high global warming potentials (GWPs). See Table 3.1 below. Best available technology for emission control of volatile organic solvents is reproduced in Appendix 6.

Table 3.1 Global Warming Potentials for CF₄, C₂F₆ and SF₆ (11).

Time Span (years) relative to CO ₂ = 1	20	100	500
CF ₄	3700	5100	8800
C ₂ F ₆	7300	10000	17-30
SF ₆	14600	20000	34600

Figure 3.2 depicts two types of equipment operating with Swedish ordinance and avionics manufacturers (12). Regarding emission control, see Appendix 6.

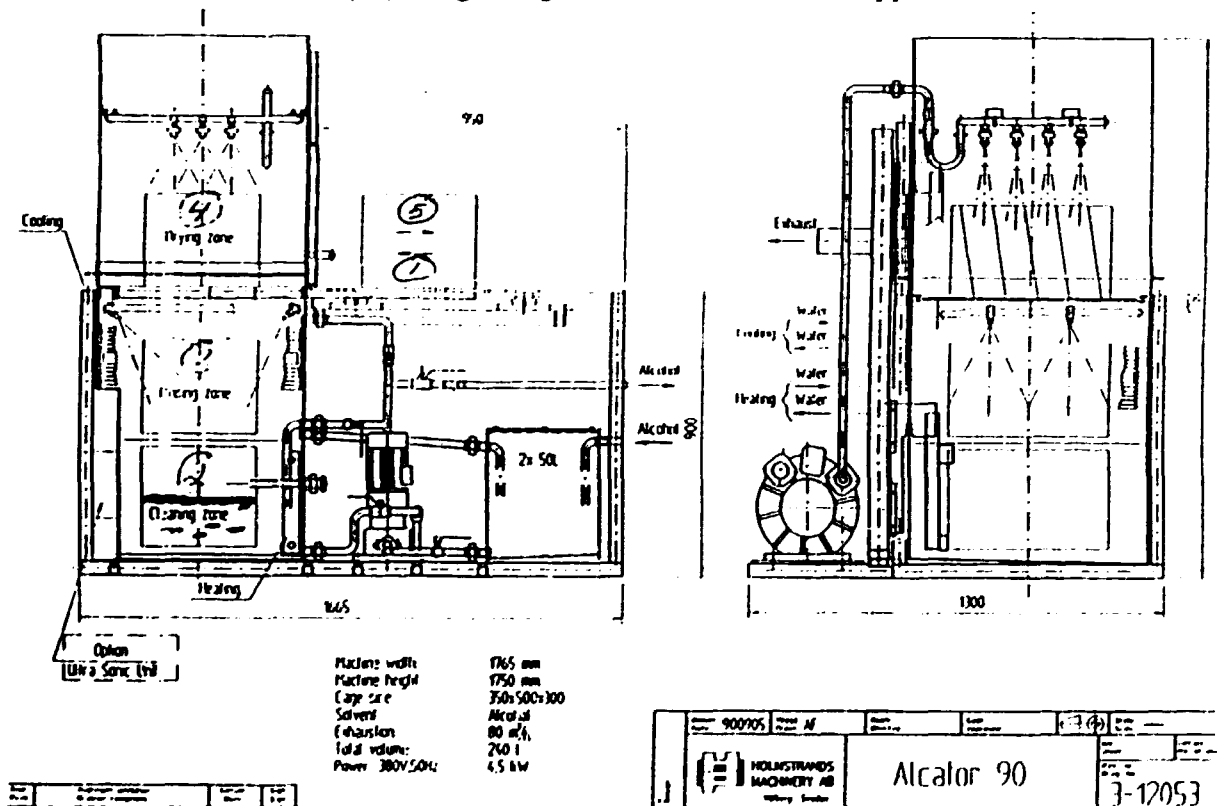


Figure 3.2 (a) Example of washing system using alcohol for cleaning of high performance military and aviation components.

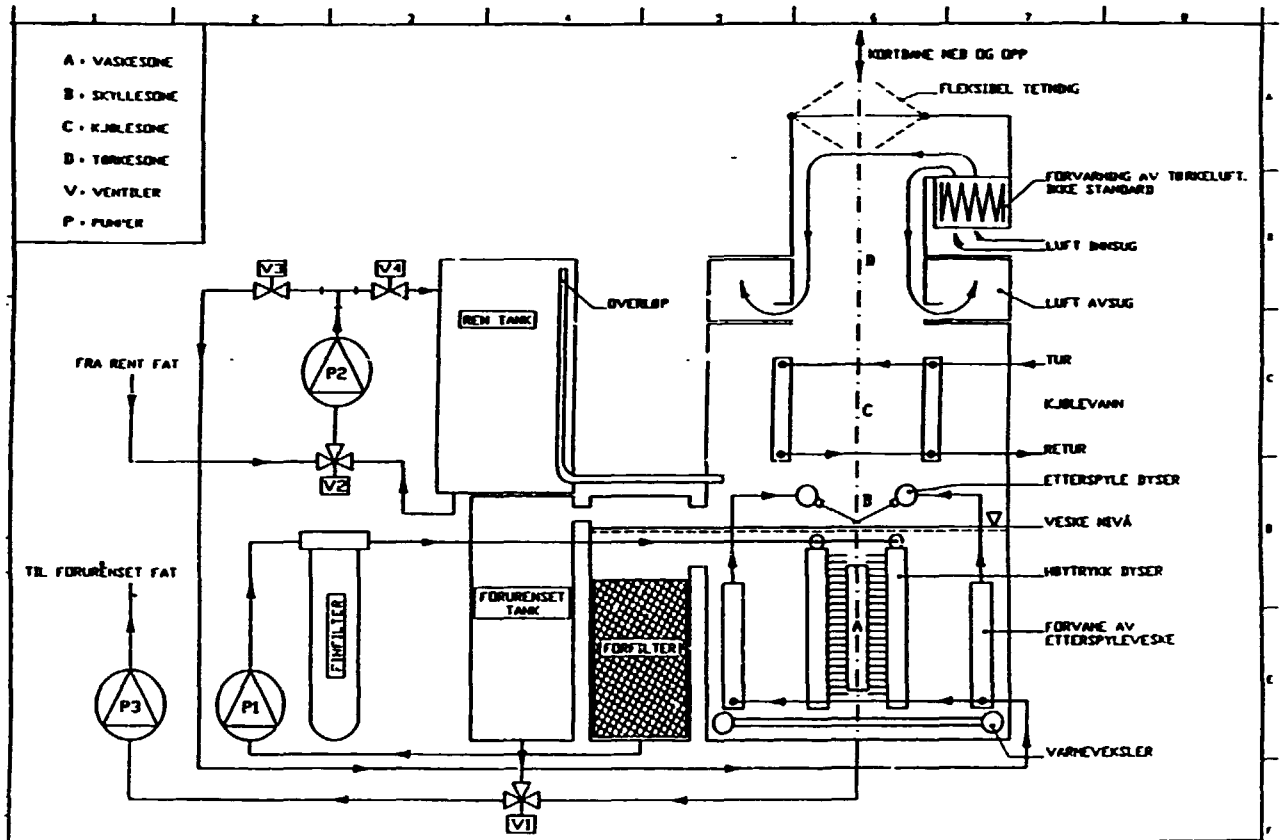


Figure 3.2 (b) Example of washing system using alcohol for cleaning of high performance military and aviation components. Glossary A = wash zone; B = rinse zone; C = cooling zone; D = drying zone; V = valves; P = pumps. The components are introduced and removed from the top right via a flexible seal.

d) Cleaning with chlorinated organic solvents, e.g. perchloroethylene, trichloroethylene or methylene chloride. These compounds are known to have an adverse impact on the environment and are increasingly coming under strict regulations and phase outs in developed countries. When these solvents are used anyway, the best technology should be used in order to limit emissions, see Appendix 6. As an interim solution to ODSs, mechanical precision parts, including bearings used in the aerospace industry can be cleaned in small four sectioned watch cleaning machines. Better results have been achieved with bearings than with CFC-113. A combination of white spirits and glycoether along with a solution

of trichloroethylene, methylene chloride and benzene are used in the four baths. Trichloroethylene is also being used in dewaxing operations but here again, alternatives are being pursued, e.g. hot wax; hot oil etc.

- e) **Cleaning with other new chemicals.** New chemicals under development include HydroFluoroCarbons, HFCs; HCFC (HydroChloroFluoroCarbon) compounds such as HCFC-123, 141b or 225b, or for example pentafluoropropanol ("Pefol"), benzotrifluorides, monochlorotoluenes etc. HCFC compounds cause degradation of the stratospheric ozone layer, but to a lesser extent than the CFC compounds. Moreover HCFC are transitional substance and are required by the MP to be eliminated by 2030 in industrialized countries and by 2040 in the developed countries. The environmental impact of most new chemicals is not fully known. Perfluorocarbons (FC) are being used to clean fluorinated lubricants and particulates effectively in combination with ultrasonics for removing particulate contaminants. Hydrocarbons are not removed effectively by FC. Such contaminants may be precleaned in an aqueous alkaline cleaner, rinsed in demineralised water and drying in FC vapours. Components used in aircraft oxygen systems, e.g. valves, transducers etc. can thus be cleaned. The major drawback is the high volatility of FC, their extreme global warming potential and the costs associated with FC compounds. Aqueous cleaning followed by HCFC 141b and isopropanol has also been used for the same purpose but one major user found the combination impractical in existing equipment and that the volatility of HCFC 141b was even greater than that of the PFC (PF5060).

An effective cleaning system is a function of the cleaning equipment and the cleaning agent. Often the optimized solution has to be found experimentally. Table 3.2 summarizes the main considerations for analysis of alternative cleaning system requirement (13).

Table 3.2 Some Considerations for Evaluation of Cleaning Systems Requirement

<u>Environment</u>	<u>Reason for Cleaning</u>	<u>Soil to be removed</u> <u>Organic:</u>	<u>Soil to be removed</u> <u>Inorganic:</u>
Outdoors Factory Laboratory Glove Box Fume Hood Clean Bench Clean Room	Function Reliability Surface Prep. Maintenance Appearance	Oil Grease Wax Microbial	Salts Compounds Rust Scale
<u>Materials of Construction</u>	<u>Configuration</u>	<u>Work Load</u>	<u>Method or Technique</u>
Nonferrous Metal Ferrous Metal Alloys Plastics Elastomers Glass Paints Inks Combinations Fines	Flat Surfaces Convolutons Blind Holes Crevices Material Mass Fasteners	Part Size Quantity Type(s) of Soil Manual Automated	Dip Soak Flush Wipe Spray Electrolysis Vapour Degrease Ultrasonic Combinations - Monitoring

Table 3.3 Summary of main solvent systems according to chemical properties.

<u>Hydrocarbons</u> - aliphatic - cyclic paraffins - aromatics	<u>Ketones</u>	<u>Ethers</u> - synthetic high molecular weight glycol ethers
<u>Alcohols</u> - azeotropes	<u>Esters</u> - ester blends	<u>Chlorinated Solvents</u> - methylene chloride - perchloroethylene - trichloroethylene
<u>Fluorinated alcohols</u> - pentafluoropropanol	<u>Perfluorocarbons</u> - perfluoro dimethylcyclobutane - perfluoro hexane - perfluoro pentane - perfluoro tribytyl amine - perfluoro cyclic ethers	<u>Hydrochlorofluoro carbons (HCFCs)</u> - HCFC-225 ca/cb - HCFC-123 - HCFC-141b

The alternatives may be applied via combination systems using ultrasonics, high pressure sprays, bubble agitation, additives that modify the physical properties (tensides), a combination of above and ancillary equipment that render them safe according to the local regulations. In some instances, ancillary equipment also includes purification systems (e.g. when ultra pure or DI water is required).

Usually cleaning equipment can be distinguished by systems designed for aqueous cleaning or equipment designed for organic solvents. The major criteria for an alternative cleaning systems are

- choice of cleaning agent
- cleanliness requirement
- surface properties of components to be cleaned
- physical shape of components
- contamination type and loading

A clean surface is, however, not the only criteria for a cleaning system to achieve. The hydrophilic nature (surface ability to get wetted) and the chemical composition of surface contamination also play a role (e.g. the presence of silicate film on the surface after cleaning).

There is a range of cleaning equipment on the market today. The equipment use spray (including immersed spraying), ultrasonics, centrifugal systems or simple leaching. The equipment may be in batch or of continuous in-line configuration.

The major alternative cleaning media may be summarised as follows:

- aqueous based (including micro emulsions)
- Hydrocarbons (aliphatic, cyclic paraffins, aromatics)
- Ketones (acetone)
- Ethers (synthetic high molecular weight glycol ethers)
- Alcohols (IPA, ethanols, azeotropes)
- Esters (and blends)
- Chlorinated solvents (methylene chloride, perchloroethylene, trichloroethylene)
- Perfluorocarbons (perfluoro hexane, perfluorodimethylcyclobutane, perfluoro pentane)
- Hydrochlorofluorocarbons (HCFC-123, HCFC-141b, HCFC-225 ca/cb)

The choice of equipment, its automation, size/space available and capacity is a function of production volume and size of components to be cleaned. Additional factors are the requirement for rinsing, drying, maintenance, work safety and waste treatment of exhausts, effluent and soils.

The common application for aqueous cleaning are via the following processes ((14):

- manual cleaning (including wiping/drying)
- cleaning in a wash cabinet
- dip cleaning (with or without centrifuging)
- dip cleaning with ultrasonic enhancement
- dip cleaning with electrolytic applications (anodic, cathodic or alternating)

- flushing
- spray cleaning (including steam) in enclosed cabins
- spray cleaning in open
- wet media blasting

Common application systems based on alternative organic solvent systems are:

- manual cleaning/wiping and drying
- vapour phase cleaning (e.g. halogenated solvents (chlorinated), alcohol, acetone, FCs)
- dip cleaning with highly volatile organic solvents
- dip cleaning with petroleum based hydrocarbons and emulsions
- Cabinet cleaning with less volatile HCs.
- flushing

Table 3.4 summarizes the common combinations:

Table 3.4 Possible Cleaning and Equipment Combinations

Cleaning Media	Manual clean- ing	Dip- clean- ing	Dip- clean- Ultra- Sonics	Dip- clean- Elect- rolysis	Dip- clean- Centri- fuge	Exposed Spray	Closed Spray	Vapour Phase
Organic Non-halogenated solvents	X	X	X			X ¹⁾	X	X
Organic Halogenated solvents		X	X					X
Emulsions	X	X				X	X	
Alkaline formulation	X	X	X	X	X	X	X	
Acidic formulations		X	X	X	X	X	X	
Pickling formulations		X						

X = Possible combinations

¹⁾ Valid only for solvents with low vapour pressure

Plasma cleaning using various gases (e.g. hydrogen, nitrogen, oxygen, ammonia, CF₄, etc) are also used in cases. Plasma systems are usually used for final surface treatment after a precleaning stage. Additionally media blasting techniques are being applied. There are generally two systems- dry and wet-systems. For dry abrasive blasting, there are a large number of media which are currently recommended and/or are used by aircraft maintenance practices. They include: - sand, -plastic beads,- glass beads,- nut shells, -rice husks, -fruit pits, - wheat starch. Wet media is used primarily for surface cleaning prior to painting with the exception that a liquid is used in a high pressure spray. Typical media for wet media blasting are water and sodium bicarbonate, wet plastic powder, water alcohol etc. Supercritical and ultraviolet - ozone cleaning are also finding niche applications. While they are environmentally benign, their application, so far have been limited to few cases. Niche systems tend to have high start-up costs and require special operator training.

Recently an evaluation of eleven different cleaning methods was carried out with a number of available cleaning agents (15). A test piece with intricate dimensions and metal-plastic components soiled by polar and non-polar contamination was designed for consistent evaluation of the equipment and cleaning agent under similar conditions. The test system, although specifically designed for electronic assembling, nevertheless gives a comparative assessment useful for metal and precision cleaning tasks. Results were evaluated by visual examination under an optical microscope and extraction testing. Visual examination rated cleanliness from a scale of 1 (completely clean) to 5 (very contaminated). The level of ionic contamination was measured in μg -equivalent NaCl/cm^2 . The following systems were investigated:

- 1) Chemical leaching: Stagnant liquid to evaluate the chemical potential of the cleaning
- 2) Contax: Immersed high pressure spray cleaning. The equipment is designed for alcohol but can be used for most other liquids. Spray pressure is adjustable up to 60 bar.
- 3) Concoat ICOM 8000: A spray cleaner for isopropanol (IPA)/water mixtures. It has an in-built ionic extraction testing to determine the final contamination remaining on components.
- 4) Bubble Agitation: Pressurized nitrogen gas is injected via a number of nozzles at the bottom of liquid chamber. Mechanical agitation is thus affected by a pseudo boiling state.
- 5) Ultrasonic cleaning - Batch: Batch equipment for containment of 15 l liquid. Ultrasonic system operations could be operated at a frequency of 40 kHz and 275 W.
- 6) Ultrasonic cleaning - In-line Continuous: This equipment was operated 420 W with 30 l terpene/water blend.
- 7) Branson MicroCoustics: Ultrasonic cleaner with 200 W output at 400 kHz. Operated with a work volume of 15 l of cleaner fluid.
- 8) Electronic Control Design: Batch cleaner designed for terpene/water mixtures.
- 9) Westkleen Formula III+: An in-line spray cleaner for aqueous systems. The machine is equipped with a wash and rinse stage, air knife and infra-red drying oven.
- 10) Elute: A batch cleaner designed for aqueous or semi-aqueous cleaning agents.
- 11) Centrifugal: The equipment uses centrifugal force for cleaning of components.

The following agents were tested:

<u>Agent</u>	<u>Composition</u>
Isopropanol/water	75%IPA; 25% Deionized water
Kemetyl I-111	Ethanol blend with dipropylene glycol - monomethylether.
Citrikleen	Terpene (mainly d-limonene) blend with some diethylene glycol -butyl ether.
Terpene emulsion	A mixture of terpene and alkaline water
Terpene/water	60% Citrikleen with 40% DI-water
Terpene/IPA	50% terpene with 50% IPA
Prozone	Main ingredient diethylene glycol-monobutyl ether
Axarel (38)	An ester based mixture of polar and non-polar hydrocarbons
Dowanol PX-16S	Mainly diethylene glycol - monoethyl ether
Ionox HC	A blend of alcohol, water, polar and non-polar solvents with surfactant and activators.
Purasolv	Ethyl lactate
Aquanox /water	Semi-aqueous cleaner dedicated for spray cleaning. Used as a 25% solution with water (75%).
Water	100% water

The following conclusions could be drawn:

<u>Agent</u>	<u>Results</u>
Isopropanol/water	Cleaning result is enhanced by any form of mechanical agitation.
Kemetyl I-111	A slightly better result than IPA/water. Cleaning result is enhanced by any form of mechanical agitation, e.g. spraying, bubbles, ultrasonics or centrifugal force.
Citrikleen	Terpene. Gives acceptable to good results. Difference between leaching and ultrasonic enhanced cleaning is not substantial.
Terpene emulsion	Residues in crevices were obtained. Performance on more accessible areas is better but some residues remain.
Terpene/water	Ultrasonic and spray cleaner perform equally well but some residues in difficult to access remain.
Terpene/IPA	A cleaning agent that shows promise. Good cleaning is obtained even in difficult crevices. Ultrasonic does not seem to enhance results.
Prozone	Visual examination gives good results. Ceramic components come out completely free from contamination. Mechanical agitation enhances cleaning.
Axarel (38)	Low extraction values are obtained. Ionic contamination reduction is good. Difficult to access crevices/geometry

reveals some visual contamination. Use of ultrasonic enhances cleaning potential.

<u>Agent</u>	<u>Results</u>
Dowanol PX-16S	Similar results as with Prozone above: i.e. visual examination gives good results. Ceramic components come out completely free from contamination. Mechanical agitation enhances cleaning. Slightly inferior results were obtained with respect to visual examination.
Ionox HC	Has a good ability to penetrate crevices and small stand-off heights. Combination with ultrasonics removes practically all organic contamination. Visual inspection gave a somewhat lower rating due to water-stains.
Purasolv	Residues remain on test piece in the case of straight forward leaching. The residues can be removed with ultrasonics. Results from extraction measurements are rather good.
Aquanox/water	The 25% dilution of the semi-aqueous cleaning agent was unable to fully remove contaminations from the test piece.
Water	Pure water is an excellent remover of ionic contaminants. Using Westklean (in line spray cleaner for water) and Elute (Ultrasonics batch cleaner) give excellent visual results. Ionic contamination reduction was by 95-99%.

The general conclusions are as follows:

- All tested cleaning equipment are proven to be effective. The effect is greater with poor cleaning agents than with the better cleaning agents.
- Terpene-alcohol solutions; glycols and alcohol-surfactant systems perform very well and give satisfying results.
- Aqueous system properly applied gives very satisfying end results also.

Table 3.5 summarizes the advantages and disadvantages of aqueous cleaning and Table 3.6 summarizes the advantages and disadvantages of process equipments.

Table 3.5 Advantages and disadvantages of aqueous cleaning (13).

ADVANTAGES

Aqueous cleaning has several advantages over organic solvent cleaning.

- **Safety** – Aqueous systems have fewer worker safety problems compared to many solvents. They are not flammable or explosive. Consult material safety data sheets for information on health and safety.
- **Cleaning** – Aqueous systems can be designed to clean particles and films better than solvents.
- **Flexibility** – Aqueous systems have multiple degrees-of-freedom in process design, formulation and concentration. This freedom helps aqueous cleaning provide superior cleaning for a wider variety of contamination.
- **Removal of Inorganic or Polar Soils** – Aqueous cleaning is particularly good for cleaning inorganic or polar materials. Many machine shops are using water-based lubricants and coolants to replace oil-based lubricants for environmental and other reasons. Water-based lubricants are well suited to aqueous cleaning processes.
- **Oil and Grease Removal** – Organic films, oils, and greases can be effectively removed by aqueous chemistry.
- **Multiple Cleaning Mechanism** – Aqueous cleaning functions by several mechanisms rather than just dissolution. These include saponification (chemical reaction), displacement, emulsification, dispersion, and others. Particles are effectively removed by surface activity coupled with the application of mechanical energy.
- **Ultrasonics Applicability** – Ultrasonics are much more effective in water-based solvents than in CFC-113 or MCF solvents.
- **Material and Waste Disposal Cost** – Aqueous cleaning solutions are generally less expensive than solvents and, when properly handled, will reduce waste disposal costs.

DISADVANTAGES

Depending upon the specific cleaning application there are also disadvantages.

- **Cleaning Difficulty** – Parts with blind holes, small crevices, tubing, and honeycomb structures may be difficult to clean and/or dry, and may require process optimization.
- **Process Control** – Solvent cleaning is a very forgiving process. To be effective, aqueous processes require careful engineering and control.
- **Rinsing** – Some aqueous cleaner residues, particularly from surfactants, can be difficult to rinse. Trace residues may be detrimental for some applications and materials. Special caution should be taken for parts requiring subsequent vacuum deposition, liquid oxygen contact, etc. Rinsing can be improved using DI water or alcohol rinse.
- **Drying** – It may be difficult to dry tubing and certain part geometries with crevices and blind holes. Drying equipment is often required.
- **Floor Space** – In some instances aqueous cleaning equipment may require more floor space.
- **Capital Cost** – In some cases, new facilities will need to be constructed.
- **Material Compatibility** – Corrosion of metals or delayed environmental stress cracking of certain polymers may occur.
- **Water** – In some applications high purity water is needed. Pure water can be expensive.
- **Energy Consumption** – Energy consumption may be higher than solvent cleaning if applications require heated rinse and drying stages.
- **Wastewater Disposal** – In some instances, wastewater may require treatment prior to discharge.

Table 3.6 Advantages and disadvantages of aqueous process equipments (8,13)

IMMERSION WITH ULTRASONIC AGITATION	IMMERSION WITH MECHANICAL AGITATION	SPRAY WASHER
ADVANTAGES		
High level of cleanliness; cleans complex parts/ configurations	Cleans complex and configurations	High levels of cleanliness
Can be automated	Will flush out chips	Inexpensive
Usable with parts on trays	Simple to operate	Will flush out chips
Low maintenance	Usable with parts on trays	Simple to operate
May be performed at ambient temperatures	Can use existing vapour degreasing equipment with some modifications	High volume
Spray unit may be portable		
DISADVANTAGES		
High cost	Requires rinse water for some applications	Requires rinse water for some applications
Requires rinse water for some applications	Harder to automate	Not effective in cleaning complex parts
Limits part size and tank volumes	Requires proper part orientation and/or changes while in solution	May require separate dryer
May require separate dryer	May require separate dryer	

Aircraft maintenance typically represents a mixture of small and medium scale applications. Operations also involved straight forward metal cleaning as well as advanced precision cleaning. Table 3.7 below represents typical solutions to the use of ODS at one aircraft maintenance facility (12)

Table 3.7 Alternatives Opted at the Aeronautical Precision Equipment Processor.

Area	Application	Alternative	Phase out/problem	Emission
Avionics	Manufacture/ Modifications/ Maintenance (MMM) (e.g gyros, electronics, electro-mech)	- Alcohol (industrial spirit A, ethanol, 2- propanol, IPA) - IPA, aqueous alkaline- Filtered-Pressurised IPA rinse - Exosol D60/80, Actrel 3338L, with & without: - NAPPAR cold cleaning - PFC	Phased out CFC-113	
- Surveillance/ optics/Missiles	MMM	as above	Krytox grease (problem solved)	
- Countermeasures		as above	Supplier-spec.(MIL) (problem solved) CFC-113 phased out	
- Electronic	MMM	as above,	Supplier-spec.(MIL) (problem solved) CFC-113 phased out	Tot Ind. spirit A=600kg
Motors				
- Lapping	MMM	as above	CFC-113 phased out	Ind sp A 3600kg
- Mounting	MMM	as above		

- Caution should be practised with use of IPA with titanium and beryllium components.

- Caution should be practised with ultra-sound alkaline aqueous with some coated products.

Alternatives investigated:

- aqueous based (eg alkaline, terpenes) with ultra-sound

- IPA, acetone, with ultra-sound and vapour zone

- Cold cleaning with deaerated HC (e.g. Exosol D60) under pressure and or ultrasound.

NB: Where applicable, Ultra-sound, high pressure, and prefiltration is being practised

3.5 Other Uses of ODSs (3,16)

3.5.1 Drying of Components

Rapid drying of components in some application is a critical function. A number of technologies exist for drying, including:

- Centrifugal drying
- Cold/hot forced air/inert gas
- Infra-red lamps
- Vacuum drying
- Absorbent drying (e.g alcohol)
- Vapour phase displacement drying (perflouorocarbon; alcohol, acetone etc)
- Oil displacement

Table 3.8 Summarises a comparison of drying techniques (3, 17)

Table 3.8 Comparison of drying techniques

Dewatering/drying Technique	Advantage	Disadvantage
Centrifugal processing and hot air drying	Low equipment cost, handling	Can be used for simple shaped products. High energy costs, spots
Absorbent drying using alcohol	Drying at room temperature	Large solvent consumption. Fire protection measures are required
Displacement drying with HCFCs and HFCs	Satisfactory drying at 50°C or below	High costs of solvents. ODP and high GWP
Displacement drying with chlorinated solvents	Proven, reliable, possible to retrofit equipment	Possible incompatibility with materials. Requires careful management and handling
Displacement drying with ketones, alcohols	Proven, reliable.	Possible incompatibility with materials. Requires fire control measures. Expensive equipment.

The following alternatives are feasible for the other uses of ODSs in the engineering industry:

- 3.5.2 Drying after cleaning. Drying can be done by e.g. centrifuging, hot air or under nitrogen atmospheres. Steam with or without chemical additives is also used. Other drying agents are alcohols (isopropyl alcohol, ethanol), acetone and perfluorocarbons.
- 3.5.3 Carriage of special greases. In some cases the grease can be applied mechanically directly. In other cases water-based emulsions can serve as carriers of the grease. Solvent-based emulsions that are compatible with the perfluorinated grease can also be used for these purposes.
- 3.5.4 Leak detection in conjunction with maintenance can be done with helium.
- 3.5.5 Use of ODDs (e.g. CCl₄, CFC-113) as a standard laboratory solvent e.g. as per Swedish Standard SIS 028145 which mandates use of CFC-113 for oil/grease analyses. This is assessed to be difficult area to remedy. Use of ODSs in analyses has been proposed for a UNEP exemption for the near future.
- 3.5.5 Use of CFC-113 for decontamination in the nuclear industry can be replaced by aqueous cleaning whereby the object is blasted with a slurry of water and aluminium oxide/glass in particulate form (0.1 mm). The water from the collected residue is evaporated while the solid residues are immobilized and disposed of as radioactive waste.
- 3.6 Possible environmental problems with the alternatives.

A criteria for hazard evaluation being developed for the European Community is depicted in Table 3.9. the major concern are the biochemical degradation, acute toxicity and bioaccumulation potentials. For the case of volatile organic compounds (VOC) which give rise to increased "low level" atmospheric ozone levels (in contrast to stratospheric depletion of the ozone layer) Table 3.10 depicts a

classification that can be used as a guide for adequate counter measures according to domestic regulations.

Table 3.9 Criteria values used as a guide for determining the environmental toxicity of a system

Parameter	Test Method	Criteria Value
Biochemical degradation	OECD's test (Ready bio-degradability)	$BOD_5/ThOD \leq 60\%$ $DOC_{20} \geq 30\%$ $BOD_5 \leq 50\%$
Toxicity:		
Rat		$LD_{50} \leq 25\%$
Fish		$LC_{50} \leq 0.1 \text{ mg/l}$
Daphnia		$EC_{50} \leq 0.1 \text{ mg/l}$
Algae		$EC_{50} \leq 0.1 \text{ mg/l}$
Bioaccumulation		
Bioconcentration		$BCF \geq 100$
Octanol/water		$K_{ow} \geq 1000$
Molecular weight		$M \leq 1000$

BOD = Biochemical Oxygen Demand (5; 28 days resp.)

DOC = Dissolved Organic Carbon

LD = Lethal Dose

LC = Lethal Concentration

EC = Effect Concentration

BCF = BioConcentration Factor

K_{ow} = Coefficient of Partition (n-octanol/water)

M = Molecular weight

Table 3.10 Classification of Volatile Organic Compounds (VOCs) (3).

<u>More important VOCs</u>	<u>Comments</u>
Alkenes Aromatics Alkanes Aldehydes Biogenics	> C6 alkanes except 2,3 dimethylpentanes All aldehydes and benzaldehyde Isoprene
<u>Less important VOCs</u>	
Alkanes Ketones ketone Alcohols Esters	C3 - C5 alkanes and 2,3 dimethylpentane Methyl ethyl ketone and methyl t-butyl Ethanol All esters except methyl acetate
<u>Least important VOCs</u>	
Alkanes Alkynes Aromatics Aldehydes Ketones Alcohols Esters Chlorinated hydrocarbons	Methane and ethane Acetylene Benzene Benzaldehyde Acetone Methanol Methyl acetate Methylene chloride Trichloroethylene, tetrachloroethylene

Waste from cleaning processes contain solid residues, hydrocarbons, solvent and water. Waste should be treated with recirculation of some materials and/or sent for destruction.

The alternatives to CFCs may give rise to new environmental problems. These can be divided into:

- **Water pollution** with increased discharges of e.g. heavy metals, tensides (nonyl phenoethoxylates (NPE) and nonyl phenols (NE)) and complexing agents. These pollutants can cause adverse biodegradability and/or synergistic toxicity, e.g. NPE and NE are targeted for introduction into the OECD risk reduction programme.

New technology based on e.g. chemical precipitation, filtration, reverse osmosis, ion exchange, adsorption, evaporation etc. can drastically reduce effluent volumes.

Such systems are already on the market.

- **Air Pollution** Increased emissions of volatile organic compounds (VOCs) contribute to formation of atmospheric ozone and the greenhouse effect. Certain other compounds (e.g. 1,1,1-trichloroethane, HCFCs) also contribute to depletion of the stratospheric ozone layer.

Appendix 6 summarizes guidelines for what is considered to be the best available technology, BAT, for some of the alternative methods, which do lead to increased VOC emissions. It is estimated that the solvent emissions can be reduced by 80-90 percent if these recommendations are followed. This means that solvent losses can be reduced from 2-5 kg/h,m² of bath area with conventional practice to 0.2-0.5 kg/h,m² of bath area. For certain alcohol-based and partially aqueous systems, the losses are around 0.03-0.05 kg/h,m² (3,16).

- **Occupational hygiene standards** and fire safety standards must also be met when alternative solvents are used. Regarding fire safety, taking the use of ethanol within enclosed fortifications, as an example, LEL = 67 g/m³, density 0.8 g/ml. (LEL = lower explosion limit).
 - At an evaporation rate of 10 l/8h a minimum ventilation of 140 m³/h per machine may be required (i.e at a concentration limit 10 percent LEL). Addedly, electrical supply should be clamped via the exhaust channels and the door handle to the room should be earthed. Adsorption filters within such enclosed room add to the risk and may require additional classifications.
 - Solvent transport and storage in the vicinity of the cleaner should be reduced to the absolute minimum and monitored
 - Alarm systems should be installed and backed up by fire extinguishers (water, or preferably non-halon, foam type).

4.0 PHASING-OUT PROBLEMS RELATED TO SMALL AND MEDIUM SIZE INDUSTRIAL UNITS

Medium and small industrial units (SMIs) in developing countries are typically locally owned enterprises and usually capital stretched. Usually they are understaffed with respect to expertise. A major problem is identification and reach out to these enterprises with information.

Care also has to be exercised that competitiveness between various SMIs is not offset when assistance is availed to one and denied or delayed to another. A phase out programme has to be devised in a manner that unnecessary red tape is minimized and investment is timely. Also an assessed robust and reliable technology has to be provided. It is vital that experts from the implementing agencies take the local conditions into mind. In some countries supply of state of the art equipment may be difficult to obtain in the light of policy from government to save on foreign exchange and desire to develop or use local suppliers. For some alternatives, constant advice and back up support is necessary for some time after commissioning. Unless a framework has been established to take care of problems emanating after start up the exercise of ODS phase out may result in failures.

The MF assistance is devised for coordination via government focal points. This may be necessary for coordination and monitoring purposes but can result in a bottle neck for the users due to inertia in governmental institutions. With rapid phase out occurring in developed countries, pressure is put on so that imports should also be ODS-free or not manufactured with ODSs. This may entail phase out time schedules for SMIs in developing countries, those who depend upon export to developed countries, that comply with those of the developed countries. Some countries are introducing labelling requirements for products manufactured or containing ODSs. This aspect is an extra burden for the local SMIs.

It is important in light of above to have an implementing mechanism that addresses or is able to cope with contingencies arising in cases of delays.

Firstly it is vital to advise SMIs about what costs are eligible for funding. This issue is addressed further in Section 5 below. Secondly it is vital that a transfer of know-how is made to local experts who have the time to put together relevant packets within a specific time period. This issue is addressed in Section 6 below. There is the advantage of achieving an economy of scale as well project appraisal robustness for all parties involved, i.e. SMIs, local government, the implementing agency, the MF and donors. Lastly, in reiteration, a back-up support mechanism (i.e. domestic technical expertise) needs to be in place that recognizes local short-comings and can troubleshoot in time and at low cost.

5.0 COST OF PHASING-OUT (INVESTMENT COSTS, OPERATING COSTS, INCREMENTAL COSTS)

Montreal Fund assistance essentially provides funding for incremental cost reimbursement to the local enterprises (18, 19).

Basis for incremental Costs Calculation Method can be summarised as follows:

1. Determine all eligible capital costs using detailed budget estimates (consider estimates from more than one supplier). Taxes levied on equipment purchases or imports must be excluded from investment costs calculations. Include all one-time costs that are directly related to ODS reduction, including:

- design
- equipment
- patents or licenses
- construction
- installation
- training
- start-up
- permanent working capital

The subproject proponent is also entitled to reimbursement for any expenses incurred during project development including preparation of the preinvestment study or any environmental impact study/statement. ODS phase out project development costs that can be documented by the SMIs should be included in the investment costs.

2. Determine the economic life of the investment. Typically the economic life of an investment is the period over which the capital investment is depreciated.
3. Calculate the net present value (NPV) using a discount rate equal to the opportunity cost of capital for the cumulative incremental recurring costs/savings over the economic life of the project.

NPV of recurring incremental costs and savings may be calculated using a discount rate equal to the discount interest rate (or incremental cost of capital) using the following formula:

$$NPV_{n,n} = \frac{\sum_{i=1}^n R_i}{(1 + DI)^i}$$

where

$NPV_{n,n}$ = NPV of incremental costs or savings

R_i = Net operating costs of the i the year

DI = Discount interest rate or incremental cost of capital (ICC)

n = Economic life of investment, generally taken as 10 years.

Table 5.1 below reproduces the results of NPV_{rec} calculations for $R_i = 100$, $DI = 10\%$ and $n = 1, 2, 3, 4$ and 10 years

Table 5.1 NPV values for years 1-4 and 10.

	Year 1	Year 2	Year 3	Year 4	Year 10
Annual Incremental Operating Costs, R_i	100	100	100	100	100
NPV_{rec}	90.91	173.55	248.69	316.99	614.46

Determination of incremental recurring costs/savings requires a comparison between projected baseline operating costs for continued production with ODS and for production using non-ODS technology. Cost estimates should be based on estimates from suppliers. In many cases, the project will not effect recurring costs, i.e. the operating costs will be the same as before adoption of alternative technology. In such instances, the incremental recurring costs will be zero. Reimbursement for recurring costs according to the MF is limited to four years. Reimbursement for longer periods need to be approved on a case by case basis. Depreciation and interest are not to be included in the incremental operating cost calculations. Eligible incremental operating costs/savings may include:

- Raw materials and components
 - Electricity and other utilities
 - Labour
 - Maintenance
4. Calculate the NPV of any benefits that result, such as revenues from sales of recycled ODS using a discount rate equal to the opportunity cost of capital. In most cases, projects will not affect revenues.
 5. Total incremental costs of a project may be calculated by employing the following formula:

$$T = C + NPV_{rec} - NPV_{rs}$$

Where

T = Total incremental costs

C = capital costs

NPV_{rec} = NPV of incremental recurring costs

NPV_{rs} = NPV of incremental recurring savings

For projects with no recurring savings or net benefits the above exercise is sufficient.

6. Unit abatement costs (UAC) is an indicator of the cost effectiveness in terms of ODS reduction. The UAC is the annual cost required to eliminate 1 kg of ODS weighted for its ODP value. UAC indicator helps set priorities among ODS reduction projects. The most cost effective projects, those with the lowest UAC, should in most cases be implemented ahead of projects with a higher

UAC. It may borne in mind, however, that UAC is only one indicator of cost effectiveness for ODS phase-out projects. Other considerations, e.g. the cumulative ODS savings are also important effectiveness indicators. UAC can also be used to compare the costs among countries for similar projects.

$$\text{UAC} = \frac{\text{C(F)} + (\text{OC-OS/R})}{\text{ODP}}$$

Where

UAC = Unit abatement cost USD/kg ODP/year

C = ODS reduction investment cost, including all initial one time costs such as technology and training

F = Capital recovery factor; the annualized capital cost charges discounted at a standard rate of 10 percent per year over the economic life of the investment

OC = the annual incremental operating costs in the first year of full operations
OS/R = the annual incremental operating savings or revenue in the first year of full operations

ODP = the annual ODS reduction at the first year of full operations expressed in ODP units

Calculation of C(F): The annualized investment costs considers the total investment plus the amount of interest that would be repaid over the life of the project if the investment were a loan and if the loan was repaid in equal instalments.

Case 1: Interest (discount) rate 0% (no time value for money)

C = Investment = USD 100 000

Economic life 10 years

Discount rate = 0%

Annualized investment cost C(F) = USD 10 000

Case 2: Interest (discount) rate 10% (as used in the UAC formula)

C = Investment = USD 100 000

Economic life 10 years

Discount rate = 10%

Annualized investment cost C(F) = USD 16 275

Table 5.2 below reproduces a typical breakdown of incremental operating costs/savings in the solvents sector

Table 5.2 Breakdown of Incremental Operating Costs/savings

	Description	Unit	Unit cost, US\$	Qty	Pre-project total cost, US\$	Post-project total cost, US\$
A.0	Solvent/media costs per year					
A.1	CFC-113/Methanol	kg	5.00	15,000	75,000	
A.2	MCF	kg	1.50	60,000	90,000	0
A.3	Plastic wet-media	kg	6.00	7,000	0	42,000
A.4	Water (90 % recycling)	m3	0.20	6,000	0	1,200
B.0	Electricity costs per year					
B.1	Current systems	kWh	0.10	36,000	3,600	0
B.2	Wet-media process	kWh	0.10	1,500,000	0	150,000
B.3	Aqueous cleaner	kWh	0.10	30,000		3,000
C.0	Water treatment costs per year					
C.1	Media regeneration					5,000
C.2	Filter maintenance					3,000
	TOTAL PRE-PROJECT COSTS/YEAR				168,600	
	TOTAL POST-PROJECT COSTS/YEAR					204,200
	TOTAL INCREMENTAL COSTS/YEAR				35,600	

Some benchmark unit abatement costs have been published by the World Bank (Sourcebook of Benchmark Unit Abatement Costs, October 1992). Table 5.3 summarizes rounded costs for the Metal and Precision cleaning solvents subsector:

Table 5.3 Some benchmark unit abatement costs for the solvents sector

Sector	Title	UAC (USD/kg ODS)	
		Batch	Continuous
Solvents	Reduction of CFC emissions	0.6	1.9
	Recovery/recycling of MC	1.6	6.8
	Substitution of CFC-113 with HCFC	1.5-2.8	1.4
	Substitution of MC with HCFC	0.3-2.9	5.3-7.1
	Substitution of MC with organic solvents	8.7-11.1	4.1-5.8
	Substitution of MC with chlorinated solvents	20.5-22.8	4.2-5.9
	Substitution of MC with semi-aqueous clean	0.2-2.6	5.8-7.5
	Substitution CFC-113 with semi-aqueous	0.04-1.3	1.8-3.7
	Substitution of MC with aqueous cleaning	7.2-9.6	4.5-6.2
	Substitution of CFC-113 with aqueous cleaning	3.4-4.7	1.3-6.2

Some additional comparisons of costs are tabulated below for systems discussed above.

Table 5.4 Estimate of Capital and Operating Costs (20).

Application: Removal of machinery oils and soils from small metal parts and stamping			
Production Load: 18 m ² /h (1440 m ² /wk)			
Bath life: 64 h without recovery			
	AQUEOUS SYSTEM WITHOUT RECOVERY USD	AQUEOUS SYSTEM WITH RECOVERY USD	SOLVENT (TCE) HALOGENATED USD
CAPITAL COSTS			
Equipment			
- 1020 l tank with heater (9100 x 9100 x 12200 mm)	7 300	7 500	
- Rinse tank	6 750	6 750	
- Conveyor	800		
- Ceramic membrane recovery system (0.1 m ³ /h)	-	21 000	
- Drying Unit, 25 kWh (9100 x 9100 x 12200 mm)	15 800	15 800	
Total Capital Cost (CC)	30 850	51 850	
OPERATING COSTS			
	USD/y	USD/y	USD/y
- Cleaner cost			
a) (125 l concentrate/1155 m ² x 1440 m ² /w x 52 w/y x 2.33 USD/l)	18 900		
b) (46% of (a) USD 18 900/y)		8 700	
c) Electricity (7.5 hp x 0.745 kWh/h x 260 d/y x USD 0.06/kWh x 16 h/d)		1 400	
d) Chemical cleaning (1 lot x USD 7/lot x 52 d/y)		360	
e) TCE, 0.86 USD/kg (45.8 t/y)			39 400
- Water cost (7.6 l/m x 60 m/h x 16h/d x 260 d/y x 0.0008 USD/l)	1 500	1 500	
- Drying cost (20 kW x 40 h/w x 52 w/y x 0.06 USD/kWh)	2 500	2 500	
- Disposal cost			
a) (1135 l of 10% cleaner/1155 m ² x 1440 m ² /w x 52 w/y x 0.09 USD/l)	6 600		
b) (Recovery soil; 19 l/w x 52 w/y x 0.09 USD/l)		90	
c) TCE; (9 drums; USD 175/drum)			1 600
- Maintenance (2% of CC)	600	1 000	
- Labour (2.5 h/w x 52w x 20 USD/h)	2 600	2 600	2 600
(Recovery unit 0.25 h/d x 260 d/y x USD 20/h)		1 300	
- Steam heat (0.83 m ² x 2000 BTU/h.ft ² x 52 w/y x 80 h/w x USD 6/1000000 BTU)	450	450	not included/no chilling cost
Total Operating Costs	33 150	19 900	43 600

Typical investment cost for aqueous based system vary. An indicative cost overview is provided in Table 5.5. Operating cost tend to vary between 10-45 percent and depend upon the scale of operations. The higher operating costs reflect the smaller users.

Table 5.5 Some typical costs and operating costs for a large aqueous system

Supplier	Stage	Construction Material	Dimension mm (hwx)	Capital Cost USD	Annual Operating Cost USD
A	1	Stainless Steel (SS)	350x700	3 100	
B	1	Mild Steel (MS)	550x700	7 300	
B	1	SS	550x700	9 800	
B	2	SS	800x800	27 000	
B	3	SS	1200x2200	61 000	
C	2	SS	900x1300	24 400	
C	3	SS	900x2500	45 000	
D	4	SS	1500x1500	298 000 ¹⁾	24 400 ¹⁾

¹⁾ Includes cost for installation and Ultrafiltration equipment (21).

Table 5.6 Investment and operating costs for Membrane Filtration (Ultrafiltration (UF) and combined UF and Reverse Osmosis (RO)). The capacity has been estimated on the basis of 250 d/y operation with UF-flux of 100 l/m².h and a RO flux of 20 l/m².h (22).

UF Membrane Area m ²	Capital Cost USD	Operating Cost ¹⁾ USD/m ³	UF+RO Membrane Area m ²	Capital Cost USD	Operating Cost USD/m ³	Annual Capacity m ³ /y
1	18300-24400	0.24-0.50	1+5	24400- 61000	0.85-1.22	600
2	18300-36600	0.24-0.50	2+10	30500- 85400	0.85-1.22	1200
3	24400-42700	0.24-0.50	3+15	36600- 97600	0.85-1.22	1800
4	24400-67000	0.24-0.50	4+20	36600-122000	0.85-1.22	2400
5	24400-73200	0.24-0.50	5+25	42700-146300	0.85-1.22	3000

¹⁾ Includes cost for electricity (USD 0.06/kWh), membrane cleaning chemicals & maintenance.

Cost for membrane replacement is excluded from the above estimates. Life span of membranes vary considerably and is a function of pH, operating temperature and material of construction of the membrane. Ceramic membrane lifespans are not yet available. Organic membranes have a life span that varies between 6 months to two years depending on the operating conditions. Membrane costs including module costs are depicted in Table 5.7 below.

Table 5.7 Membrane costs (22).

Membrane	Cost USD/m ²
Ceramic, tubular	3700
Organic, tubular	250
Organic, spiral (RO)	125

Cost for vacuum evaporation equipment varies depending upon maker. Table 5.8 below depicts the range of cost. The annual capacity is based on a 250 day operation per year.

Table 5.8 Investment costs for vacuum evaporation equipment (22).

Capacity l/h	Capital Cost USD	Annual Capacity m ³ /y
20-40	24400- 42700	120- 240
60-100	42700- 67100	360- 600
150-200	54900- 85400	900-1200
200-300	67100-103700	1200-1800
400-500	91500-146300	2400-3000

Energy consumption is dependant on the configuration and ranges between 50-200 kWh/m³ of evaporated fluid. This is equivalent to 3.05-12.2 USD/m³ (0.061 USD/kWh). Maintenance is equivalent to 1,5-2% of investment costs per year. Annual operating cost for treating 1000 m³/y would accordingly be 4.3 USD/m³ on the basis of an energy consumption of 50 kWh/m³ and 13.4 USD/m³ on the basis of 200 kWh/m³. Development with respect to energy effectivization is rapid, however. There are evaporators in the market with an energy consumption of 15 kWh/m³. It may be borne in mind that it is also possible to utilize waste energy for evaporation.

The total costs associated with the phase out of ODS-solvents at an aircraft maintenance facility, equivalent to a grouping of a number of small operations, recently has been estimated at about 700 000 USD equivalent to about USD 54 USD/kg of ODS phased-out (Table 5.9).

Table 5.9. Cost Overview for Substitution of Ozone Depleting Solvents at an aircraft maintenance facility.

No SHOP	DEGREASER No	ODS-Use tonnes/y	ALTERNATIVE	ODS REDUCTION	COST %USD	
1	Engine	1	8.0 (1,1,1-TCE)	- Conservation - Aqueous	40 100	3 000 280 000
2	Avionics/ Oxygen systems I	1	1.6 (CFC-113)	- trichloroethylene - Conservation - PFC/IPA - n-heptane	100 40 100 100	40 000 2 000 55 000 negligible
3	Filter	1	1.0 (CFC-113)	- Conservation - Terpene based - No Clean	40 100 100	2 000 60 000 not available
4	Fuel & Hydraulic	2	2.0 (CFC-113)	- Conservation - Terpene based - Aqueous	40 100 100	3 000 60 000 25 000
5	Aerosols and others	n.a.	1,4 (CFC & TCE)	- HC, HCFC, HFC	100	equivalent
ALL SHOPS Implementation Technical Support Training/Operating		6	14.0	-	100	580 000 186 000 766 000

6.0 METHODOLOGY OF TRANSFER TO ODS-FREE PROCESSES IN RELATION TO SMALL AND MEDIUM SIZE ENTERPRISES

A methodology for facilitating ODS-free Alternative Technology Transfer to Small and Medium Sized Units is needed particularly due to the difficult nature of the exercise. The SMIs are usually numerous, wide spread and in many cases reserved in approaching the governmental establishment. Reaching out to SMIs is a tedious exercise and for a successful implementation of phase out exercise engagement of local expertise is essential. The local expertise should preferably be a production engineering oriented institution and should have chemical expertise on hand. Active engagement of the domestic expert institution, training of its personnel in the various aspects of technology transfer and cost is vital.

Incentives need to be provided to the domestic/regional institution for successful identification and implementation of each projects. Incentives can be pro rata and subject to negotiation.

In the exercise of know-how transfer, initially foreign expertise should be provided for the training of the local experts. The expatriate expertise should demonstrate a full cycle of project implementation. The projects should be preferable of a varied nature both regionally and technology wise. Addedly, it is recommended that the technology should be modern but robust and suitable to the needs of the developing countries.

For the Metal/Precision Cleaning Sub-sector, the scope of an overall programme should provide assistance packets consisting of the following segments:

1. - a systemized reference manual on state of the art ODS-free technologies including good housekeeping practices,
2. - costs associated with the alternatives,
3. - identification and training (including transfer of technology) of indigenous technical institution.

This sub-programme should facilitate local/regional dissemination of technical know-how including awareness packets through indigenous experts. The programme should ensure coordination/implementation of sub-projects with appropriate technology; and provide a collation point (e.g. to various enterprises) for indigenous technical progress in the sub-sectors.

The sub-sectoral local expert institution should also service, by providing monitoring support and data, the National Focal Point responsible for reporting on ODS phase-out progress.

4. - technical back-up/support with collation and trouble-shooting of post installation difficulties with sub-sectoral phase out projects enabling a cost effective phase-out of ODS in programme countries.

5. Independent assessment/review should be catered for to ensure the soundness of the implementing technologies and subsequent commissioning of ODS-free technologies. Independent assessment should also scrutinize the quality of back-up service being provided to the SMIs by the domestic/regional institution.

7.0 TRAINING NEEDS

Training needs for implementing ODS-free technology in the metal and precision cleaning sub-sector is dependant upon the availability and identification of qualified local institution. These may be local or regional in reach. A training exercise would need to be adaptable for each circumstance. The main aspects of the exercise can nevertheless be identified as follows:

1. Recruitment of local expert/institution or focal point (FP)
2. Selection of a number of geographically out spread sites
3. Designing of a detailed programme addressing:
 - formulation of an appropriate questionnaire
 - data collection on the SMIs
 - analyses of the data
4. Know-how transfer to the FP and SMIs, e.g. on specific focused, reliable and robust technologies
5. Evaluation of a quantum of projects with the FP and NFP, assessment according to MF guidelines and participation in obtaining approval of the projects
6. Implementation of the projects at the SMIs.
7. Monitoring methodology for the implemented projects and provision for rapid local trouble shooting with the SMIs.

8.0 REFERENCES

1. UNEP Ozone Secretariat; Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer, 3rd Edition, August 1993
2. UNEP IE/PAC; Ozone Action No.7, June 1993
3. UNEP Solvents, Coatings, and Adhesives Technical Options Report; December 1991.
4. UNEP/OzL.Pro/ExCom/5/5/Rev2, ExCom/5/16; Procedures for Presentation of Country Programmes and Project Proposals to the Executive Committee, 1993
5. Multilateral Fund for the Implementation of the Montreal Protocol; Information 1993.
6. UNEP/OzL.Pro/WG.1/9/4, Proposed Three Year Plan and Budget of the Multilateral Fund (1994-1996); Sept. 1993.
7. Ahmadzai, H.; Phasing-out Ozone Depleting Solvents; India Sectoral Workshop, New Delhi, July 1993.
8. JICOLP/MITI; Manual for Reductions in the Use of Ozone Depleting Substances; February 1992.
9. Ardebrant, H. et al; Rengöring av produktionsytor; IM-3008/YKI-B310; August 1993.
10. Ardebrant, H. et al; Rengöring av metallrytor - en översikt; IM-2907, YKI-B282, IVL A-820; October 1992.
11. Isaksen, I.S.A.; Study pertaining to preliminary measures to abate polyfluorinated carbons; Report to Naturvårdsverket, Project 553-1682-93; October 1993.
12. FMV-FFV Arbetsgrupp; "Freonavveckling" - Sammanträdesanteckningar med delrapporter; Archives Naturvårdsverket; 1988-1991.
13. ICOLP/US EPA; Eliminating CFC-113 and Methyl Chloroform in Aircraft Maintenance Procedures; October 1993
14. Norrby, C. and Skogsmo; Handbok för industriell avfettning; IVF/CNY 3007/AA14; April 1993.
15. Cider, L; Testing of Cleaning Equipments and Cleaning Agents; IVF Internal report 92/23.
16. Naturvårdsverket; Avvecklingen av CFC inom elektronik- och verkstadsindustrin i Sverige; Rapport 3870, December 1990

17. Thiokol Corporation Space Operations; Essential Use Exemption Request; NASA Contract NAS8-38100; June 1993.
18. IBRD; Pro Forma Sub-project Appraisal Document; April 8, 1993
19. UNIDO; A Sample Project Proposal for the Multilateral Fund for the implementation of the Montreal Protocol; June 1993
20. Rose, K.J.; The Brulin Corporation, Personal communications, Nov.1 1993.
21. SAS; Phase-out of Ozone Depleting Solvents at Thai International Ltd, Maintenance Center, Internal Report January 1994
22. Ekengren, Ö. and Tolf, J.; Recirkulerings- och slutbehandlingsteknik - Delrapport till projektet "Rengöring av metallytor"; IVL A876; August 1993.

APPENDIX 1

**STATUS OF RATIFICATION OF THE MONTREAL PROTOCOL AND LIST
OF COUNTRIES ELIGIBLE FOR FUNDING**

The Montreal Protocol, as amended in London, Article 4, controls trade of Parties with non-Parties. As of January 1993, each Party shall ban the export of substances in Annex A (5 main CFCs: CFC-11, CFC-12, CFC-113, CFC-114, CFC-115 and halons) and, as of 10 August 1993, the export of substances in Annex B (other CFCs, carbon tetrachloride and methyl chloroform (1,1,1-trichloroethane)) to any non-Party. For the purpose of Annex B, any Party which has not ratified the London Amendment is a non-Party.

Paragraph 8 of Article 4, however, provides for a non-Party being exempt from trade restrictions if it provides data to prove compliance with the Protocol. Non-Parties, whether to the Montreal Protocol or to its London Amendments, that furnish data before 31 March 1993 will be exempt from trade restrictions until the 5th Meeting of the Parties (November 1993), which will examine their data. Article 5 Parties benefit from a 10 year grace period for phasing out the controlled substances for their basic domestic needs.

Only developing countries which are parties to the Protocol and whose annual per capita consumption of ozone depleting substances is less than 0.3 kg are eligible to receive assistance from the Montreal Ozone Trust Fund. These Parties are referred to as Article 5 countries.

Parties to the Montreal Protocol (117 Parties; as of June 1993) are as follows.

* Asterisks denote Article 5 Parties; Ratifiers of the London Amendment are underlined.

<u>Algeria*</u>	<u>Antigua and Barbuda*</u>	<u>Argentina*</u>	<u>Australia</u>
<u>Austria</u>	<u>Bahamas</u>	<u>Bahrain*</u>	<u>Bangladesh*</u>
<u>Barbados*</u>	<u>Belarus</u>	<u>Belgium</u>	<u>Botswana*</u>
<u>Brazil*</u>	<u>Brunei Darussalam*</u>	<u>Bulgaria</u>	<u>Burkina Faso*</u>
<u>Cameroon*</u>	<u>Canada</u>	<u>Central African Republic*</u>	
<u>Chile*</u>	<u>China*</u>	<u>Costa Rica*</u>	<u>Cote d'Ivoire*</u>
<u>Croatia*</u>	<u>Cuba*</u>	<u>Cyprus*</u>	<u>Czech and Slovak Rep.</u>
<u>Denmark</u>	<u>Dominica*</u>	<u>Ecuador*</u>	
<u>Egypt*</u>	<u>El Salvador*</u>	<u>European Community</u>	
<u>Fiji*</u>	<u>Finland</u>	<u>France</u>	<u>Gambia*</u>
<u>Germany</u>	<u>Ghana*</u>	<u>Greece</u>	<u>Grenada*</u>
<u>Guatemala*</u>	<u>Guinea</u>	<u>Hungary</u>	<u>Iceland</u>
<u>India*</u>	<u>Indonesia*</u>	<u>Iran*</u>	<u>Ireland</u>
<u>Israel</u>	<u>Italy</u>	<u>Jamaica*</u>	<u>Japan</u>
<u>Jordan*</u>	<u>Kenya*</u>	<u>Kiribati*</u>	<u>Korea (Rep.)</u>
<u>Kuwait</u>	<u>Lebanon*</u>	<u>Libyan Arab Jamahiriya*</u>	

<u>Liechtenstein</u>	<u>Luxembourg</u>	<u>Malawi*</u>	<u>Malaysia*</u>
<u>Maldives*</u>	Malta	<u>Marshall Islands*</u>	
<u>Mauritius*</u>	<u>Mexico*</u>	<u>Monaco</u>	<u>Netherlands</u>
<u>New Zealand</u>	<u>Nicaragua*</u>	Niger*	<u>Nigeria*</u>
<u>Norway</u>	<u>Pakistan*</u>	<u>Panama*</u>	<u>Papua New Guinea*</u>
<u>Paraguay*</u>	<u>Peru*</u>	<u>Philippines*</u>	
Poland	<u>Portugal</u>	<u>Rumania*</u>	<u>R u s s i a n Federation</u>
<u>Saint Kitts and Nevis*</u>	<u>Samoa*</u>	<u>Saudi Arabia</u>	<u>Senegal*</u>
<u>Seychelles*</u>	<u>Singapore</u>	<u>Slovenia*</u>	<u>South Africa</u>
<u>Spain</u>	<u>Sri Lanka*</u>	<u>Sudan*</u>	<u>Swaziland*</u>
<u>Sweden</u>	<u>Switzerland</u>	<u>Syrian Arab Republic*</u>	<u>Tunisia*</u>
<u>Thailand*</u>	<u>Togo*</u>	Trinidad and Tobago*	
<u>Turkey*</u>	<u>Uganda*</u>	<u>Ukrainian SSR</u>	<u>United Arab Emirates</u>
<u>United Kingdom</u>	<u>United States</u>	<u>Uzbekistan</u>	<u>Tanzania*</u>
			<u>(U n i t e d Republic of)</u>
<u>Uruguay*</u>	<u>Venezuela*</u>		
<u>Yugoslavia*</u>	<u>Zambia*</u>	<u>Zimbabwe*</u>	

Parties that did not ratify the London amendment but submitted data in accordance with decision IV/17C:

Belgium, Hong Kong, Jordan*, Malta, Nicaragua*, Sudan*, Turkey*, Uruguay*

Non-Party countries that submitted information pursuant to Decision IV/17C:

Comoros, Congo, Dominican (Rep.), Gabon, Guyana, Lao (People's Democratic Rep. of), Lithuania, Madagascar, Mali, Myanmar, Slovak (Rep.), Solomon Islands, Surinam, Vietnam.

To obtain the most current list of Parties to the Montreal Protocol, check the official "Status of Ratification of the Montreal Protocol" which is updated every month. This document is obtainable from the UNEP Ozone Secretariat, the Fund Secretariat or UNEP IE/PAC.

APPENDIX 2

CFC TRADE NAMES AND CFC-113 CONTENT OF SELECTED PRODUCTS

TABLE -1. CFC TRADE NAMES

Company	Country	Trade Name
ICI	UK	Arklone
Dupont	US	Freon
AroChem	France	Flugene
Hoechst	Germany	Frigen
Kali Chem	Germany	Kaltron
ISC Chemicals	UK	Fluorisol
Allied	US	Genesolve
Montefluos	Italy	Delifrene
Asahi Glass	Japan	Fronsolve
Daikin	Japan	Daiflon
Central Glass	Japan	CG Triflon
Showa Denko	Japan	Flon Showa Solvent

TABLE D-2. CFC-113 CONTENT OF SELECTED PRODUCTS

<u>Company</u>	<u>Product</u>	<u>% CFC-113</u>
Dupont	Freon TMS	94.05
	Freon TES	95.2
	Freon SMT	69
	Freon MCA	62.8
	Freon TA	88.9
	Freon TDF	99.9
	Freon TWD 602	91.5
	Freon TP35	65
	Freon TE35	65
	Freon TMC	50.5
	Freon TF	100
	Freon PCA	100
	Asahi Glass Co., Ltd.	Fronsolve
Fronsolve AE		96
Fronsolve AP		65
Fronsolve AM		50.5
Fronsolve AES		96
Fronsolve AMS		94
Fronsolve AD-7		99.5
Fronsolve AD-9		99.5
Fronsolve AD-17		83
Fronsolve AD-19		82
Fronsolve UF-1		80
Fronsolve UF-4		86
Fronsolve UF-5		90
Fronsolve AC		87.5
Fronsolve AW		97
Nanofron E		96
Nanofron A	75	
Nanofron B	65	
Central Glass Co., Ltd.	CG Triflon	100
	CG Triflon E	96
	CG Triflon P	65
	CG Triflon M	50.5
	CG Triflon ES	95.5
	CG Triflon EE	92
	CG Triflon E35	65
	CG Triflon MES	93.3
	CG Triflon C1	98.7
	CG Triflon D1	99.5
	CG Triflon D3	99.4
	CG Triflon W1	91.2
	CG Triflon A	87.5
	CG Triflon FD	78
	CG Triflon CP	90
CG Triflon EC	85.5	

TABLE D-2. CFC-113 CONTENT OF SELECTED PRODUCTS
(Continued)

<u>Company</u>	<u>Product</u>	<u>% CFC-113</u>
Daikin Industries, Ltd.	DAIFLON S3	100
	DAIFLON S3-E	96
	DAIFLON S3-P35	65
	DAIFLON S3-MC	50.5
	DAIFLON S3-ES	95.3
	DAIFLON S3-W6	91.5
	DAIFLON S3-EN	86
	DAIFLON S3-HN	90
	DAIFLON S3-A	87.5
	MAGICDRY MD-E6	94
	MAGICDRY MD-E35	65
	MAGICDRY MD 201	99.5
	MAGICDRY MD 202	99.5
	MAGICDRY MD 203	99.5
Du Pont-Mitsui Fluorochemicals Co., Ltd.	Freon TF	100
	Freon TE	95.5
	Freon T-P35	64.7
	Freon TMC	50.5
	Freon TES	95.2
	Freon T-E6	94
	Freon T-E35	65
	Freon T-DEC	93.5
	Freon T-DECR	64.5
	Freon TMS	94.0
	Freon SMT	69.1
	Freon T-B1	98.6
	Freon T-DA35	99.7
	Freon T-DA35X	99.6
	Freon T-DFC	99.9
	Freon T-DFCX	99.9
	Freon T-WD602	91.5
	Freon TA	88.9
	Freon MCA	63
ICI PLC	ARKLONE P	100
	ARKLONE PSM	100
	ARKLONE L	97.1
	ARKLONE AS	96
	ARKLONE AM	94.2
	ARKLONE K	75
	ARKLONE W	91.5
	ARKLONE EXT	64.7
ARKLONE AMD	94.1	

TABLE D-2. CFC-113 CONTENT OF SELECTED PRODUCTS
(Continued)

<u>Company</u>	<u>Product</u>	<u>% CFC-113</u>
Showa Denko K. K.	Flon Showa FS-3	100
	Flon Showa FS-3E	96
	Flon Showa FS-3P	65
	Flon Showa FS-3M	50.5
	Flon Showa FS-3ES	96
	Flon Showa FS-3MS	50.5
	Flon Showa FS-3D	99.9
	Flon Showa FS-3W	91.5
	Flon Showa FS-3A	87.5

APPENDIX 3

1,1,1-TRICHLOROETHANE TRADE NAMES AND CONTENT OF SELECTED PRODUCTS

Manufacturer	Trade Name
ICI	Genklene Prepaklone
Dow	Chlorothene* (R) Industrial Solvent Chlorothene* (R) NU Chlorothene* (R) SM Chlorothene* (R) VG Chlorothene* (R) XL Chlorothene* (R) SL Solvent Dowclene (R) EC-CS Dowclene* (R) LS ¹ Dowclene* (R) EC Prelete* (R) Defluxer Solvent Proact* (R) Solvent ² Aerothene* (R) TT Solvent Aerothene* (R) TA Solvent Film Cleaning Grade S.E.M.I. Grade ³ Methyl Chloroform, Low Stabilized - PW ³ Methyl Chloroform, Low Stabilized ³ Methyl Chloroform, Technical
AtoChem	Baltane
Solvay	Solvethane
PPG	Triethane
Vulcan	1,1,1, Tri
Asahi Glass	Asahitriethane
Toagosei	1,1,1, Tri
Kanto Denka Kogyo.	Kanden Triethane
Central	1,1,1, Tri
Tosoh	Toyoclean

* Trademark of The Dow Chemical Company.

¹ 75 percent 1,1,1-Trichloroethane and 25 percent perchloroethane.

² Aerosol Grade.

³ Non-trademark product names.

TABLE D-4. 1,1,1-TRICHLOROETHANE CONTENT OF SELECTED PRODUCTS

<u>Manufacturer</u>	<u>Trade Name</u>	<u>1,1,1-Trichloroethane Content %</u>
Asahi Chemical Industry, Co., Ltd.	ETHANA NU	94
	ETHANA VG	94
	ETHANA AL	94
	ETHANA HT	94
	ETHANA RD	94
	ETHANA IRN	90
	ETHANA FXN	90
	ETHANA SL	94
	ETHANA TS	94
	ETHANA RS	84
	TAFLEN	90
	(Dry cleaning solvent)	
AQUADRY 50	94	
Asahi Glass Co., Ltd.	ASAHITRIETHANE	96
	ASAHITRIETHANE ALS	93
	ASAHITRIETHANE UT	96
	ASAHITRIETHANE LS	96
	ASAHITRIETHANE BS	92
	ASAHITRIETHANE V5	91
	ASAHITRIETHANE EC Grade	96
	SUNLOVELY	95
(Dry Cleaning Solvent)		
Central Glass Co., Ltd.	CG TRIETHANE N	97
	CG TRIETHANE NN	96
	CG TRIETHANE NNA	94
	CG TRIETHANE F	97
ICI PLC	GENKLENE LV	95.2
	GENKLENE N	95.4
	GENKLENE A	96.5
	GENKLENE P	99.7
	PROPAKLONE	89.6
	GENKLENE LVS	95.7
	GENKLENE LVX	90.7
	GENKLENE LVJ	95.2
	GENKLENE PT	99.9
Kanto Denka Kogyo Co., Ltd.	KANDEN TRIETHANE R	97
	KANDEN TRIETHANE H	97
	KANDEN TRIETHANE HA	94
	KANDEN TRIETHANE HAK	93
	KANDEN TRIETHANE E	98
	KANDEN TRIETHANE EP	97
	KANDEN TRIETHANE HB	94
	KANDEN TRIETHANE HC	94
	KANDEN TRIETHANE HF	94

TABLE D-4. 1,1,1-TRICHLOROETHANE CONTENT OF SELECTED PRODUCTS
(Continued)

<u>Manufacturer</u>	<u>Trade Name</u>	<u>1,1,1-Trichloroethane Content %</u>
Kanto Denka Kogyo Co., Ltd. (continued)	KANDEN TRIETHANE HG	94
	KANDEN TRIETHANE HS	99
	KANDEN TRIETHANE HT	97
	KANDEN TRIETHANE N	100
	KANDEN TRIETHANE ND	97
	KANDEN TRIETHANE SR	90
	KANDEN TRIETHANE SRA	91
	KANDEN TRIETHANE EL	97
	KANDEN TRIETHANE ELV	97
Toagosei Chemical Industry Co., Ltd.	Three One-R	96
	Three One-S	95
	Three One-A	95
	Three One-AH	95
	Three One-S(M)	95
	Three One-F	95
	Three One-TH	95
	Three One-HS	95
	Three One-EX	90
	Shine Pearl (Dry Cleaning Solvent)	94
Tosoh Corporation	Toyoclean EE	97
	Toyoclean T	97
	Toyoclean SE	84
	Toyoclean O	100
	Toyoclean HS	96
	Toyoclean IC	91
	Toyoclean NH	96
	Toyoclean AL	95
	Toyoclean ALS	91
Toyoclean EM	96	

APPENDIX 4

SOURCES OF INFORMATION ON MONTREAL PROTOCOL

It is not possible in a publication of this nature to annex all the essential information needed. This part, therefore, provides a list of documents which could be found useful as guides or sources of information needed to prepare country programmes and project proposals for consideration by the Executive Committee. Some of the materials are routinely provided by the Fund Secretariat, the UNEP Ozone Secretariat in Nairobi and UNEP IE/PAC in Paris. However, all the essential documents, including those routinely distributed to governments are listed to make sure that governments or relevant agencies of governments have access to the information available. Addresses of the sources and a brief description of the document, where necessary, have been provided.

SOURCE AND ADDRESS	No.	TITLE OF DOCUMENT	BRIEF DESCRIPTION
The Fund Secretariat Montreal Trust Building 27th Floor 1800 McGill College Avenue Montreal, Quebec, Canada H3A 3J6	1	The Interim Multilateral Fund for the Implementation of the Montreal Protocol	A four page fact sheet on the Interim Multilateral Fund.
	2	Implementation Guidelines and Criteria for Project Selection	Describes the roles and responsibilities of the Executive Committee and the Implementing Agencies, framework for activities supported by the Fund, project eligibility criteria, guidelines for setting priorities, reporting requirements.
	3	Procedures for Presentation of Country Programmes and Project Proposals to the Executive Committee	Describes format and content of country programmes and project proposals and approval procedures.
	4	Guidelines for Presentation of Projects and Criteria for Project Approval	Presents the specific criteria considered in the project approval process.
	5	Bilateral and Regional Co-operation Guidelines for Cost Assessment of Bilateral and Regional Activities	Guidelines for channelling 20% of pledged contribution through bilateral assistance.
	6	Whether Support of the Fund Could be Given Retroactively	Discusses funding prior to a country becoming a Party to the Protocol.
	7	Whether the Fund Should Finance Activities Related to Enterprises that are Wholly or Partly owned by Transnational Corporations	Criteria for financing projects relating to transnational corporations.
	8	Whether the Fund Should Finance Activities Related to Enterprises that are Wholly or Partly owned by Countries that are not Parties to the Montreal Protocol	Criteria for financing projects relating to enterprises which are totally or partially owned by countries that are not parties to the Montreal Protocol.
	9	Further Definitions of Incremental Costs	Highlights practical problems associated with incremental cost assessment and makes practical recommendations for their resolution.
	10	Institutional Strengthening	Guidelines to be followed in applying for financial support for institutional strengthening.
	11	Executive Committee Meeting Reports	Executive Committee Deliberation and discussions

SOURCE AND ADDRESS	No.	TITLE OF DOCUMENT	BRIEF DESCRIPTION
UNEP Industry and Environment Programme Activity Centre 39-43 Quai André Citroën 75739 Paris CEDEX 15 France	12	OzonAction Newsletter	Quarterly newsletter dedicated to ozone protection and the implementation of the Montreal Protocol. Reports on activities and programmes being undertaken under the Montreal Protocol. Available in Arabic, Chinese, English, French and Spanish.
	13	Technical Brochure Series on Protecting the Ozone Layer Volume 1 Refrigerants Volume 2 Solvents, Coatings and Adhesives Volume 3 Halons Volume 4 Foams Volume 5 Aerosols, Sterilants, Carbontetrachloride and Miscellaneous uses	Easy-to-understand documents that provide an overview of the technical options for phasing-out the controlled substances. Based on the UNEP Technical Options Committees reports, they are designed for decision makers in government and industry in Article 5 countries. All brochures available in English, French and Spanish (some to be published in first quarter 1993).
	14	UNEP Regional Workshops	Reports of UNEP's workshop series designed to promote implementation of the Montreal Protocol in Article 5 countries. Workshop reports available for Asia and the Pacific (1991), West Asia and Arabic Speaking Countries (1991), Latin America and the Caribbean (1992), and Africa (1992).
	15	First Regional Training Course on Refrigeration	Report of UNEP's technical training course for Africa, held in Nairobi in December 1992.
	16	OAIC Document Abstracts (OAIC diskette under preparation)	Abstracts and contact information for over 250 publications contained in the OzonAction library. Contains technical, policy, and programmatic literature from around the world.
	Ozone Secretariat UNEP P.O. Box 30552 Nairobi Kenya	17	Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer (1991) and 2nd Edition (1992)
		Montreal Protocol Assessment Panel and Committee Reports (1989) and (1991):	The 1991 editions provide updates. The Refrigeration Panel considers their 1991 report a new version than an update. The reports will be updated annually.
18		Economic Options Committee	Discusses lessons from the transition and the wider policy content - economic efficiency, equity, international trade and environmental policies. Makes a number of recommendations to the Parties.
19		Halons Technical Options Committee	Presents use patterns, emission reduction strategies, halon alternatives, management of banked halons. Discusses special needs of developing countries.

SOURCE AND ADDRESS	No.	TITLE OF DOCUMENT	BRIEF DESCRIPTION
	20	Rigid and Flexible Foams Technical Options Committee	Presents technological options for phasing out CFCs in flexible and rigid foam manufacturing.
	21	Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee	Presents options for eliminating CFC refrigerants and investigates the viability of HCFC and HFC as replacement refrigerants for each end use.
	22	Solvents, Coatings and Adhesives Technical Options Committee	Discusses the solvent, coating and adhesive uses of CFC-113 and methylchloroform and the technical feasibility of replacing them with alternative chemicals or processes.
	23	Aerosol and Sterilants Technical Options Committee	Presents options for eliminating CFCs in aerosol products, sterilization processes. Provides options for replacement of carbon tetrachloride as feedstock and miscellaneous uses and other applications.
	24	Environmental Effects Panel (1989): Environmental Effects of Ozone Depletion; (1991) Update.	Deals mainly with the direct effects of increased ultra-violet B (UV-B) radiation on man and environment. The reports review and integrate scientific information on potential effects associated with ozone decrease in an effort to assist decision makers, particularly those involved in the policy process.
	25	Technology Review Panel (1989); Technology and Economic Assessment Panel (1991)	Provide comprehensive description of technically feasible reduction schedules, integration of the technical information schedules of CFC and halon reductions from the various use sectors and technical considerations of a phase-down. The 1991 report provides estimates and period for use of transitional substitutes and describes implications of 1997 or earlier phase-outs.
	26	Methyl bromide: Its Atmospheric Science, Technology and Economics, Montreal Protocol Assessment Supplement, Synthesis Report	Provides current understanding of the impact of methyl bromide on the ozone layer and on the uses of and alternatives to methyl bromide.
Global Environmental Facility The World Bank 1818 H Street, Northwest Washington, D.C. 20433, USA	27	Sourcebook of Benchmark Unit Abatement Costs (1992)	Responds to the need to determine the relative cost-effectiveness of technically similar ODS phase-out activities across the world and to define a best cost approach to ODS phase-out within and between countries in the face of resource scarcity.
	28	Operational Interpretations of Incremental Costs and Eligible Expenditures	
	29	Ozone Projects Trust Fund Grant Agreement	Indicates the agreement to be concluded between the World Bank and a recipient Government prior to project implementation.

Annex

SAMPLE EXECUTIVE PROJECT SUMMARY (EPS)

This is a sample Executive Project Summary (EPS) is based on a format used by the World Bank and contains the information required for approval by the Executive Committee. In some cases the summary has been exemplified to give a clearer understanding of what information is to be included in a project proposal.

PROJECT COVER SHEET

COUNTRY:	Name of Article 5 country
PROJECT TITLE:	Conversion of CFC Aerosol Plant to LPG
SECTOR COVERED:	Aerosols
ODS CONSUMPTION IN SECTOR:	9420 metric tons CFC 12 in 1991
PROJECT IMPACT (OBJECTIVE):	Phaseout 7,900 metric tons CFC 12 by year 1996
PROJECT DURATION:	Two years
TOTAL PROJECT COST:	US \$5,200,000
PROPOSED ODS GRANT (INCREMENTAL COST):	US \$3,440,000
COST EFFECTIVENESS:	US \$.44/KG ODP
NATIONAL COORDINATING AGENCY:	Ministry of Industries
COORDINATION WITH OTHER IMPLEMENTING AGENCY:	UNEP___ UNDP___ UNIDO___ OTHER

EXECUTIVE PROJECT SUMMARY FOR PROJECTS OVER US \$500,000

TITLE: CFC Conversion to LPG
 COUNTRY: Name of Article 5 country
 COST: US \$5,200,000

BACKGROUND

1. *The background information section describes a project's long and short term objectives by summarizing project goals. It places the project objectives in the wider context of the implementation of the Montreal Protocol for the country.*

This project aims at phasing out chlorofluorocarbon (CFC) consumption in aerosols for the Eastern Province of by establishing a Liquefied petroleum gas (LPG) purification plant and a centralized filling station. The availability of hydrocarbon aerosol propellants (HAPs) and a central filling station in the Provincial Capital will lead to the elimination of one third of 's estimated CFC use in aerosols or about 5,700 metric tonnes in 1995. In 1996, this could increase to 7,900 metric tonnes as the majority of manufacturers in the nearby areas begin to use the provincial filling station.

2. *Information should also be given on the ozone depleting potential (ODP) of the substance to be phased-out and ozone depleting substance (ODS) consumption by sector and year.*

While a final country programme has not been approved, the following preliminary information is available on the aerosols sector. The aerosol sector is characterized by high growth. In 1989 consumption was 2,000 metric tonnes. This figure jumped to 4,800 in 1990. In 1991 aerosol consumption of CFCs reached 9,410 metric tonnes or 19 per cent of total ODS consumption. Of this 9,410 metric tonnes, about 2,300 metric tonnes were consumed in the Eastern Province. If uncontrolled, consumption is projected to reach 23,500 metric tonnes or 27 per cent of estimated ODS consumption in 1996.

PROJECT DESCRIPTION

1. *This should include a brief description of the production facilities, as well as the ownership of the enterprise, clearly stating to which extent it is owned by transnational companies, if any.*

The Chemical Corporation is a totally nationally owned company. About one-third of all aerosol products are produced in and around the capital city. Most are manufactured within 50 kilometres of the capital city's business centre. For this project, the Chemical Corporation will establish an LPG purification plant and a centralized filling station.

2. *The description should explain why the project is needed. (rationale, justification, and explanation of the problem the project is to address).*

The Corporation's development of an LPG purification plant and an HAPs centralized filling station will allow for the immediate replacement of CFCs by both small and large manufacturers in the Provincial Capital area. For small manufacturers, it may not be cost effective to install safety equipment needed to handle filling of flammable propellants. They discontinue their CFC filling operations and contract with centralized filling station for filling propellants. HAPs are typically four times cheaper than CFCs by weight. A portion of this cost saving will be passed on to small manufacturers to encourage conversion to HAPs and to offset transportation costs to the centralized filling station. Larger manufacturers will convert their filling lines for use with HAPs which they will purchase from the Corporation. Imported HAPs can be used by the filling station and large manufacturers until the purification plant is on line.

3. *What are the actions to be undertaken and what is to accomplished?*

This project includes four activities to ensure the successful development and operation of the purification plant and filling station: (i) establishment of a quality assurance laboratory, (ii) development of a safety monitoring programme for the filling and purification plants, (iii) overseas and local training programmes in handling of flammable products, product reformulation and use of other propellant alternatives; and, (iv) lab tests and trial runs.

4. *What is the project relation to and priority within, the Country Programme?*

Previous country investigation have identified this as a high priority phase-out project.

5. *What is the soundness of the technology chosen?*

This project is technically sound, as this provides an immediate reduction in ODS's using proven technology and substitute chemicals that are both proven and available. Conversion of rapidly expanding aerosol industry from CFCs to LPG propellant is the most proven, cost effective option for rapidly reducing and eliminating CFC use in this sector. Another item that must also be addressed in the conversion of CFCs to hydrocarbon propellants is their safe use. National Environmental Protection Secretariat (NEPS) is responsible for assuring that the Government's policy on the shipments of propellants are being met. Retraining of personnel to improve their knowledge of aerosol safety will have to be undertaken. Industrial fire training would also be necessary.

6. *Why is the project eligibil for funding?*

The Country is a Party operating under paragraph 1 of Article 5. It has ratified the 1990 London Amendment to the Montreal Protocol. Based on the information provided above, the project meets the Executive Committee's Implementation Guidelines and Criteria for Project Selection (UNEP/OzL.Pro/ExCom/3/18/Rev. 1 Annex III).

PROJECT COSTS

Total Cost:

1. *What is the rationale for the project's budget estimates ?*

The total cost for this project is estimated at US \$5,200,000. This cost will cover the development of an LPG purification plant and a HAPs centralized filling station, and include many of the compensable cost elements taken note of by the Executive Committee in UNEP/OzL.Pro/ExCom/7/21.

Incremental Cost:

2. *How was the incremental cost calculated ?*

In recognition of the fact that HAPs are cheaper than CFCs and that the positive return on this investment will be achieved in a relatively short time, the incremental cost of the project has been determined to be US \$3,440,000. This was calculated by subtracting from the total capital cost estimate, the net present value of operating costs (\$ X) and benefits (\$ Y) discounted at 10 per cent per year.

- *Note: This part should include an indicative budget figure showing all projected expenditures and the anticipated timing of disbursement. There should also be a description of each budget item as well as explanation of how each budget item is functionally related to activities, rationale for the budget estimates, and explanations of any in-kind contributions and/or bilateral assistance.*

PROJECT FINANCING

1. *Summarize the external and domestic financing arrangements for the project, highlighting complex cofinancing arrangements.*

PROJECT IMPLEMENTATION

1. *Summarize the plans for project implementation and project management arrangements, the names and responsibilities of participating agencies and, if applicable, onlending arrangements. The anticipated start-up and termination date for the implementation of the project and schedule for the various activities designed should also be included.*

The Ministry of Industries will be responsible for overseeing the successful completion of this project. It will be executed by the Chemical Corporation over a two year period following signature of a grant agreement. An indicative schedule of events with estimated timing is included for information:

Project description	June
Project appraisal mission	June
Final project draft	August
Legal document sent	September
Financial negotiations	through December
Documents signed	January
Disbursements	March

Following the signing of legal documents with the Government, the time frame for project implementation, described in annual quarters, could be as follows:

Procurement:	Quarter 1 through 3
Construction:	Quarter 2 through 4
Installation:	Quarter 3 through 5

ENVIRONMENTAL CONSIDERATION

1. *A statement on the environmental soundness of the project, the obligation of the beneficiary companies to comply with existing environmental standards and the mode of environmental review of the project is provided. Environmental screening is conducted during project preparation and finalized during project appraisal.*

PROJECT SUSTAINABILITY

1. *Explain how the project design contributes to the institutional and financial sustainability of the project.*
2. *Explain how the project addresses market imperfections and summarizes the project's loan recovery features.*

LESSONS FROM PREVIOUS EXPERIENCE

1. *Summarize lessons learned by the Implementing Agency (in this case the World Bank) from ongoing and completed operations.*

Aerosol projects have been undertaken in (X countries) and these experiences were taken into account in the development of this project.

PROJECT BENEFITS AND RISKS

1. *Summarize the main project benefits, showing the expected financial and economical rate of return.*
2. *Summarize relevant project risks, indicating key variables influencing project success.*

RATIONALE FOR USE OF MULTILATERAL FUND

1. *Indicate the contributions of the project to the policy objectives, institutional development and other goals for phasing-out ODS that are consistent with the obligations of the country programme and the Montreal Protocol.*
2. *Also, give the estimated cost-effectiveness of the project in US\$ per Kg.*

ISSUES AND ACTIONS

1. *Discuss outstanding project issues and how they should be handled.*

TECHNICAL ASSESSMENT

1. *A technical review should be provided with the project document.*

The Ozone Operations Resources Group (OORG) prepares the technical review on World Bank projects.

APPENDIX 5

CONTACT ADDRESSES FOR OBTAINING FUNDING ASSISTANCE

Interested countries, who wish to seek assistance from the Fund can contact one of the following addresses:

1. The Fund Secretariat

The Fund Secretariat can assist in the identification of an Implementing Agency to help develop a Country Programme or Project Proposal. Please contact the Fund Secretariat at the following address:

Chief Officer

**The Multilateral Fund for the Implementation
of the Montreal Protocol**
Montreal Trust Bldg, 27th Floor,
1800 McGill College Avenue
Montreal, Quebec, Canada H3A 3J6

Tel: (1-514) 282-1122
Fax: (1-514) 282-0068

2. The Implementing Agencies

The Implementing Agencies assisting the Fund are: UNDP, UNEP, UNIDO and the World Bank. They co-operate closely with each other in project and programme design and implementation. Their main fields of activity and contact addresses are as follows:

2.1 The World Bank

The World Bank is involved in developing and implementing investment projects. It assists countries in gathering the necessary data on ODS in the country, defines objectives, target and means, develops projects and calculates costs and benefits. It also assists in preparing Country Programmes. Please contact the World Bank at the following address:

GEF Operations Coordinator
Global Environment Fund
The World Bank
1883 H Street, Northwest
Room S-15041
Washington, D.C. 20433, USA

Tel: (1-202) 477-1234
Fax: (1-202) 477-6391
Tlx: RCA 248423

2.2 The United Nations Development Programme UNDP

UNDP assists eligible Parties in the planning, preparation and implementation of country programmes, projects, institutional strengthening, as well as training and demonstration projects. Please contact the UNDP at the following address:

Montreal Protocol Task Manager
Environment and Natural Resources Group
Room DCI-2056
United Nations Development Programme
New York, New York 10017, USA

Tel: (1-212) 906-5004/5005
Fax: (1-212) 906-5365

2.3 The United Nations Environment Programme UNEP

UNEP assists Article 5 countries through data collection, conducting research, and providing an information clearinghouse function (exchange of information on-line as well as off-line i.e. by diskettes, fax, letters, etc.), training and networking. It also assists low ODS consuming countries in country programme preparation. UNEP's role as an implementing agency is undertaken by UNEP Industry and Environment Programme Activity Centre (UNEP IE/PAC) in Paris. The contact address of UNEP IE/PAC is:

The Director
 UNEP Industry and Environment Activity Centre
 39-43 Quai André Citroën
 75739 Paris CEDEX 15, France

Tel: (33-1) 4058-8858
 Fax: (33-1) 4058-8874
 Tlx: 204997 F
 Cable: Uniterra Paris

2.4 The United Nations Industrial Development Organization UNIDO

The main focus of UNIDO's assistance is on small to medium scale projects. In this regard, UNIDO assists Article 5 countries in the design and implementation of projects identified in country programmes. It also offers support in the identification of opportunities for ODS reduction, as well as in technical assistance and training at the plant level. UNIDO also provides advice to Governments in industrial policy formulation and planning, and assists in the preparation of country programmes in co-operation with other implementing agencies. The contact address of UNIDO is:

The Director
 Industrial Operations Technology Division
 UNIDO
 Vienna International Centre
 P.O. Box 300
 A-1400 Vienna, Austria

Tel: (43-1) 21131-3742
 Fax: (43-1) 230-9615

GUIDELINES AND CONTROL ACHIEVABLE WITH BEST AVAILABLE TECHNOLOGY (BAT) FOR SOLVENT-BASED CLEANING

I GENERAL

Solvent losses are often very great in a conventional or poorly maintained plant. Figure A1 shows characteristic percentage losses for such a plant. In a poorly maintained plant, only about 20 percent of the purchased solvent quantity is generally recovered.

Depending on what measures have already been adopted at a plant, application of the guidelines summarized below can enable total emissions to be reduced by 90 percent.

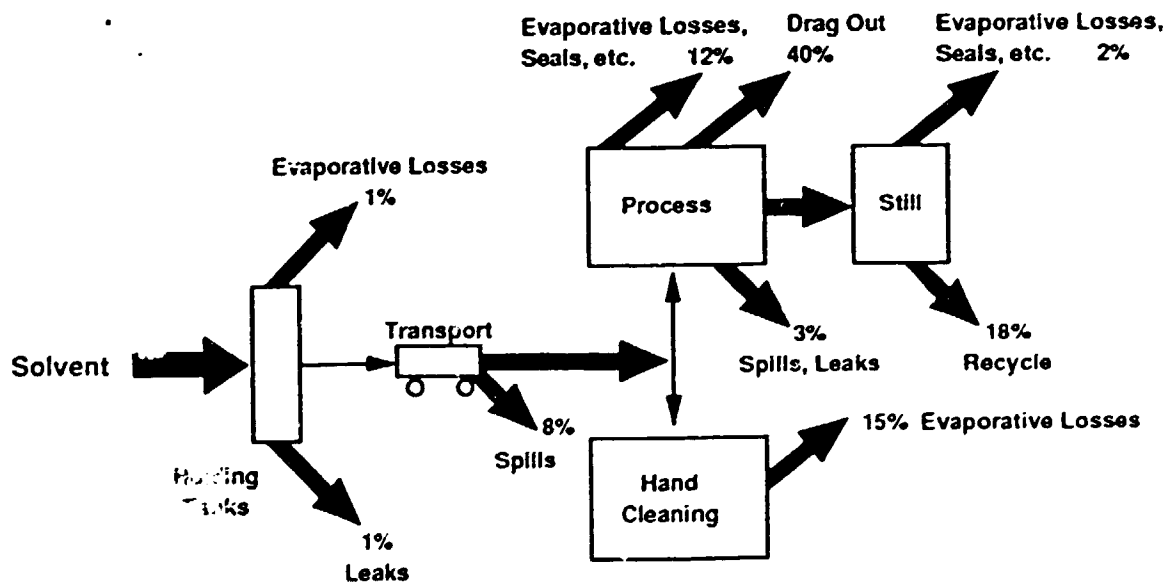


Figure A1. Solvent losses in a typical, poorly maintained plant.

The guidelines are concerned with the best available technology for the following:

- cold cleaning
- vapour cleaning (including equipment with spray/ultrasound)
- continuous "in-line" cleaning

II DESIGN OF THE CLEANING EQUIPMENT

1. Cover

For processes where the solvent has a vapour pressure > 2 kPa (15 mm Hg) at 38°C (e.g. all chlorinated solvents), or

- the solvent is heated, or
- the solvent is agitated mechanically, or
- where the equipment's opening is > 1 m²

it should be possible to operate the cover automatically, or easily with one hand. Cover design (e.g. guillotine-type action) should permit operation that does not create turbulence in the vapour zone. The equipment should be designed so that the cover(s) opens and closes only during charging or discharging of the workload (e.g. air lock).

2. Arrangement for drainage of cleaned components.

For solvents with a vapour pressure > 2 kPa (at 30 mm Hg, 38°C), drainage should take place inside the machine with the cover closed.

3. Safety devices

To prevent solvent evaporation during equipment stoppages, the following safety devices should be installed:

- a) The flow of liquid to the condenser and heating element should be monitored by monitors and thermostats ($< 18^\circ\text{C}$), and the equipment shut off in the event of a circulation stoppage or overheating.
 - b) Spray monitor that shuts off the spray device if the vapour level drops 10 cm.
4. Operating instructions should be posted visibly and should summarize all operating steps.
 5. Design of solvent spray.

To conserve solvent, the spray should be of the continuous type (not atomizing). The nozzle pressure should be regulated so it does not give rise to excessive splatter.

6. Design of work load carrier.

Components should be fed in automatically. The design of the work load carrier should facilitate drainage and not cause a "piston effect". A hook arrangement is preferable.

7. For solvents with a vapour pressure > 4 kPa (30 mm Hg, 38°C), or solvents that work at temperatures > 50°C, the following features should be incorporated where technically feasible:

- freeboard zone ratio⁴ should be 0.75-2.00, preferably ≥ 1.0 (ratio B/A in fig. A2)
- water cover (the solvent should not be water-soluble and should be heavier than water) should be ensured. Water cover counteracts evaporation of solvent (to the atmosphere).
- refrigeration coil (mandatory with vapour cleaners), should have a working temperature of about -25°C. A defroster should be included. The following capacities can be adequate for this purpose:

Bath width (m)	Cooling capacity (W/m circumference)
< 1.0	190
> 1.0	290
> 1.8	385
> 2.4	480
> 3.0	580

- adsorption filter based on e.g. activated carbon, zeolite or polymer, shall be rated to ensure good function (at least 90-95 percent efficiency), so that outgoing solvent concentrations do not exceed 25 ppm⁵ toward the end of an adsorption cycle. The ventilation air flow should be 15-20 m³/minute and m² bath area.
- other technology (e.g. thermal destruction) that can ensure a better or more efficient control of emissions than that described above.

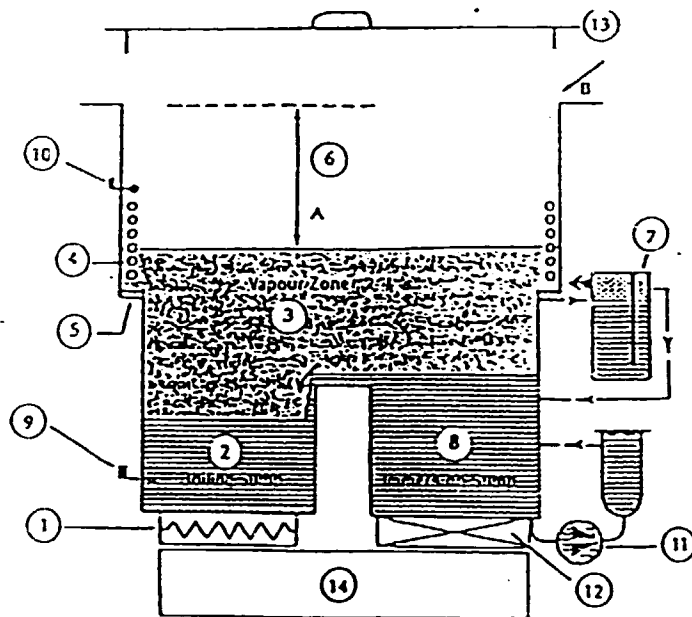
8. Design of devices for transport, filling and emptying of solvent.

Devices for transport, storage and discharge of volatile solvents should be built as closed-loop systems.

⁴The freeboard zone ratio is the ratio between the distance from the vapour level to the rim of the tank (the freeboard height) and the width of the equipment.

⁵Concentration in mg/m³ = ((molar weight in g)/22.414) * (concentration in ppm)

NOTE: 22.414 = molar volume expressed in litres at 0°C and 101.3 kPa.



- | | |
|-------------------------|---------------------------------|
| 1. Heating element | 8. Immersion sump |
| 2. Boiling sump | 9. Low level safety cut-out |
| 3. Vapour zone | 10. Vapour level safety cut-out |
| 4. Condenser | 11. Recirculation pump/filter |
| 5. Condensate trough | 12. Ultrasonic transducer |
| 6. Freeboard zone | 13. Removable cover |
| 7. Condensate separator | 14. Refrigerator |

Figure A2. Batch vapour cleaning system

III OPERATION OF THE CLEANING EQUIPMENT

1. **SOLVENT LOSSES SHOULD NOT EXCEED 10-20 WT PERCENT OF PURCHASED QUANTITY. SPENT SOLVENT SHOULD BE TRANSPORTED AND STORED IN CLOSED VESSELS ONLY.**
2. Close the cover after each concluded work operation in the cleaning bath.
3. Place the components in a manner that permits complete drainage of solvent. The speed of component feed should not exceed 3 m/min vertically, 3-6 m/min horizontally. A slower feed speed is preferable (modern equipment permits horizontal speeds of 0.5-2.0 m/min and 0.3 - 0.8 m/min vertically). Clean in the vapour zone for at least 30 s or until condensation on the components ceases. Allow clean components to drain for at least 15-30 s or until they stop dripping. During vapour cleaning, components should drain until they are visibly dry.
4. Never clean porous materials (e.g. cloth, leather, rope) or absorbent materials in the vapour zone.
5. The horizontal area of the workload should not exceed half of the bath

area.

6. The distance between the workload and the edges of the opening at entry and exit should be < 10cm or < 10 percent of the width of the opening (calculated on the basis of the workload silhouette).
7. The vapour level should not drop more than 10 cm when the workload is introduced into the vapour zone.
8. Never spray above the vapour level. Avoid spraying with cold solvent.
9. Leak detection of the entire system should be done regularly. The system includes cleaning and peripheral equipment (filters, storage and filling/-emptying devices etc.). In the event of leakage, the equipment must be shut off and repaired immediately. A floor sump should be provided for collection of spillage.
10. The ventilation air flow should not exceed 15-20 m³/min,m² of bath area unless a higher rate is required to meet mandatory work hygiene limits. Ventilation fans shall not be positioned near the bath opening.
11. Water should not be visible in the solvent leaving the condensate separator (vapour cleaning system). Water forms a low-boiling azeotrope, increases solvent consumption and causes corrosion damage.
12. Shut off the equipment (vapour cleaning) if it is expected to remain idle for more than 2 hours.
13. Use of solvent filter will extend solvent life and reduce the amount of solvent waste. In general, solvent should be changed when the contamination level reaches about 10 percent by volume. Solvent should be added via closed-loop systems with entry below the liquid surface.
14. Check the pH regularly, adjust as necessary. More often, solvent suppliers recommend monitoring of the acid acceptance of the solvent. The procedure may differ but it is imperative that these recommendations are followed to avoid equipment corrosion problems.

IV WASTE TREATMENT AND DISPOSAL

Waste from degreasing processes are primarily hydrocarbons and solid residues. Depending upon the pretreatment, waste can contain anywhere from 20-70 percent solvent and water condensate. In some cases distillation can be used to concentrate soils and recover solvent for reuse. Distillation combined with ultra-filtration and desiccation can produce virgin quality solvent product assuming no other solvent may have been introduced as a contaminant. The oil can be concentrated for reuse.

Waste waters can be treated by e.g. activated carbon to remove trace solvent. Unrecoverable solvent wastes can be neutralised by incineration operating with appropriate pollution mitigation equipment.