



**PROCEEDINGS OF THE  
U.S. ENVIRONMENTAL PROTECTION AGENCY  
WORKSHOP ON  
INTEGRATING CASE STUDIES CARRIED OUT  
UNDER THE MONTREAL PROTOCOL**

**January 15-17, 1990**

**Washington, D.C.**

**Division of Global Change**

**Office of Air and Radiation**

**United States Environmental Protection Agency**

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2. "Global Environmental Problems - Policy in Mexico", Mr. Sergio Reyes-Luján, Undersecretary for Ecology, SEDUE (Secretaría de Ecología y Desarrollo Urbano.)
3. "Status of Case Study: Egypt", Dr. Ahmed Amin Ibrahim, Consultant for Egyptian Environment Affairs Agency.
4. "Status of Case Study: Brazil", Mr. Alberto Carrizo, White-Westinghouse Climax, Brazil.
5. "Status of Case Study: China", Mr. Zhang Chongxian, Senior Engineer, National Environmental Protection Agency - China.
6. "Overview of UNEP Technical Assessment", Mr. G. Victor Buxton, Environment Canada.
7. "Technology Transfer Projects by the Industry Cooperative for Ozone Layer Protection", Mr. A.D. FitzGerald, Director, Environmental Affairs, Northern Telecom, Canada.
8. "Switch from CFCs to Hydrocarbon Propellants", Mr. Montfort Johnsen, President, Montfort A. Johnsen and Assoc., United States.
9. "Adapting Aerosol Technologies to Developing Country Needs", Mr. Jorge Corona, CANACINTRA (Cámara Nacional de la Industria de la Transformación), Mexico.
10. "Electronics Cleaning in Developing Countries", Mr. Brian Ellis, General Director, Protonique S.A., Switzerland.
11. "Replacement of CFC-113 Solvent", Mr. Bryan Baxter, British Aerospace Precision Products Group, United Kingdom.
12. "Assessment of Alternative Substitutes and Technologies in Refrigeration", Dr. Lambert Kuijpers, Philips Research Laboratories, Netherlands.
13. "Important Considerations in Evaluating Substitutes to CFC Blowing Agents in Foam Plastic Products", Ms. Jean M. Lupinacci, Office of Air and Radiation, U.S. Environmental Protection Agency.
14. "CFCs and HCFCs as Feedstocks", Dr. Nobuo Ishikawa, Director F & F Research Center, Japan.
15. "Halons: Advantages and Disadvantages", Halons Work Group.

ATTACHMENT 4 - Terms of Reference for the Case Studies

ATTACHMENT 5 - Survey Questionnaire for the Case Studies

**APPENDICES**

**SOURCE MATERIALS AND DOCUMENTS DISTRIBUTED AT THE WORKSHOP**

1. "Replacement of CFC-113 in Industry", Swiss Federal Office of Environment, Forests and Landscape.
2. "CFC Alliance Special Bulletin", Alliance for Responsible CFC Policy, United States.
3. "The Destruction of Halons in the Nordic Countries", Jan Bergstrom, Raine Harju, and Eva Hyden, Nordic Council of Ministers' Steering Committee for the Halon Project.
4. "CFCs in India - Phase 1 Work Plan", Avani Vaish, Ministry of Environment and Forests, India.
5. "Protonique News", Protonique, S.A., Switzerland.

## EPA WORKSHOP SUMMARY

The U.S. Environmental Protection Agency (EPA) sponsored a workshop on "Integrating Case Studies Carried Out Under the Montreal Protocol" in Washington, D.C., on January 15 to 17, 1990. The workshop was attended by representatives of government and private organizations from Australia, Brazil, Canada, China, European Economic Community (EEC), Egypt, Federal Republic of Germany, India, Japan, Malaysia, Mexico, Norway, Singapore, Sweden, United Kingdom, United States, Venezuela, the United Nations Development Programme (UNDP), and the World Bank. In addition, a group of experts on various use sectors of CFCs were also present. The purpose of the meeting was to:

- develop a methodology and framework to encourage uniformity between case studies being conducted in various countries;
- obtain first hand information from representatives of various countries on the status of case studies being conducted;
- assemble a group of representatives and experts from various countries to share ideas, provide information, and discuss arrangements for conducting case studies in each country; and to
- identify commercially available, cost-effective, reliable technology that could be used by developing countries to reduce and/or eliminate their particular uses of CFCs, halons, and other ozone depleting chemicals.

Exhibit 1 summarizes the status of the case studies being conducted in various countries.

The Mexican, Egyptian, and Brazilian case studies jointly sponsored by the U.S. and these host countries are well underway. Mr. Sergio Reyes Luján, Undersecretary for Ecology, SEDUE (Secretaría de Ecología y Desarrollo Urbano) discussed the progress of the Mexican case study. Mr. Reyes Luján discussed SEDUE's pioneering initiatives in efforts to protect the ozone layer by reaching nine voluntary agreements with various industry groups to reduce their consumption of CFCs and halons. It is expected that a first draft of the Mexican Case Study will be available by February 15, 1990 and the cost estimates for this study will be prepared by March 1990. The draft report on the case study will be available for the April 4-6, 1990 UNEP meeting.

Dr. Ahmed Ibrahim, consultant to the Egyptian Environmental Affairs Agency, presented information on the status of the Egyptian case study. Dr. Ibrahim noted that Egypt does not produce any CFCs and that the majority of the CFCs use in Egypt results from the use in refrigeration and aerosol applications. A number of Egyptian aerosol manufacturers have already switched to alternatives such as liquified petroleum gas (LPG) which mainly consists of propane and pentane. The use of LPG has been demonstrated as a cost effective and technically viable alternative to CFC use in aerosols. Dr. Ibrahim stated that the first draft of the Egyptian case study will be completed by March 15, 1990 and the draft including some costs estimates will be completed by the April, 4-6, 1990 UNEP meeting.



Mr. Alberto Carrizo, representing the Brazilian case study project team discussed the progress on the Brazilian case study. The Brazilian case study project team includes representatives from IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis -- the Brazilian environmental agency), Foreign Affairs, Health, and Industry & Trade Ministries, and members of various industry groups. The project team expects to have a first draft of the study by the April 4-6, 1990 UNEP meeting.

The case study on India is being conducted in collaboration with the United Kingdom. Mr. Avani Vaish, Ministry of Environment & Forest, noted that India currently has a production capacity of 7,500 metric tons that is expected to increase to about 20,000 metric tons by 1995. He noted that the majority of CFC use in India results from the use in refrigeration applications. Mr. Vaish stated that preliminary estimates of costs are likely to be available by the February 1990 meeting of the Protocol Parties. It is expected that the cost estimates provided during the February meeting will be refined and that improved estimates will be available for the April UNEP meeting.

The case study on China is being sponsored by the United Nations Development Program and Finland. Mr. Zhang Chongxian, National Environmental Protection Agency, stated that China has an indigenous CFC production capacity of approximately 30,000 metric tons and that the majority of CFC use in China is in refrigeration and foam blowing applications. Mr. Chongxian stated that preliminary results may be available by the June meeting of the Protocol Nations and that the final estimates would be available by November 1990.

Venezuela is conducting its own case study and the government representatives present at the workshop stated that they expect that preliminary cost data will be available by the April 1990 meeting.

Sweden, possibly in cooperation with Norway is planning to sponsor a case study on Kenya. An agreement formalizing the case study is likely to be signed in the near future. It is expected that a preliminary report will be available for the June 1990 meeting of the Protocol Nations.

Canada has decided to sponsor a case study on Malaysia. An agreement is currently being worked out and Canada expects that preliminary information on costs will be available for the June 1990 meeting of the Protocol Nations.

The Australian, EEC, Federal Republic of Germany, and Japanese representatives expressed their willingness to sponsor case studies. The following countries were suggested as possible candidates for additional case studies: Algeria, Argentina, Chile, Czechoslovakia, Hungary, Indonesia, Libya, Pakistan, Philippines, Poland, Saudi Arabia, Tanzania, Thailand, and Yugoslavia. It was suggested that sponsoring and case-study countries should contact each other.

The workshop participants formed six work groups to discuss and prepare guidance material for the case studies. The working groups consisted of:

- a group that developed the "terms of reference" for the case studies (Attachment 4);
- a group for each of the end use sectors: aerosols, foam, halons, refrigeration, solvents that developed the survey questionnaire materials that could be used to gather relevant information on each end use sector for the case studies (Attachment 5).

The materials developed by each of the work groups were distributed among the workshop participants for final review. The workshop participants by consensus agreed on the "Terms of Reference" and the survey questionnaire materials prepared for the case studies. It was agreed that these materials were guidelines and local conditions in each country might necessitate some variation.

### Technical Presentations

The technical presentations by the industry experts are included elsewhere in this volume. A brief summary of each presentation follows.

Mr. Montfort Johnsen, Technical Consultant, U.S., presented information on the use of hydrocarbons as substitutes for CFCs in aerosol applications. Mr. Johnsen stated that hydrocarbon propellants cost less than CFC based propellants. He also stated that because the hydrocarbons are flammable, special precautionary measures such as properly designed gas house have to be used in the aerosol filling process.

Mr. Jorge Corona, representative of CANACINTRA (the Mexican Technical and Economic Chamber of Industries) discussed the characteristics of hydrocarbon propellants and explained how the Mexican aerosols industry has adapted technology to local circumstances to successfully switch from CFCs to hydrocarbons. He offered Mexican assistance to other developing countries in adapting Mexican designs to their environment.

Mr. Bryan Baxter, British Aerospace Dynamics Ltd., U.K., discussed the technical feasibility of using isopropanol as a possible replacement for CFC-113 based cleaning for precision cleaning applications. He noted that the flammability aspects of isopropanol are completely suppressed by blending the isopropanol with perfluorohydrocarbons. In addition, he stated that British Aerospace is designing special equipment that would eliminate the loss of solvent vapor for this cleaning application.

Mr. Brian Ellis, Protonique, S.A., Switzerland, presented a comparative assessment of various alternative technologies that could be used to replace CFC-113 use in the electronics industry. These technologies include the use of aqueous based processes with and without saponifiers, the use of low solid/"no clean" flux, controlled atmosphere soldering, and the use of hydrochlorofluorocarbon (HCFCs) and hydrocarbon (HC) based solvents.

Dr. Lambert Kuijpers, Philips Research Laboratories, The Netherlands, presented information on alternative refrigerants being considered for various refrigeration applications. Dr. Kuijpers stated that the currently available

substitute refrigerants include ammonia, HCFC-22, hydrocarbons, HCFC-142b and HFC-152a. Medium term alternatives include HFC-134a, HCFC-123, and azeotropic mixtures. Finally, long term alternatives include HCFC-124, HFCs 125, 134, 32, and 143a. Dr. Kuijpers summarized the current state of technology for these refrigerants and presented information on the research efforts under way to commercialize the use of these new refrigerants.

Ms. Jean Lupinacci, U.S. EPA presented information on alternatives to CFC blow foams. Ms. Lupinacci stated that countries with large CFC consumption in flexible and packaging foams have the largest opportunity to reduce their use of CFCs using alternatives such as water blown foams, increase foam density, use of HCFC-22 as a blowing agent, and through product substitutes. In the case of polyurethane insulation foam applications the foam industry faces greater challenges to reduce their use of CFCs. In these end uses the use of HCFC-123, HCFC-141b, and the use of water blow foams represent promising alternatives.

Dr. Nobuo Ishikawa, F&F Research, Japan, presented a summary of chemical processes that can transform CFCs, HCFCs, and methyl chloroform to other useful chemicals. For example, methyl chloroform can be converted to HCFC-141b and HCFC-142b. The HCFC-142b can then be converted to vinylidene fluoride that is used to produce polymers and copolymers that are used in a number of application (e.g., electrical applications such as wire insulation and fiber optics, and as piezoelectronic materials). Similarly, HCFC-22 can be converted to HCFC-225, HFC-134a, and a variety of polymers and copolymers.

# EXHIBIT 1. STATUS OF NATIONAL CASE STUDIES

CASE STUDY COUNTRY	SPONSORING COUNTRY	STATUS
Mexico	U.S.	First draft - February 12, 1990; Draft with cost estimates March 1990; Report to UNEP April, 1990.
Egypt	U.S.	First draft March 15, 1990; Draft with cost estimates March 30, 1990; Report to UNEP April, 1990.
Brazil	U.S.	Draft with cost estimates April 1990; Report to UNEP April, 1990.
India	U.K.	Preliminary cost estimates February 1990; Better estimates April 1990.
China	UNDP/Finland	Preliminary report April 1990; Final November, 1990.
Venezuela	None	Preliminary cost estimates April 1990.
Kenya	Sweden & Norway	Not yet begun; Preliminary report June 1990.
Malaysia	Canada	Not yet begun; Preliminary report June 1990.

**EPA WORKSHOP:**

**Integrating Case Studies Carried  
Out Under the Montreal Protocol**

**January 15-17, 1989  
J.W. Marriott at National Place  
1331 Pennsylvania Ave.  
Washington, D.C. 20004  
(202) 393-2000**

**Final Agenda**

**JANUARY 15**

<b>8:00-9:00am</b>	<b>Workshop Check-in and Coffee</b>
<b>9:00-9:30am</b>	<b>Welcome and Introductions</b>  -- Eileen Claussen, Director, Office of Atmospheric and Indoor Air Programs, EPA
<b>9:30-10:00am</b>	<b>Proposal for a Unified Approach</b>  -- Stephen Andersen, Chief, Economics and Technology Branch, EPA
<b>10:00am-12:00pm</b>	<b>Status of Ongoing Case Studies</b>  -- Alberto Carrizo, Gerente Divisao Qualidade de Produto, Climax, White- Westinghouse, Brazil  -- Ahmed Amin Abraham, Consultant to Egyptian Environmental Affairs Agency (EEAA), Egypt  -- Sergio Reyes-Lujan, SEDUE Undersecretary for Ecology, Mexico  -- Zhang Chongxian, Division Chief, Office for Foreign Affairs, China
<b>12:00-2:00pm</b>	<b>Lunch</b>

January 15

2:00-5:00pm

Open Discussion

Characterizing CFC and Halon Use

Applications (refrigeration, solvents,  
foam, etc.)

Source (chemical imports, imported  
products containing or made with  
CFCs or halons)

Company/facility

Estimating Future Demand

Historic growth rates or specific  
estimation for end-use sectors

Special Circumstances of Developing Countries

Access to new technology

Industrial and development policy

Infrastructure and training

Technical expertise and research  
facilities

6:00pm

Presentation & Dinner

"Technology Transfer Projects by the  
Industry Cooperative for Ozone Layer  
Protection," Art FitzGerald

Dinner sponsored by the National  
Institute for Emerging Technology (NIET)

Location: Hogates Restaurant  
9th St. & Maine Ave. S.W.  
Washington, D.C.  
484-6300

January 16

9:00am-12:00pm

Overview of UNEP Technical Assessment

-- G. Victor Buxton, Chief, Chemical  
Controls, Environment Canada

Best Existing Technology Presentations by  
Technical Experts

-- See Attachment A

Open Discussion

-- Matching Best Technology to Existing  
and Anticipated Uses

-- Utilizing Technical Experts for  
National Case Studies

12:00-2:00pm

Lunch

2:00-5:30pm

Preparation of guidance for case studies

7:00pm

Dinner

Location: Eileen Claussen's Home  
4733 Fulton St. N.W.  
Washington, D.C. 20007

Suggested Transportation - Taxi

January 17

9:00am --

Final drafting and editing of case study  
outlines; end-use survey forms; demand  
estimation methods; text and data files

Next steps (organization, operation &  
cooperation)

## Technical Experts

### FOAMS:

Jean Lupinacci, EPA, USA

### AEROSOLS:

Jorge Corona, Astral Internacional, Mexico  
Montfort Johnsen, Consultant, USA

### SOLVENTS:

Bryan Baxter, British Aerospace, UK  
Brian Ellis, Protonique S.A., Switzerland

### HALONS:

Hans Lagerhorn, Brandtekniska Ingenjosbyron, Sweden  
Gary Taylor, Taylor/Wagner Associates, Canada

### REFRIGERATION & AC:

Lambert Kuijpers, Phillips, Netherlands

### CHEMICAL ALTERNATIVES TO CFC & FACTORY RETROFITS

Nobuo Ishikawa, F & F Research Center, Japan



# ATTACHMENT 1: DEVELOPED COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
Australia	David Roberts International Development Assistance Bureau GPO Box 887 Canberra ACT 2601	062-764658	062-487521
Canada	G. Victor Buxton Environment Canada 351 St. Josephs Blvd. Ottawa, Ontario Canada K1A 0H3	819-953-1675	819-997-0547
Canada	Ann Corwin-Cossette Canadian Embassy 501 Pennsylvania Avenue, NW Washington, DC 20001	202-682-1740	202-682-7792
Canada	Rebecca Milo Environment Canada 22nd Floor Terrasses de la Chaudiere Ottawa, Ontario Canada K1A 0H3	819-953-9000	819-953-5975
Canada	Julie Vandershot Environment Canada 10 Wellington St. Hull, Quebec Canada K1A 0H3	819-953-8999	819-953-5975

# ATTACHMENT 1: DEVELOPED COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
Canada	Robert Weir Canadian Development Agency 200 Promenade du Portage Hull, Quebec Canada K1A 0G4	819-997-6731	819-953-4676
EEC	Heinz Hilbrecht Energy/Environment/Transport Commission of the European Community 2100 M St., NW 7th Floor Washington, DC 20037	202-862-9578	202-429-1766
FRG	Jurgen Lottmann Kreditantstalt fur Wiederaufbau Palmengartenstrabe 5-9 D-6000 Frankfurt am Main	069-7431-3142	069-7431-2944
Japan	Yasu-hiro Shimizu Environmental Attache, Embassy of Japan 2520 Massachusetts Ave, NW Washington, DC 20008	202-939-6725	202-939-6788
Norway	Eli Vike State Pollution Control Authority P.O. Box 8100 DEP N-0032 Oslo 1. Norway	47-2-659810	47-2-658890
Sweden	Ingrid Kokeritz Swedish Environmental Board Smidasvagen #5 17125 Solna Sweden	468-799-1565	468-799-1253

# ATTACHMENT 1: DEVELOPED COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
Sweden	Tom Hedlund Swedish Environmental Board Smidesvagen #5 Box 1302 S-171 25 SOLNA, Sweden	358-8799-1137	(Telex #) 11131 Environ S
USA	Eileen Claussen Environmental Protection Agency Office and Air and Radiation 401 M St. SW Washington, DC 20460	202-382-7407	202-382-6344
USA	Stephen Seidel Environmental Protection Agency Office of Air and Radiation 401 M St., SW Washington, DC 20460	202-382-2787	202-382-6344
USA	Stephen O. Andersen Environmental Protection Agency Office of Air and Radiation 401 M St. SW Washington, DC 20460	202-475-9403	202-382-6344
USA	Jean Lupinacci Environmental Protection Agency Office of Air and Radiation 401 M St. SW Washington, DC 20460	202-475-8468	202-382-6344

# ATTACHMENT 1: DEVELOPED COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
USA	Denise Mauzerall Environmental Protection Agency Office of Air and Radiation 401 M St, SW Washington, DC 20460	202-245-3554	202-382-6344
USA	William Rhodes Environmental Protection Agency AEERL MD 62B Research Triangle Park North Carolina 27711	919-541-2853	919-541-7885
INTERNATIONAL ORGANIZATIONS:			
UNDP	Erik Helland-Hausen UNDP/BPPE/TAD One UN Plaza New York, NY 10017	212-906-5057	212-906-5365
The World Bank	Peter Bohm 1818 H St. NW Room S-5125 Washington, DC 20433	202-473-3426	202-477-0565

# ATTACHMENT 2: DEVELOPING COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
Brazil	Monica Moraes Brazilian Environmental Agency SAIN - QL 4 IBAMA Brasilia - D.F. 70.000 Brazil	061-274-6850	In Care of: Karla Amorin 5561-224-5206
Brazil	Regina Helena Costa Brazilian Environmental Agency SAIN - QL 4 IBAMA Brasilia - D.F. 70.000 Brazil	061-321-2324	In Care of: Karla Amorin 5561-224-5206
Brazil	Santiago Mourao Brazilian Embassy 3006 Massachusetts Ave, NW Washington, DC 20008	202-745-2766	202-745-2827
Brazil	Alberto Carrizo White Westinghouse, representing the Brazilian Industry Av. Jose Pereira Lopes, 250 - 13560 Sao Carlos - SP Brazil	162-711235	162-725768

# ATTACHMENT 2: DEVELOPING COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
Brazil	Paulo Vieira DuPont do Brazil, representing the Brazilian Industry Al. Itapecuru, 506 Alphaville CEP 06400 - C.P.26 Barueri - SP Brazil	55-11-421-8005	55-11-4214051
China	Zhang Chongxian Senior Engineer, National Environmental Protection Agency of China No. 115, Xizhimennei Nanxiaojie Beijing, China	861-6011193	861-653681
Egypt	Ahmed Ibrahim Consultant, Egyptian Environment Affairs Agency 80 Ahmed El-Sayat St. Dokki, Egypt	202-701655	202-342-0768
India	Avani Vaish Director, Ministry of Environment & Forest Paryavaran Bhavan C.G.O. Complex Lodi Road New Delhi 110003	362840	(Telex #) 3166185 DOE IN

# ATTACHMENT 2: DEVELOPING COUNTRY REPRESENTATIVES

COUNTRY	NAME	TELEPHONE	FAX NO.
Malaysia	Tan Meng Leng Dept of Environment 12th Floor Wisma Some Darby 50662 Kuala Lumpur	603-293-8955	603-293-6006
Mexico	Sergio Reyes-Luján Undersecretary for Ecology, SEDUE Rio Elba No. 20 PISO 16 Col. Cuaahatemoc 06500 MEXICO, D.F.	905-553-9538	905-271-3205
Singapore	Lim Choon Slew Institute of Standards & Industrial Research 1 Science Park Drive Singapore 0511	65-772-9568	65-778-3798
Venezuela	Carmelina de Lombard Ministry of Environment COVENIN Avenida Andres Bello Torre Fonde Comun, Piso 11 Caracas, Venezuela 51116-1050A	58 2-408-1497	In Care of: Jean Preston 582-285-0336
Venezuela	Milagros Diaz Ministry of Environment COVENIN Avenida Andres Bello Torre Fonde Comun, Piso 12 Caracas, Venezuela 51116-1050A	58 2-575-2298	In Care of: Jean Preston 582-285-0336

### ATTACHMENT 3. TECHNOLOGY EXPERT PARTICIPANTS

TECHNOLOGY	COUNTRY	NAME	TELEPHONE
AEROSOLS	Mexico	Jorge Corona Director General Astral Internacional Mar Negro No. 99 Col. Popotla 11410 MEXICO, D.F.	905-399-9130
AEROSOLS	USA	Montfort Johnsen President Montfort A. Johnsen & Associates 26 Sheral Drive Danville, IL 61832-1354	217-442-1400
FOAMS	USA	Jean Lupinacci Technology & Economics Branch Global Change Division, U.S. EPA 401 M St, NW Washington, DC 20460	202-475-8468
HALONS	Canada	Gary Taylor Consultant Taylor/Wagner Incorporated 177 Maxome Ave Willowdale, Ontario-Canada M2M 3L1	416-222-9715
HALONS	Sweden	Hans Lagerhorn Skandia Insurance Co. S - 103 50 Stockholm	468-7881436



### ATTACHMENT 3. TECHNOLOGY EXPERT PARTICIPANTS

TECHNOLOGY	COUNTRY	NAME	TELEPHONE
HALONS	USA	Tom Morehouse Project Manager Air Force Engineering & Service Center HQ USAF/LEEL Pentagon Washington, DC 20330-5124	904-283-6194
REFRIGERATION & AIR CONDITIONING	Netherlands	Lambert Kuijpers Project Leader Phillips Research Laboratories Building WAp.6.20 PO Box 80000 5600 JA Eindhoven	3140-742860
CFC ALTERNATIVES	Japan	Nobuo Ishikawa Director F & F Research Center 2-9-3, Akasaka Minato-ku, Tokyo 107	03-5828896
SOLVENTS	Canada	A.D. FitzGerald Director, Environmental Affairs Northern Telecom Limited 3 Robert Speck Parkway Mississauga, Ontario Canada L42 3C8	416-566-3048

# ATTACHMENT 3. TECHNOLOGY EXPERT PARTICIPANTS

TECHNOLOGY	COUNTRY	NAME	TELEPHONE
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SOLVENTS	Switzerland	Brian Ellis General Director Protonique, S.A. PO Box 78 CH-1032 Romanel	412-1382334
SOLVENTS	USA	Sudhakar Kesavan Vice President ICF Incorporated 409 12th St. SW Washington, DC 20024	703-934-3052
SOLVENTS	UK	Bryan Baxter Chief Materials Scientist British Aerospace Six Hills Way Stevenage Herts, United Kingdom SG1 2DA	438-753222

## **PRESENTATIONS**

# **PROPOSAL FOR A UNIFIED APPROACH**

**Stephen O. Andersen**

**Chief, Technology and Economics Branch**

**Office of Air and Radiation**

**U.S. Environmental Protection Agency**

# **Brazil, Egypt and Mexico Case Studies**

- **Managed by national environment agency**
- **Participation by other important agencies**
- **Strong cooperation with national industry**
- **Developing and developed country experts**

# **National Experts**

- **Excellent technical skills**
- **Experience in adapting technology to local conditions**
- **Better able to improvise and fabricate**

# **Developing Countries as Sources of Technology**

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- **On-site fabrication of hydrocarbon aerosol factories**
- **Open-air aerosol filling stations**
- **Ammonia refrigeration**
- **CFC-12/HCFC-22 swing plants**

# **Advantages of Cooperation on Case Studies**

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- **Assure comparable methods and presentation**
- **Investigate all special needs**
- **Discover innovative technical solutions**
- **Identify model institutions**
- **Share best technical experts**
- **Organize for technology transfer**



# **Comparable Existing and Future Use**

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- **Same scope and outline**
- **Same chemical coverage: CFC, Halon, MC, carbon tetrachloride**
- **Same basic tables and figures**
- **Same units of measure**
- **Same demand estimation**

# **GLOBAL ENVIRONMENTAL PROBLEMS POLICY IN MEXICO**

**Mr. Sergio Reyes-Luján**

**Undersecretary for Ecology**

**Secretaría de Ecología y Desarrollo Urbano**

(MICA NO. 1)

**GLOBAL ENVIRONMENTAL PROBLEMS**

**POLICY IN MEXICO**

**PRESENTED BY:**

**MR. SERGIO REYES LUJAN**

**UNDERSECRETARY FOR ECOLOGY**

**SECRETARIAT FOR URBAN DEVELOPMENT AND ECOLOGY (SEDUE)**

**Washington, D.C.**

**January 15, 1990**

(MICA NO. 2)

## OUTLINE

### I. INTRODUCTION

### II. IMPLEMENTED MEASURES TO REDUCE THE USE OF OZONE DEPLETING SUBSTANCES

- A. VOLUNTARY AGREEMENTS WITH THE MEXICAN INDUSTRY
- B. STATUS OF JOINT SEDUE/INDUSTRY/EPA CASE STUDY

### III. ACHIEVED AND PROJECTED RESULTS

- A. FOAMS
- B. AEROSOLS
- C. HALONS

### IV. ADAPTING TECHNOLOGY TO DEVELOPING COUNTRY NEEDS

### V. MEASURES TO BE IMPLEMENTED TO ADDRESS GLOBAL WARMING

### VI. CONCLUSIONS

## I. INTRODUCTION

(MICA NO. 3)

Stratospheric ozone depletion by chlorofluorocarbons, halons, and other ozone-depleting substances is one of the most important environmental problems of our time. For the first time ever a truly global agreement for the protection of the environment was reached: the Montreal Protocol on Substances that Deplete the Ozone Layer. The development of the Protocol involved more than a decade of multidisciplinary research and a number of international meetings.

Governments, industries, and non-governmental organizations, took part in the negotiations under the auspices of the United Nations Environmental Program (UNEP).

Mexico was invited to participate as an observer at the working group to prepare a global framework convention for the protection of the ozone layer, resulting in Mexico's accession to the Vienna Convention. Since then, Mexico has actively participated in deliberations under the auspices of the United Nations on legal and technical matters relative to CFC controls. This is the case of the SEDUE's meetings with the two CFC manufacturers in Mexico before the Montreal Protocol. In these meetings, the CFC producers agreed to collaborate with SEDUE in controlling the production and emissions of ozone depleting substances. With these results, the Undersecretary of Ecology, as representative of the Mexican Government attended Montreal

Protocol's meetings. Mexico was the first country in ratifying the Protocol.

## II. IMPLEMENTED MEASURES TO REDUCE OZONE-DEPLETING SUBSTANCE USE

### A. VOLUNTARY AGREEMENTS WITH THE MEXICAN INDUSTRY TO REDUCE CFC AND HALON USE

(MICA NO. 4)

As a result of the commitment associated with the ratification of the Montreal Protocol, the Mexican Government proceeded to implement measures that will yield significant near-term reductions in the consumption of ozone depleting substances. The Secretariat for Urban Development and Ecology negotiated and signed nine agreements with industry which control the consumption of CFCs and halons. The CFC producers and halon distributors, and representatives of industries that use CFCs in Mexico voluntarily agreed to the same reduction measures and, therefore, the SEDUE/Industry agreements control ozone-depleting substances in upstream and downstream markets.

(MICA NO. 5)

In the area of polyurethane foams, the two CFC producers in Mexico have committed to eliminate all of the distribution of CFCs for flexible polyurethane foam manufacturing by 1990. Flexible foam manufacturers that use the CFCs have agreed to undertake this reduction. These industry groups have also indicated their commitment to keep users updated with the latest information on the development of CFC substitutes for rigid

polyurethane foams so that these substitutes are adopted in the future. The signatories of these agreements also promised to facilitate technology transfer.

Only 10% of all aerosol cans manufactured in 1988 in Mexico contained CFCs. Based on 1988 CFC consumption in aerosols, the suppliers of CFCs as well as aerosol manufacturers represented by CANACINTRA (the National Chamber of Industries -- the major Mexican association of manufacturing industries), the Mexican Aerosol Institute, and the Chamber of the Perfume and Cosmetics Industry, agreed to reduce CFC use by 50% in 1989 and to eliminate the remaining 50% by 1990. Mexico considers that the relatively small use of CFCs in medicinal, electronic, and aircraft maintenance aerosols is essential and therefore has been exempted from reductions due to the lack of adequate substitutes for these uses. The signatories will also recommend the labelling of ozone-safe aerosols.

Mexico imports halons through three major companies. These halon distributors have agreed to provide users with information on conservation measures and recycling technologies and committed efforts to maintain users updated on important events regarding the development of alternative fire extinguishing agents.

Finally, the National Board of In-Bond Industries, a group of export-oriented industries neighboring the U.S. border -- also known as Maquiladoras -- has also signed an agreement with SEDUE that covers a broad scope of environmental initiatives. Among them, the Board has committed to promote the control of

contaminant emissions to meet official standards. Specifically, the National Board of In-Bond Industries will promote the reduction of ozone-depleting substance use to the maximum extent feasible.

B. STATUS OF JOINT SEDUE/INDUSTRY/EPA CASE STUDY  
(MICA NO. 6)

1. Background

The United States and Mexico have a long history of successful environmental cooperation as proven by the various consultations conducted since the initial international efforts to protect the stratospheric ozone layer. Recent SEDUE initiatives and the December visit to Mexico of the EPA expert team headed by Dr. Stephen Andersen of the Global Change Division consolidated our cooperative efforts and resulted in an agreement to conduct a joint study in which SEDUE, the Mexican industry, and the EPA are participating.

The case study will provide, first, an analysis of current and projected future demand of CFCs and halons given Mexican industry trends. The study will also provide a review of the use of methyl chloroform and carbon tetrachloride in Mexico in light of the current international concern regarding the ozone depletion potential of these compounds not currently regulated by the Montreal Protocol. Second, the case study will describe the industries that use CFCs and halons and the technology used in these industries, and, third, the analysis will evaluate the costs of reducing CFC and halon use to comply with the Montreal



Protocol. Hence, the study will present the net costs and ~~alternatives~~ the financing needs of our country to comply with the Protocol.

The case study currently underway will be an extremely helpful source of information for current and potential parties to the Montreal Protocol not only because of the economic assessment but also because it will list alternative technologies appropriate to developing country circumstances.

(MICA NO. 7)

## 2. Project Team

The project team integrates representatives of SEDUE, the Mexican Chamber of Industries, and the U.S. EPA. The responsibilities of each project team member is as shown in the slide.

## 3. Project Team Operation and Information Sources

The project team has worked since December of last year meeting to define the terms of reference of the study and collecting data through interviews and communications with the Mexican industry. Other sources consulted include existing government data on CFC consumption in certain industries, market reports, and technical notes of specific companies.

## 4. Status of the Study and Next Steps

The team is currently collecting data on the volume of CFCs, halons and other ozone depleting substances consumed in Mexico and is drafting descriptions of the industries that employ these substances. Next, the team will investigate the

manufacturing technology of the user industries to assess the extent of the modifications required to adopt alternative technologies. Finally, the project team will estimate and evaluate the costs associated with the alternate technologies in each end use and will generate aggregate cost estimates.

### III. ACHIEVED AND PROJECTED RESULTS

As stated earlier, SEDUE successfully negotiated nine industry agreements to reduce the production and emissions of ozone depleting substances in Mexico. Beginning discussions in 1987, these voluntary agreements were signed on November 9, 1989 and include: two agreements with companies that produce CFCs and distribute halons, and seven agreements with industries that represent users of these substances.

These efforts lead to the following current and projected results:

(MICA NO. 8)

1. The consumption of CFC-11 and CFC-12 as foam blowing agents and aerosol propellants dropped by 13.1% in 1989 with respect to 1987 levels. By 1991, we expect to achieve a 31.7 percent reduction with respect to 1987 consumption.

(MICA 9)

2. This reduction is primarily due to the sharp decrease planned in the consumption of CFC-12 as blowing agent.

This past year an annual decrease of 75% was achieved in this area and further reduction are expected as shown in the transparency.

(MICA 10)

3. Industry reports that the consumption of CFC-11 as blowing agent is likely to grow by 10 percent given current trends in the foam industry. However, growth in this area will be more than offset by the impressive decrease in the consumption of CFC-11 and CFC-12 as aerosol propellants.

(MICA 11)

4. As shown in this transparency, the current consumption of CFC-12 in aerosols will be dropped by approximately 50 percent this year and by 1991, only essential uses of CFCs will be allowed.

(MICA 12)

5. Similar reduction are planned for the use of CFC-11 in aerosols.

(MICA 13)

6. It is important to remember that today, only 12 percent of all aerosols produced in Mexico contain CFCs. This transparency shows the total number of cans produced in Mexico, and of this total, those cans still containing CFCs. The overall market is expected to grow at about 5 percent annually; however, ~~and~~ by 1991 only 3 percent of all aerosols produced will contain CFCs.

(MICA 14)

7. In the halon area, approximately 50 % of halon emissions are avoidable. This emissions will be controlled through a number of conservation measures which include limiting releases during testing and demonstration procedures. By the year 2000, we expect that halon emissions will represent only 56% of 1989 emissions.

(MICA 15)

8. This transparency shows the specific effect of each emission reduction measure. By the year 2000, most of the avoidable halon emissions will be controlled leaving only those emissions associated with the actual extinguishing of fires.

(MICA 16)

9. Finally, in addition to conservation measures, alternatives to the use of halons as fire extinguishing agents are projected to be introduced in 1992, and by 1996 these alternatives are projected to replace almost entirely the consumption of halons.

#### IV. ADAPTING TECHNOLOGY TO DEVELOPING COUNTRY NEEDS

(MICA 17)

Although Mexico is a developing country it can be a source of some new and adapted technologies to protect the ozone layer. Mexico has highly skilled and inventive engineers who have adapted and developed technology to local conditions, such as climate, and to be flexible as market changes occur.

For example, as Mr. Jorge Corona will explain, our aerosol industry has simplified the technology to fill aerosols and, overall the Mexican design approach is cost-effective and safe.

The know-how for adapting or designing new technology is available in Mexico. These technologies may be applicable to other developing countries interested in protecting the ozone layer.

## V. MEASURES TO BE IMPLEMENTED TO ADDRESS GLOBAL WARMING

(MICA NO. 18)

The combustion of fossil fuels is one of the largest sources of pollutant emissions that contribute to the problems of global warming and ozone depletion. Mexico is aware of this problem and will promote through institutions and organizations involved in this area the implementation of a program to preserve and improve the efficiency of fossil fuel utilization.

The program will also control the emissions of methane from landfills and will promote research in the use and development of alternative fuels.

The rational use of water through the legal reevaluation of the technical and economic components of water supply management are very important for Mexico, as well as the implementation of efficient techniques for water use.

The use and consumption of energy in Mexico requires the guidance of a program to increase the efficiency of energy production and use, foster the development of alternative energy systems to those based on fossil fuels, or addresses a restructuring of oil prices. There is also a need to accelerate the replacement of old machinery with new energy efficient technology.

Other measures to address air pollution that should be encouraged include tree planting, reforestation, and new agricultural technologies for the production of rice, meat, and milk.

## VI. CONCLUSIONS

1. THE PROTECTION OF THE OZONE LAYER RULES OUT THE POSSIBILITY OF "FAIR" SHARES OF OZONE DEPLETING COMPOUND USE. ALTHOUGH MOST OF THE CHLORINE IN THE ATMOSPHERE IS DUE TO EMISSIONS FROM DEVELOPED COUNTRIES, DEVELOPING COUNTRIES MUST ALSO STOP THEIR PRODUCTION AND CONSUMPTION OF THESE SUBSTANCES.
2. IT IS NECESSARY TO TIGHTEN THE IMPLEMENTED MEASURES TO REDUCE OZONE DEPLETING COMPOUND EMISSIONS AND TO TAKE ALL NECESSARY ACTIONS TO ACHIEVE THE REDUCTIONS NEEDED.
3. THE CASE STUDY UNDERWAY IN MEXICO WILL EVALUATE THE PRESENT AND FUTURE DEMAND OF OZONE DEPLETING SUBSTANCES AND THE ECONOMIC NEEDS ASSOCIATED WITH THE IMPLEMENTATION OF THE MONTREAL PROTOCOL. THE STUDY WILL ALSO PROVIDE USEFUL INFORMATION ON NEW TECHNOLOGIES AND APPROACHES USED IN MEXICO.
4. MEXICO'S TECHNICAL KNOW-HOW MAY BE USEFUL TO OTHER DEVELOPING COUNTRIES.
5. MEXICO IS CONSIDERING TO ALLOW MANUFACTURING OF CFCs FOR MEDICAL AND OTHER USES FOR WHICH NO SUBSTITUTES ARE CURRENTLY AVAILABLE.
6. THE MEXICAN GOVERNMENT PLACES HIGH PRIORITY IN AN ENERGY CONSERVATION PROGRAM FOR MEXICO.
7. TO ATTAIN SUSTAINABLE DEVELOPMENT THERE IS A NEED TO REDUCE POLLUTANT EMISSIONS FROM MAJOR CITIES AND PROMOTE COST EFFECTIVE AND EFFICIENT ENERGY SOURCES AND TECHNOLOGIES.

8. THE VIENNA CONVENTION AND THE MONTREAL PROTOCOL REPRESENT A PATTERN THAT CAN BE USED FOR A WORLDWIDE CONVENTION ON GLOBAL CLIMATE CHANGE.





**GLOBAL ENVIRONMENTAL PROBLEMS  
POLICY IN MEXICO**

# **POLICY IN MEXICO**

- I. INTRODUCTION**
- II. IMPLEMENTED MEASURES TO REDUCE THE USE OF OZONE DEPLETING SUBSTANCES**
  - A. VOLUNTARY AGREEMENTS WITH THE MEXICAN INDUSTRY**
  - B. STATUS OF JOINT SEDUE/INDUSTRY/EPA CASE STUDY**
- III. ACHIEVED AND PROJECTED RESULTS**
  - A. FOAMS**
  - B. AEROSOLS**
  - C. HALONS**
- IV. ADAPTING TECHNOLOGY TO DEVELOPING COUNTRY NEEDS**
- V. MEASURES TO BE IMPLEMENTED TO ADDRESS GLOBAL WARMING**
- VI. CONCLUSIONS**

## **INTRODUCTION**

- **THE MONTREAL PROTOCOL IS THE FIRST GLOBAL AGREEMENT TO ADDRESS A CRITICAL ENVIRONMENTAL PROBLEM OF OUR TIME**
- **MEXICO HAS ACTIVELY PARTICIPATED IN THE INTERNATIONAL EFFORTS TO PROTECT THE OZONE LAYER**
- **MEXICO WAS THE FIRST COUNTRY TO RATIFY THE MONTREAL PROTOCOL DUE TO CLOSE COLLABORATION BETWEEN THE GOVERNMENT AND INDUSTRY**

## **SEDUE/INDUSTRY/EPA'S CASE STUDY**

- . ANALYZES THE PRESENT AND POTENTIAL CONSUMPTION IN MEXICO OF CFCs, HALONS AND OTHER OZONE DEPLETING SUBSTANCES**
- . ANALYZES THE SPECIFIC APPLICATIONS AND USES OF THESE SUBSTANCES IN THE MEXICAN INDUSTRY**
- . ASSESSES THE OPTIONS TO REDUCE THE CONSUMPTION OF THESE SUBSTANCES AND THEIR IMPLEMENTATION COST**

# **SEDUE/INDUSTRY/EPA STUDY GROUP**

**. DIRECTION**

**SEDUE**

**GENERAL COORDINATION**

**MINISTRY OF FOREIGN AFFAIRS**

**INDUSTRIAL COORDINATION**

**NATIONAL CHAMBER OF INDUSTRIES**

**DATA MANAGEMENT**

**SEDUE**

**TECHNICAL ADVISER**

**EPA**

## **EPA' s    STUDY    GROUP**

### **WORK PROGRAM**

- (1)   COLLECTION OF EXISTING DATA ON CONSUMPTION AND DRAFT  
DESCRIPTION OF THE INDUSTRIES THAT USE OZONE DEPLETING  
SUBSTANCES**
- (2)   DATA COLLECTION ON THE PRODUCTION TECHNOLOGY EMPLOYED  
IN SPECIFIC INDUSTRIES USING SUCH SUBSTANCES**
- (3)   ASSESSMENT AND COSTING OF ALTERNATIVE TECHNOLOGIES  
ADEQUATE TO THE DOMESTIC CHARACTERISTICS OF EACH INDUSTRY**

**THE SEDUE/INDUSTRY AGREEMENTS CONTROL OZONE DEPLETING SUBSTANCES  
UPSTREAM AND DOWNSTREAM**

---

**CFC Produces and  
Halon Distributors**



**Nine Sedue/Industry  
Voluntary Agreements**



**End Use Industries**

## VOLUNTARY AGREEMENTS WITH THE MEXICAN INDUSTRY TO REDUCE CFC AND HALON USE

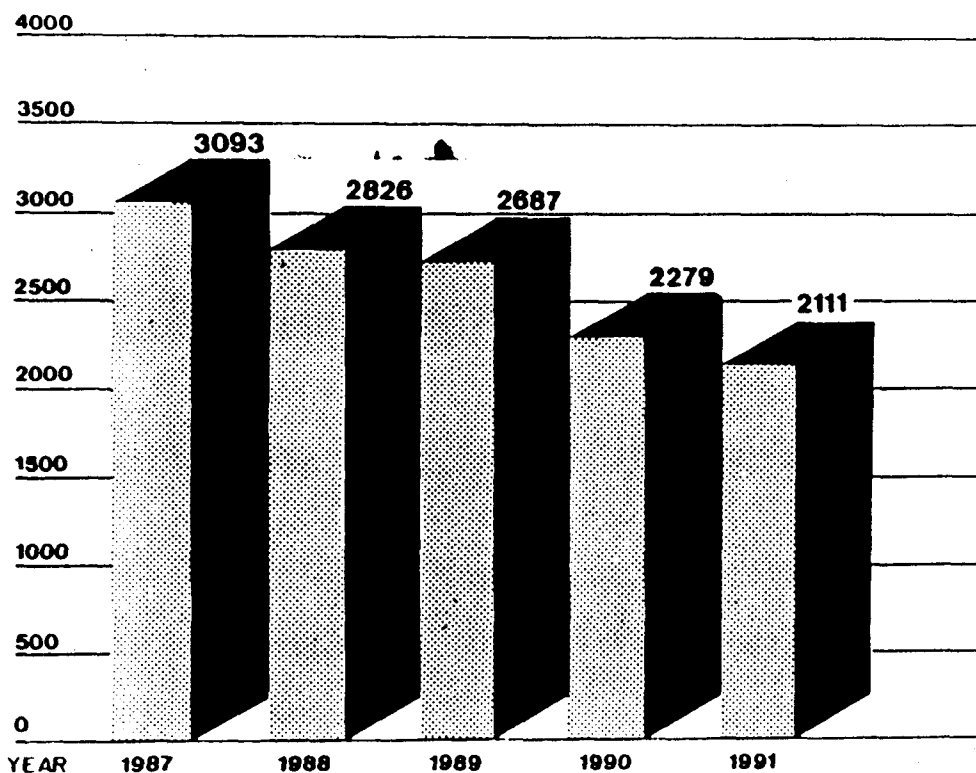
End-Use	Agreement Signatories	Nature of Organization	Measures
Polyurethane Foams	DuPont	CFC Producer	<ul style="list-style-type: none"> <li>Reduce CFC distribution and use by 100% by 1990 in flexible foams</li> <li>Update information on development of CFC substitutes for adoption in rigid foam systems</li> <li>Facilitate technology transfer</li> </ul>
	Quimobasics	CFC Producer	
	Mexican Polyurethane Institute	Industry Association	
Aerosol Products	DuPont	CFC Producer	<p>In 10% of all aerosols units still containing CFCs in 1988:</p> <ul style="list-style-type: none"> <li>Cut CFC use by 50% in 1989</li> <li>Cut remaining 50% by 1990</li> <li>Medicinals, electronic cleaners, and aircraft insecticides and deodorants are exempt</li> <li>Recommend labelling of ozone-safe aerosols</li> </ul>
	Quimobasicos	CFC Producer	
	National Chamber of Industries	Main Association of all Manufacturing Industries	
	Mexican Aerosol Institute	Industry Association	
	Chamber of Perfume and Cosmetics Industry	Industry Association	
Halons	DuPont	Halon Importer/Distributor	<ul style="list-style-type: none"> <li>Provide users with information on halon conservation measures</li> <li>Update users on development of alternatives</li> </ul>
	CAISA	Halon Importer/Distributor	
	ICI	Halon Importer/Distributor	
Miscellaneous	National Board of In-Bond (Maquiladora) Industries	Association of Export Industries Neighboring the U.S. Border	<ul style="list-style-type: none"> <li>Promote the reduction of ozone-depleting substance use and emissions</li> </ul>





# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL REDUCTION IN THE USE OF CFC'S AS BLOWING AGENTS AND PROPELLANTS

CFC-11 AND CFC-12



% DECREASE IN USE DURING PERIOD

PERIOD	% DECREASE
1987-1988	8.6
1987-1989	13.1
1987-1990	26.3
1987-1991	31.7

CONSUMPTION

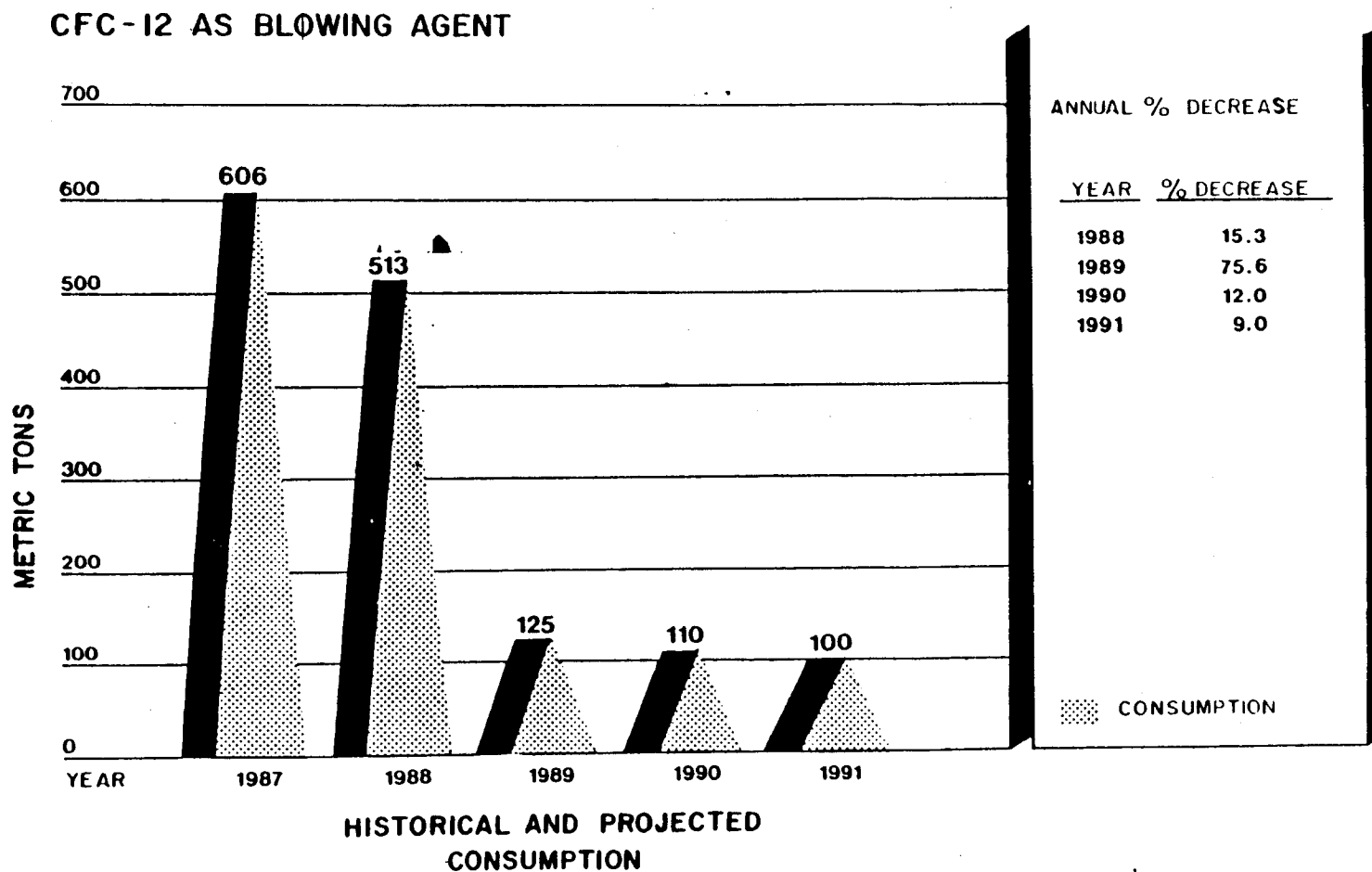
HISTORICAL AND PROJECTED CONSUMPTION

SOURCE: CFC PRODUCERS



# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL

## REDUCTION IN USE OF CFC-12 AS BLOWING AGENT

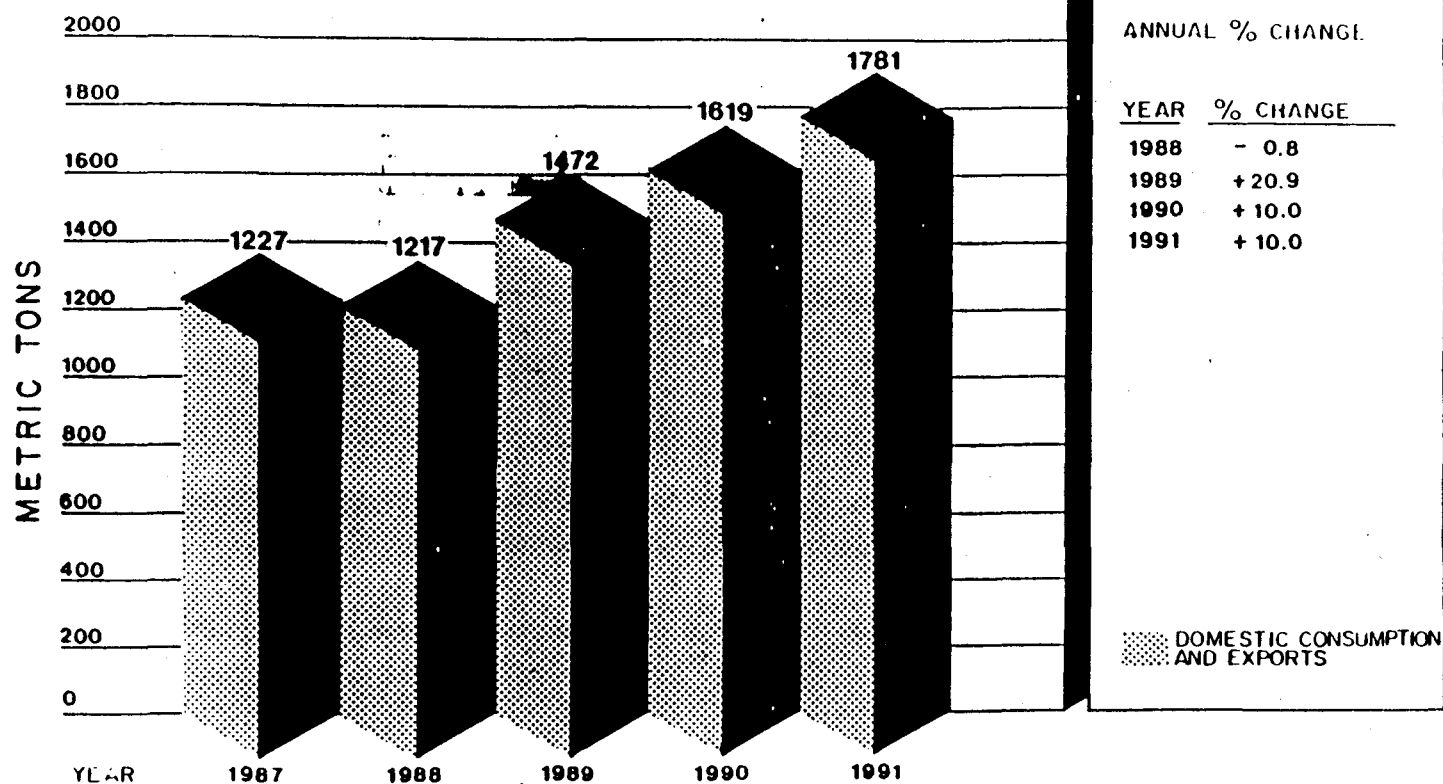




## MEXICAN PROGRAM TO COMPLY WITH MONTREAL PROTOCOL

### USE OF CFC-II AS BLOWING AGENT

#### CFC-II AS BLOWING AGENT

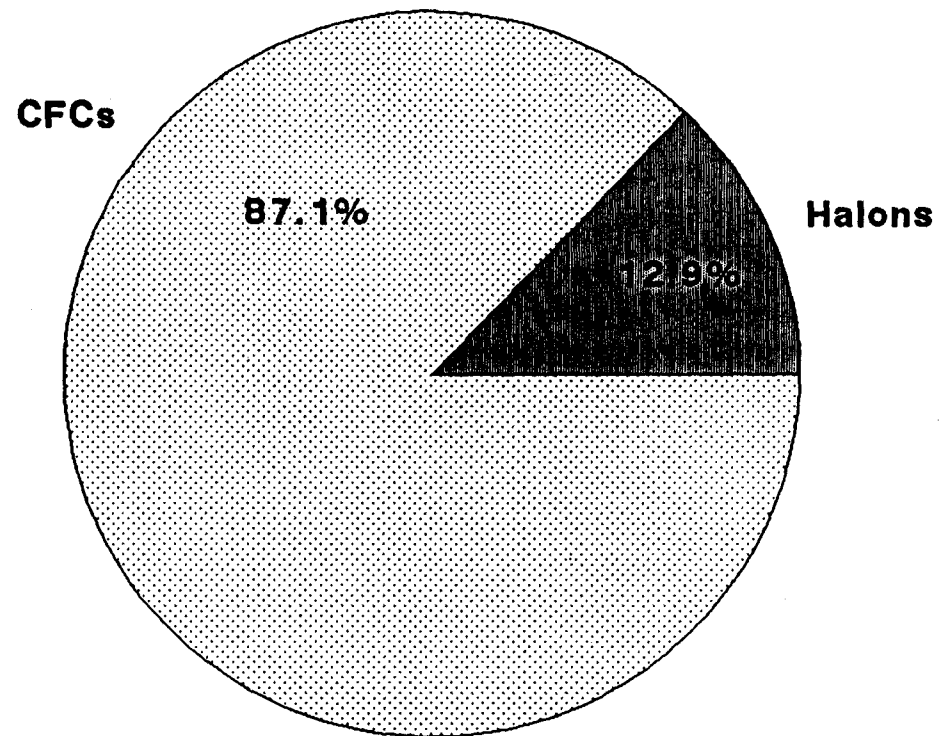


HISTORICAL AND PROJECTED CONSUMPTION

SOURCE: CFC PRODUCERS

Exhibit 2

**1986 PRODUCTION OF HALONS AND CFCs  
Weighted By ODP**



## HALONS: ADVANTAGES AND DISADVANTAGES

### Halons Work Group

#### I. Advantages of Halons

- Low Toxicity for Humans
- Non-Damaging to Electronics
- Low Space and Weight Requirements
- Highly Effective Fire Suppressant
- Low Installed Cost
- System Efficiency

#### II. Disadvantages of Halons

- High Ozone Depletion Potential (ODP)
  - Upper Bound is 30 ODP
  - Average Estimate is 10.6 ODP
- Greenhouse Warming Potential
- High (and increasing) Relative Costs
  - \$150 - \$200 per square meter for Halon Systems
  - \$10 - \$15 per square meter for Water Sprinkler Systems

### III. Halon Production Levels and Relative ODPs

- In 1986, Halons accounted for only 2.5% of total CFC production by weight. CFC-11, -12, -113, -114, and -115 accounted for 97.5% of production by weight.
- In the same year, however, Halons accounted for 12.9% of total production when compound contributions are weighted by ODP. CFCs accounted for 87.1%.
- The breakdown of Halon production for that year was as follows:
  - Halon 1211 - 56%
  - Halon 1301 - 40%
  - Halon 2402 - 4%
- Quantities of Halon banked around the world are estimated as:
  - 11,200,000 tonnes of Halon 1211
  - 7,000,000 tonnes of Halon 1301
  - 650,000 tonnes of Halon 2402
- Stockpiling is now in progress because:
  - DuPont will cease production in 1999.
  - Companies plan to inventory enough Halon for systems operation until 2050.

# **HALONS: ADVANTAGES AND DISADVANTAGES**

**Halons Work Group**

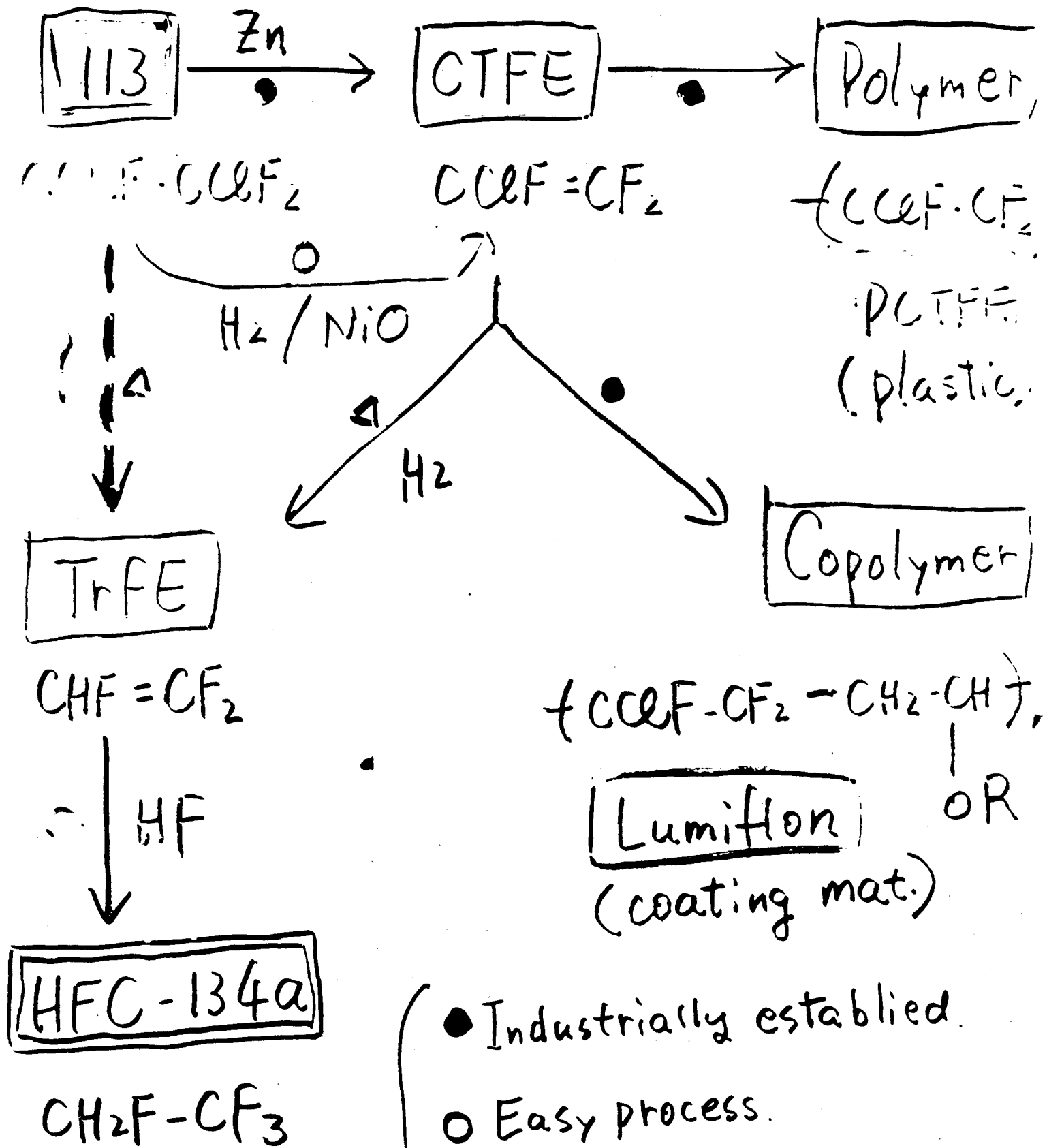
Promising HCFCs

コード	分子式	分子量	沸点℃	ODP	CLP	GWP
22	$\text{CHClF}_2$	87	-41	0.05	0.14	0.35
123	$\text{CHCl}_2 - \text{CF}_3$	153	28	0.02	0.02	0.02
124	$\text{CHClF} - \text{CF}_3$	137	-12	0.02	0.04	0.1
141b	$\text{CH}_3 - \text{CCl}_2\text{F}$	117	32	0.1	0.1	0.1
142b	$\text{CH}_3 - \text{CClF}_2$	101	-9	0.05	0.1	0.37
225ca	$\text{CF}_3 - \text{CF}_2 - \text{CHCl}_2$	203	51	?	?	?
225cb	$\text{CF}_2\text{Cl} - \text{CF}_2 - \text{CHClF}$	203	56	?	?	?
CT	$\text{CCl}_4$	154	77	1.1	1.0	0.34
MCF	$\text{CH}_3\text{CCl}_3$	133	74	0.14	0.1	0.02

\* Chlorine Loading Potential.



# CFC-113- Derivatives



21 既4王の、め2 HFC

Promising HFCs

コード	分子式	分子量	b.p. °C	備考
32	$\text{CH}_2\text{F}_2$	52	-52	HCFC-22の代。可燃。
○ 125	$\text{CHF}_2-\text{CF}_3$	120	-49	同上。F-32 GWP大 (0.6)。
134	$\text{CHF}_2-\text{CHF}_2$	102	-20	不安定?
○ 134a	$\text{CH}_2\text{F}-\text{CF}_3$	102	-27	CFC-12の代とし最有力。
143a	$\text{CH}_3-\text{CF}_3$	84	-48	可燃。GWP大 (0.7)。
○ 152a	$\text{CH}_3-\text{CHF}_2$	66	-25	可燃。GWP小 (0.03)。
227	$\text{CF}_3-\text{CHF}-\text{CF}_3$	170	-17	GWP大?

# HALOGENOCARBONS WIDELY USED IN INDUSTRY

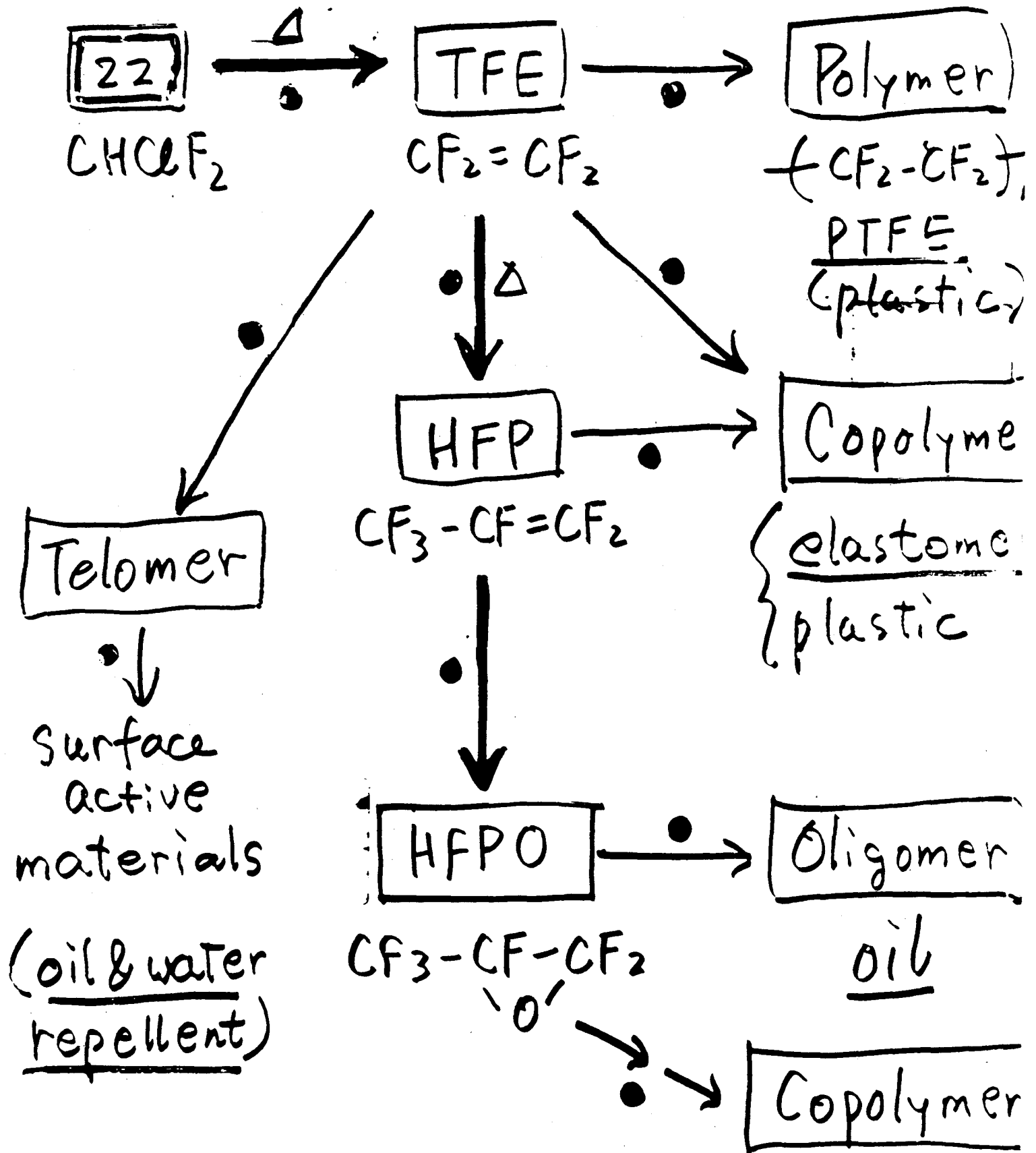
Code	Formula	b. p. °C	Life/y	ODP <sup>1)</sup>	GWP <sup>2)</sup>	Main us
CFC-11*	CCl <sub>3</sub> F	24	60	1.0*	1.0	Foaming
CFC-12*	CCl <sub>2</sub> F <sub>2</sub>	-30	120	1.0*	3.1	Cooling
CFC-113*	CCl <sub>2</sub> F-CClF <sub>2</sub>	48	90	0.8*	1.4	Cleanin
CFC-114*	CClF <sub>2</sub> -CClF <sub>2</sub>	4	200	1.0*	3.9	Blending
CFC-115*	CClF <sub>2</sub> -CF <sub>3</sub>	-39	400	0.6*	7.5	Blending
HCFC-22	CHClF <sub>2</sub>	-41	15	0.05	0.35	Cooling
halon 1301*	CF <sub>3</sub> Br	-58		10.0*		Fire ext
halon 1211*	CF <sub>2</sub> ClBr	-4		3.0*		Fire ext
halon 2402*	CF <sub>2</sub> BrCF <sub>2</sub> Br	47		6.0*		Fire e
CT <sup>2)</sup>	CCl <sub>4</sub>	.77	50	1.1	0.35	CFCs
MCF <sup>3)</sup>	CH <sub>3</sub> -CCl <sub>3</sub>	74	6.3	0.13	0.024	Cleaning

\* Production is regulated by the Montreal Protocol.

<sup>1)</sup> Ref: Synthesis Report. UNEP/Oz1.Pro.WG. II(1)/4, Nov. 4, 1989.

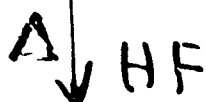
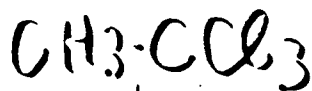
<sup>2)</sup> Carbon tetrachloride, <sup>3)</sup> Methylchloroform or 1,1,1-Trichloroethane

# HCFE-22- Derivatives (solid)

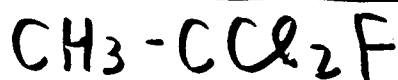


# MCF Derivatives

**MCF**



**HCFC-141b**

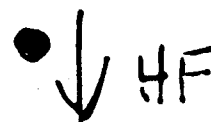
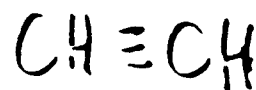


**HCFC-142b**

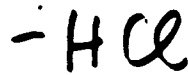
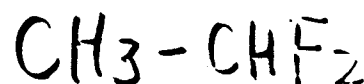


**HFC-143a**

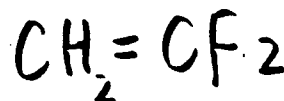
**Acetylene**



**HFC-152a**



**VdF**



**Polymer**

plastic



**Copolymer**

elastomer

anti-mat

# Characteristics of Pentafluoropropanol (5FP)

	5FP	CFC-113
Molecular Weight	150	187.5
<u>Boiling Point</u> [°C]	81	47
Specific gravity	1.509	1.561
<u>Surface tension</u> [dyne/cm]	19	18
Heat of vapourization [cal/g]	63.4	34.4
<u>Solubility of H<sub>2</sub>O</u> [%]	13.4	0.01
Flash Point [°C]	none	none
Ozone Depletion Potential	0	0.8
Green House Effect Potential	<0.1	0.3~0.8
Mutagenicity	none	none
Fish bioaccumulation	none	none
Japanese TSCA	2-3364	2-95
TSCA	422-05-9	76-13-1
EINECS	2070127	2009361
<u>Acute oral toxicity</u> LD50 [mg/kg]	2,250	43,000
Inhalation toxicity LC50 [ppm]	7,000(2H)	87,000(6H)

# **CFCs AND HCFCs AS FEEDSTOCKS**

**Dr. Nubuo Ishikawa**

**Director, F & F Research Center**

**Japan**

**CFC's & HCFC's  
as Feedstocks**

**Nobuo ISHIKAWA  
(Japan)**

**1/16/90, Washington, DC**



TABLE 1 (Continued)

## SUMMARY OF TECHNICAL OPTIONS AVAILABLE FOR CFC REDUCTIONS

- <sup>a</sup> The actual amount of water substitution possible will vary geographically by 15-50 percent according to the choice of raw materials, initial energy efficiency value of the insulation and energy efficiency standards. The following table illustrates the average reductions expected worldwide:

Region	CFC Consumption (Tonnes)	% Reduction	Total (Tonnes)
N. America	9,400	15-30	1,410-2,820
W. Europe	9,900	50	4,950
Japan	4,700	15	705
Other	13,200	15-30	1,980-3,960
Total	37,200		9,045-12,435

- <sup>b</sup> The actual amount of water substitution will vary geographically by 15-50 percent according to the type of facers, polyurethane or polyisocyanurate foam chemistry, energy efficiency, and combustibility requirements.

Region	CFC Consumption (Tonnes)	% Reduction	Total (Tonnes)
N. America	21,700	15	3,255
W. Europe/ Other	29,300	25-50	7,325-14,650
Total	51,000		10,580-17,905

- <sup>c</sup> In polyurethane rigid packaging, rigid integral skin, and other miscellaneous polyurethane applications, it is technically possible to reduce CFCs by 80 to 100 percent by 1993. For flexible integral skin foams, the level of CFC reductions worldwide is expected to be around 50 percent.

TABLE 1

## SUMMARY OF TECHNICAL OPTIONS AVAILABLE FOR CFC REDUCTIONS

Type of foam	Tonnes of CFC Used (1986)	Near Term Options	Possible Global Reductions by 1993	Longer-Term Options	Possible Global Reductions After 1993
Polyurethanes: Flexible Slabstock	45,600	New polyol technology Increased foam density/increase water "AB" technology CFC recovery Methylene chloride Product Substitutes (Fibrefill, latex foam)	80-100%	HCFC-141b	0-20%
Flexible Moulded	13,700	New polyol technology Increased water/ increased densities	80-100%	HCFC-141b HCFC-123	0-20%
Rigid Insulation: Appliance	37,200	Increased water substitution	30% <sup>b/</sup> (15-50%)	HCFC-141b HCFC-123 Product substitutes Vacuum panel insulation	Remaining CFC use
Laminate	51,000	Increased water substitution Product substitutes (EPS, perlite, fiberboard)	28% <sup>b/</sup> (15-50%)	HCFC-141b HCFC-123 Product substitutes	Remaining CFC use
Spray, Slabstock, and Poured-in-place	44,200	Increased water substitution Product substitutes	15-50%	HCFC-141b HCFC-123 Product substitutes	Remaining CFC use

TABLE 1 (Continued)

## SUMMARY OF TECHNICAL OPTIONS AVAILABLE FOR CFC REDUCTIONS

Type of Foam	Tonnes of CFC Used (1986)	Near Term Options	Possible Global Reductions by 1993	Longer-Term Options	Possible Global Reductions After 1993
Integral Skin and Miscellaneous	17,700	Increased water Total water blowing HCFC-22 Hydrocarbons Methylene chloride Air loading Product Substitutes	50-100% <sup>c/</sup>	HCFC-141b HCFC-123	0-20%
Sub-total Polyurethane	(209,400)				
Phenolic	6,900	Capture/recycle Product substitutes	50%	HCFC-141b HCFC-123	Remaining CFC use
Extruded Polystyrene Sheet	20,000	HCFC-22 Hydrocarbons Blends of these two alone and with other atmospheric gases Product substitutes	100%	HCFC-141b HCFC-123 HCFC-124 HFC-125 HFC-134a Modified resins/ atmospheric gases	N/A
Extruded Polystyrene Boardstock	17,600	HCFC-22 HCFC-142b Hydrocarbons Blends of the above Product Substitutes	100%	HCFC-124 HFC-134a	N/A
Polyolefin	13,000	HCFC-22 HCFC-142b Hydrocarbons (butane) Product Substitutes	100%	HCFC-141b HCFC-123 HCFC-124 HFC-134a	N/A
Total	266,900				

## Longer term options for reducing CFC use in Foam Plastic Products

Longer term options	Foam products for which option is appropriate			
	Insulation	Cushioning	Packaging	Other
HCFC-141b	0	0	0	
HCFC-123	0	0	0	
HCFC-124			0	
HCFC-125			0	
HCFC-134a			0	
Product substitutes	0	0	0	0
Vacuum panels	0			
Modified resins and atmos. gases			0	

## GLOBAL PHASE OUT SCHEDULE FOR CFCS IN FOAM PLASTIC

### Near Term (by 1993):

The foam plastics industry can reduce approximately 60 percent of 1986 CFC consumption with available substitutes: increased and total water blowing (carbon dioxide blowing agent), new polyol technologies, hydrocarbons, HCFC-22, HCFC-142b, and others.

Polyurethane flexible foams, polyurethane packaging and miscellaneous foams, extruded polystyrene packaging foams, extruded polystyrene insulation, and polyolefin foams have announced CFC phase out by 1993.

### Long Term (after 1993):

The foam plastics industry, principally polyurethane and phenolic insulation foams, will depend upon the development and acceptable use of HCFCs to achieve a complete phase out of CFCs.

CFC Reductions in Foam Plastics Can Vary Significantly from Country to Country Depending Upon:

Use patterns in Each country

Countries with large CFC consumption in flexible and packaging foams have opportunity for largest and quickest reductions:

- Water blown foams
- Increased foam density
- New polyol technology
- HCFC-22
- Product substitutes

Countries with large CFC consumption in polyurethane insulation foams for appliances, buildings and pipes face greatest challenge for substitutes:

Increased water blowing for immediate reductions in CFC consumption.

HCFC-141b and HCFC-123 most promising longer term substitute.

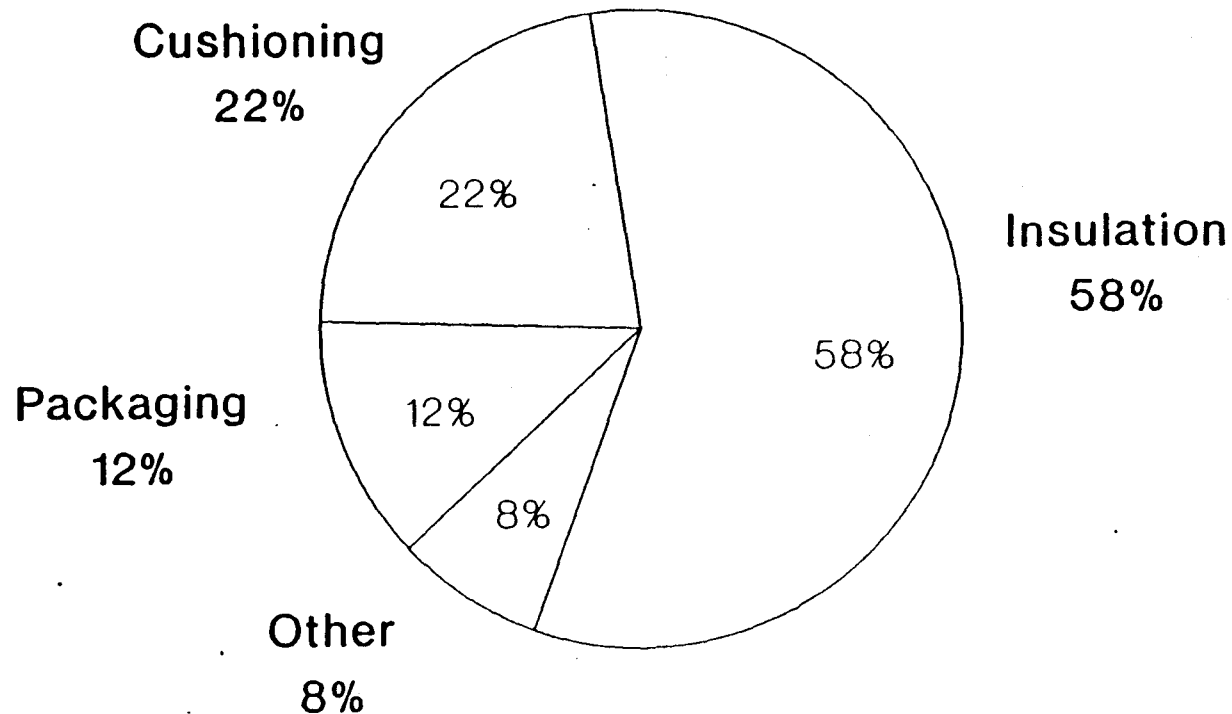
Energy efficiency is important criteria in substitute selection.

## Near term options for reducing CFC use in Foam Plastic Products

Near term options	Foam products for which option is appropriate			
	Insulation	Cushioning	Packaging	Other
New polyol technology		0		
Increased foam density		0		
Increased water blowing	0	0	0	0
Total water blowing				0
"AB" technology		0		
CFC recovery		0		
Methylene chloride		0		0
Product substitutes	0	0	0	0
Air loading				0
HCFC-22	0		0	
Hydrocarbons	0		0	0
Hydrocarbon/HCFC-22 blends	0			
HCFC-142b	0		0	

# Global CFC Use in Foam Plastics

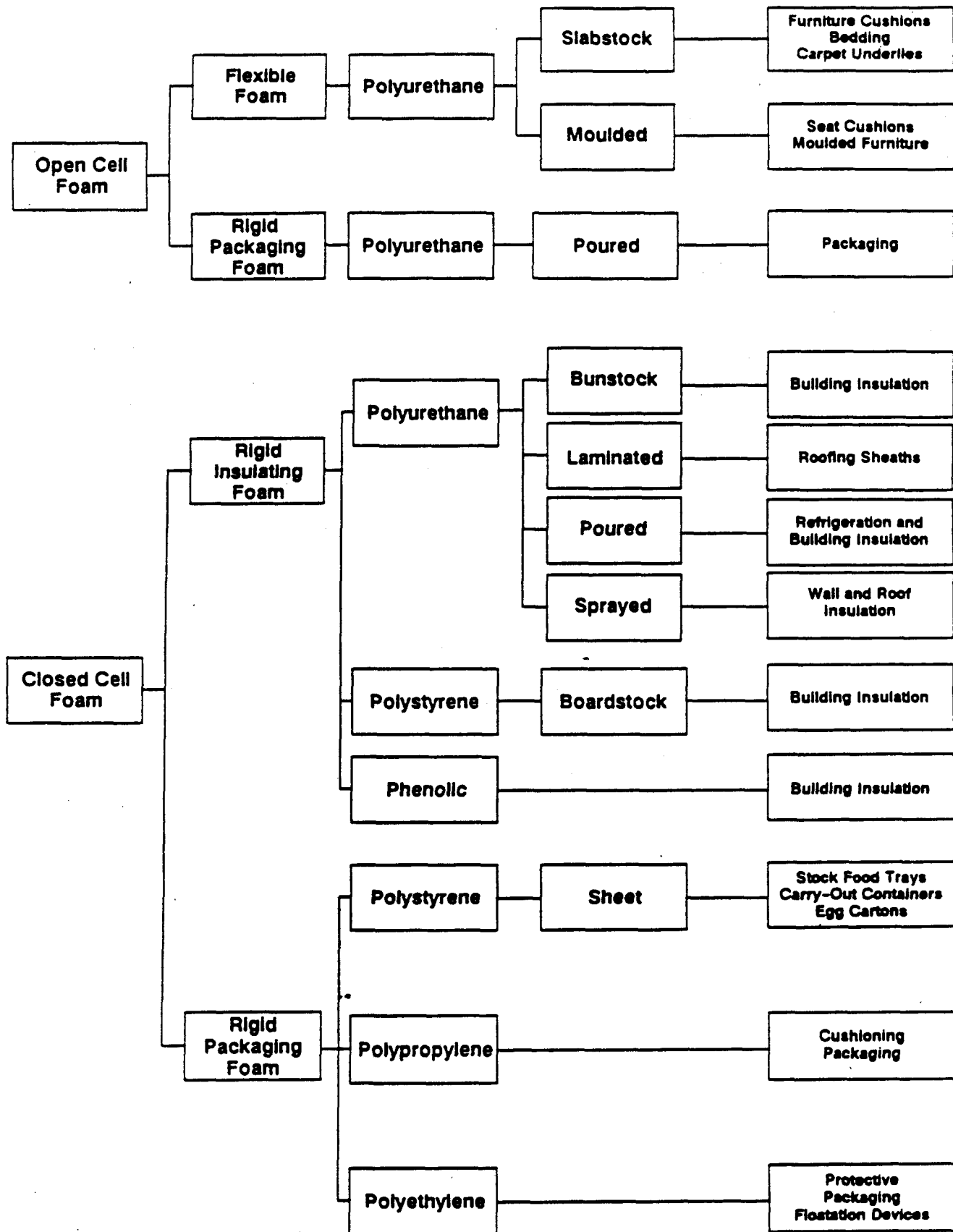
(by type of product)



Source: UNEP Foam Technical Options

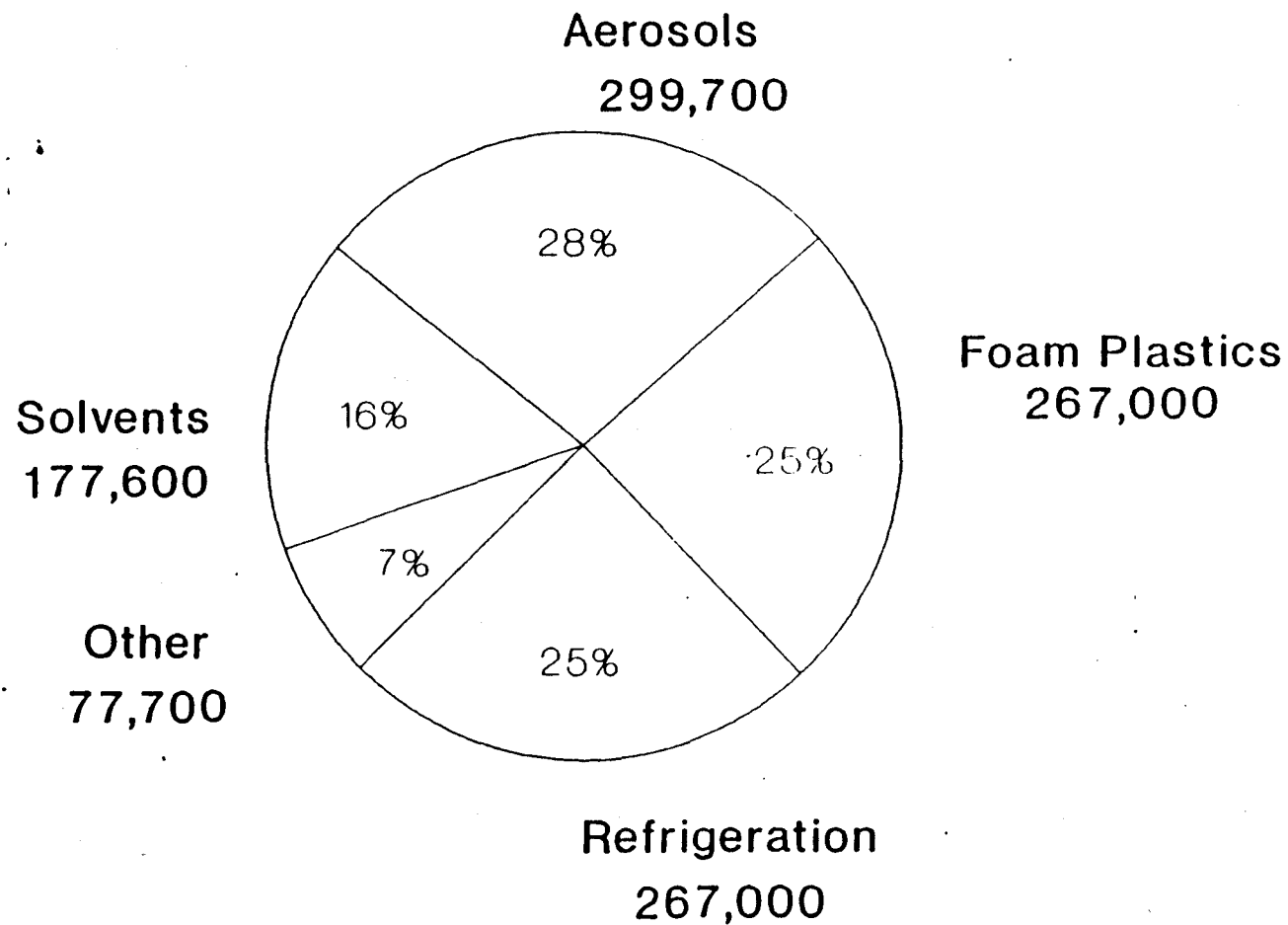


**Figure 1**  
**Types and Major Uses of CFC-Blown Foam**



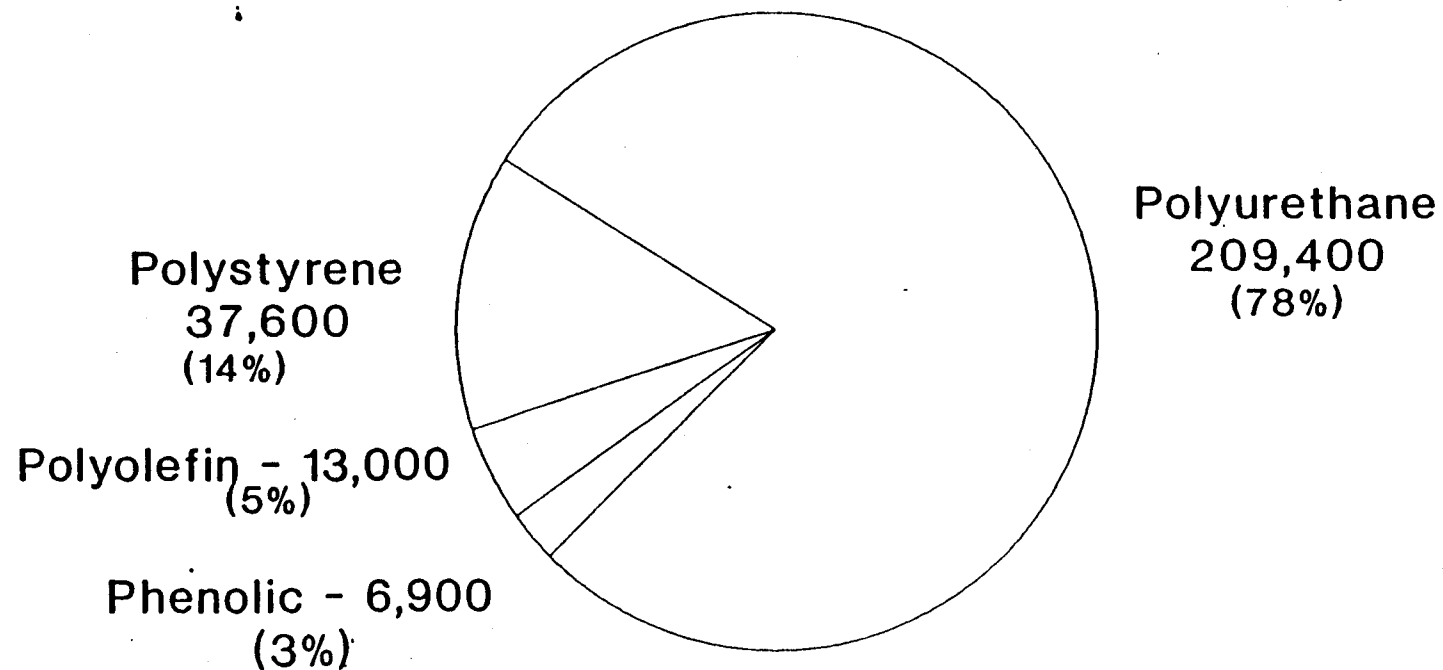
# 1986 Global CFC Use - by Application

(in metric tons)



# Global CFC Use in Foam Plastics

(in metric tons)



**IMPORTANT CONSIDERATIONS IN  
EVALUATING SUBSTITUTES TO CFC  
BLOWING AGENTS IN  
FOAM PLASTIC PRODUCTS**

**Ms. Jean Lupinacci**

**Office of Air and Radiation**

**U.S. Environmental Protection Agency**

Important Considerations in Evaluating Substitutes  
to CFC Blowing Agents in Foam Plastic Products

Prepared by:

Jean M. Lupinacci  
Chairperson,  
UNEP Foams Technical Options Committee

EPA WORKSHOP

Integrating Case Studies Carried  
Out Under the Montreal Protocol

January 16, 1990

## REFRIGERATION APPLICATION AREAS

Refrigeration/Retail/Transport/Storage/AC-Chilling/Automotive

	Refrigerators	Retail/Trans.	Storage	AC-Chill.	Automotive
Containment	-	+	-	-	+(?)
Recycling	-/+	++	++	++	++
Reduced Charge	+	+	o	o	+
HCFC-22	-	++	+	+	-
Drop-ins (R-500)	-/+	o	o	-/+	-/+
Substitutes Existing (ammonia, HC)	-	+	++	+/-	-
New Substitutes	++	-/+	-	+	++

- 
- ++ very interesting from reliability/environment point of view
  - + interesting
  - o not applicable/marginal
  - not interesting

**Examples:**

- Recycling will be interesting from a point of view of cost-effectiveness, environmental acceptability, etc.

However, recycling of refrigerant from disposed refrigerators may not be cost-effective, but may be of high public interest (environmental consciousness).

- Application of HCFC-22 in equipment can reduce the dependence on CFC-12 in a lot of equipment (in case it uses CFC-12) at short notice.
- Most of the developing countries have high CFC consumption shares in the retail/storage sector. Mostly due to recharging of leaking systems and component failures/repair. High reductions of consumption can be achieved by education of engineers and the creation of good practice methods.
- Reduction of charge may be applicable in smaller systems where piping is also used as construction material. 10/20% reduction may be possible.
- Ammonia technology should receive considerable attention and can provide substantial saving in CFC-consumption.
- New substitutes have to be applied in refrigerators, e.g., there is no reliable solution so far (near future).

# **ASSESSMENT OF ALTERNATIVE SUBSTITUTES AND TECHNOLOGIES IN REFRIGERATION**

**Dr. Lambert Kuijpers**

**Philips Research Laboratories**

**Netherlands**



## UNEP – TECHNOLOGY ASSESSMENT

25% Refrigeration	}	Global Values
25% Foams		
25% Aerosols		
Solvents		
Miscellaneous		

Refrigeration varies over countries: 5-50 percent

Low percentage of refrigeration in developed countries which have:

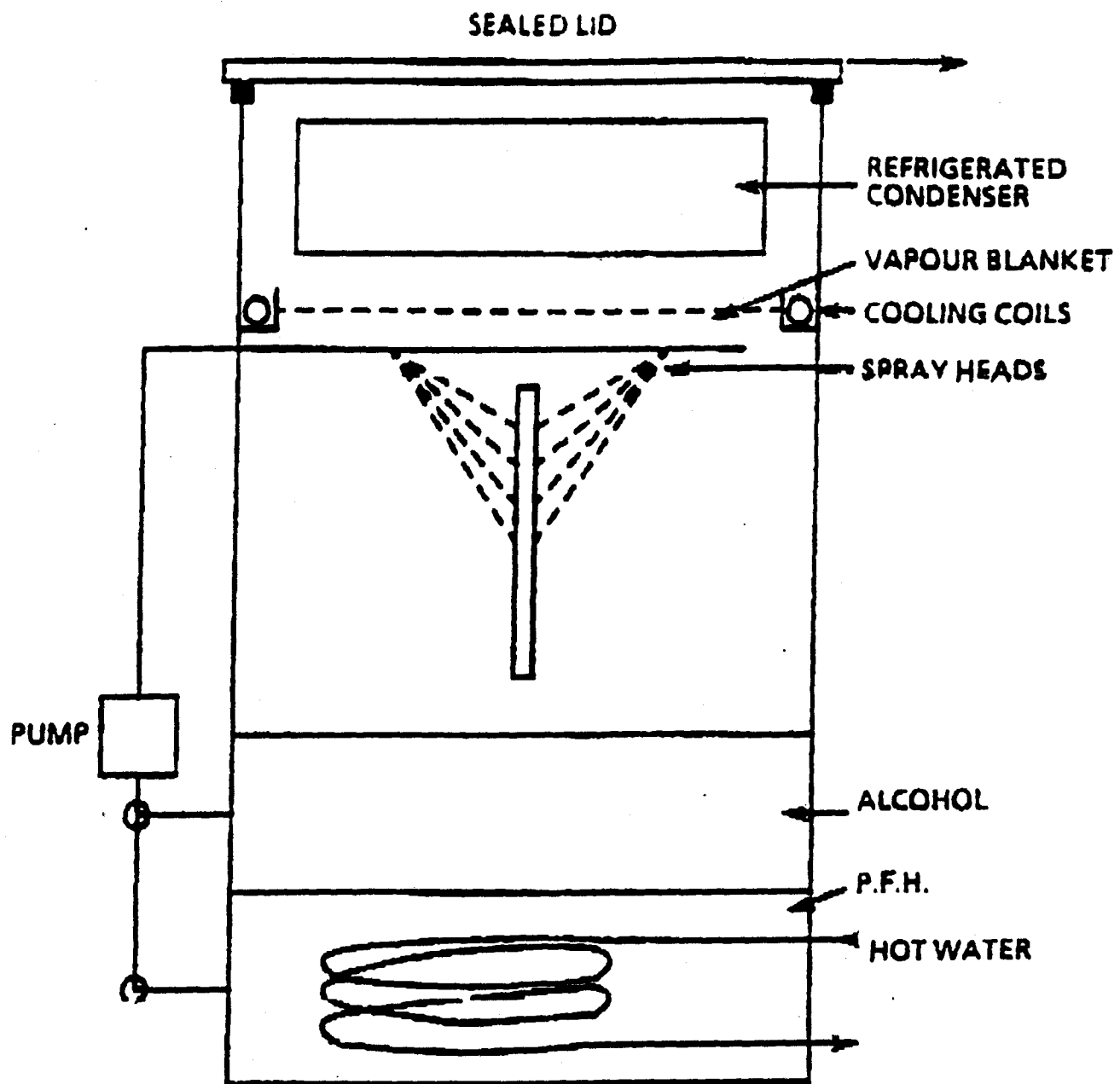
- Low amount of CFC-solvents
- No automotive air conditioning
- Aerosols

### 1986/87 Values

<u>FRG</u>	<u>USA</u>	<u>PRC</u>
Refrigeration <10%	Refrigeration ≈35%	Refrigeration 45%
10% Refrigerators	4% Refrigerators	10% Refrigerators
70% Retail/Storage, Transport	30% Storage, 20% large units	90% retail, storage, chilling
Automotive	40% Automotive	

The first application of this technique will be a batch pcb defluxing machine which is currently being assembled this year. A diagram of the principle of the system is shown in the figure. Simplified versions of the technique can be used for dewatering as well as precision small parts cleaning.

Because of the high cost of the p.f.h. and also because it has a high global warming potential, the prototype cleaner is designed to be hermetically sealed with zero solvent loss and its commercial viability will depend in large measure on the success of this aspect of the design. The alcohol is the "working solvent" for the system and can be made up automatically as flux or other soil rich solvent is discarded to waste or recovery.



**CFC FREE DEFLUXING SYSTEM**

# **REPLACEMENT OF CFC-113 SOLVENT**

**Mr. Bryan Baxter**

**British Aerospace Precision Products Group**

**United Kingdom**

## REPLACEMENT OF CFC-113 SOLVENT

Presented at the EPA Workshop: Integrating Case Studies  
Carried Out Under the Montreal Protocol

January 15-17, 1990

B.H. Baxter, British Aerospace Dynamics Ltd.

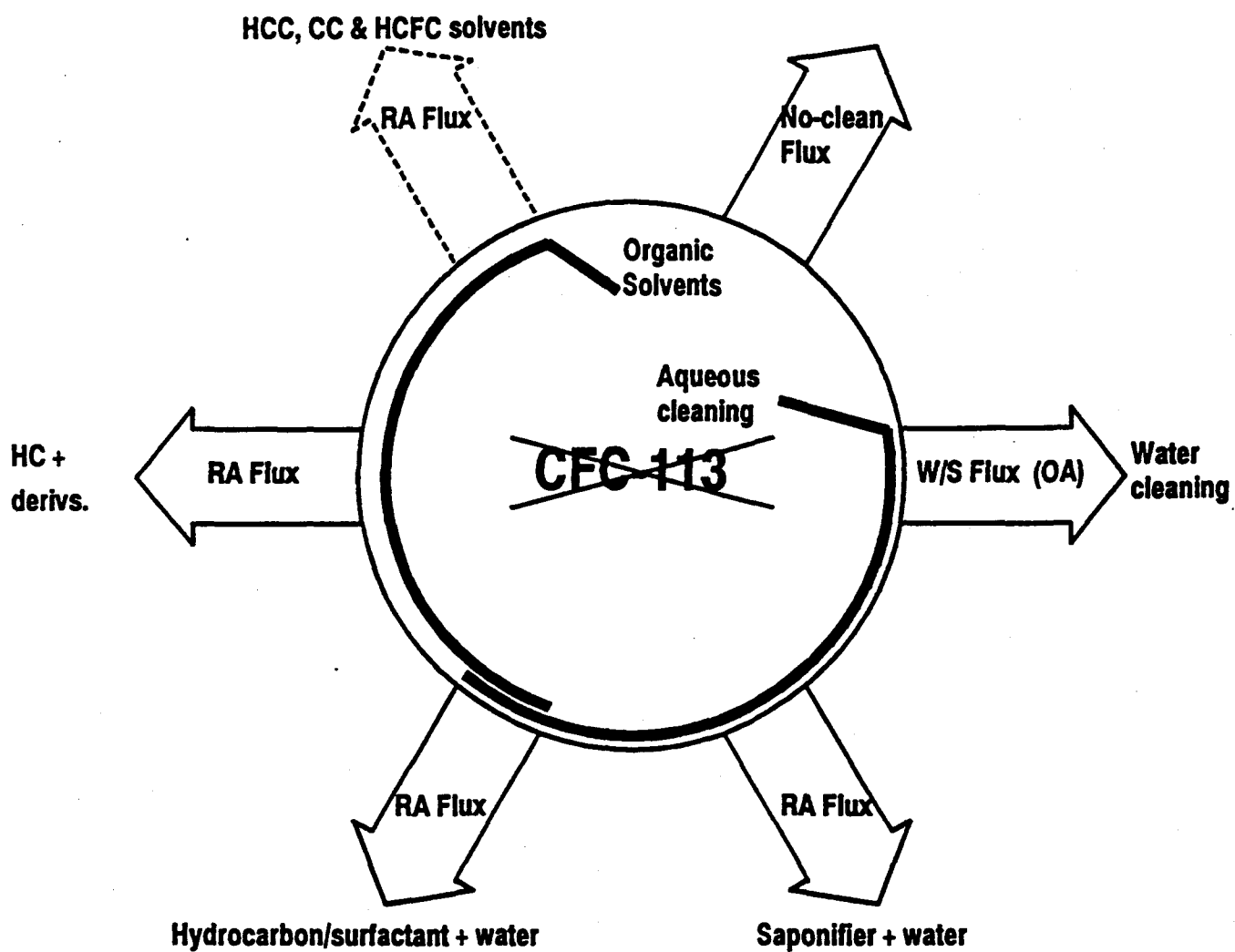
It is an easy oversimplification to assume that the only industrial use of CFC-113 is as the major solvent in the defluxing of soldered electronic circuits and components. The risk of such an oversimplification is that it can lead to the conclusion that the introduction of aqueous cleaning, no-clean flux options and controlled atmosphere soldering techniques can virtually eliminate the need for CFC-113. Unfortunately, whilst these factors apply to certain uses of the solvent, particularly in the large volume commercial electronics manufacturing industry, they fail to cover adequately many other uses of 113.

In particular dewatering and drying accounts for a large part of CFC-113 production. In some industries, especially optics and small component manufacture, up to 60 percent of 113 consumption is for this purpose. In comparison with alternate techniques such as oven or air-knife drying, it offers energy efficient "one shot" drying and produces spot free cool components of particular value in the optics and medical prosthesis industries.

The precision engineering industry also uses large amounts of 113, especially in clean areas where its low odor, zero flammability and low toxicity are essential and its chemical compatibility with reactive metals such as beryllium is difficult to match using alternate solvents.

The defense electronics industry is also radically different from large scale commercial manufacturing; a wide range of technologies often needs to be processed in the same area, sometimes in relatively small batches. Unlike the commercial sectors where circuits can be designed to meet cleaning techniques, the defense equipment manufacturer is often called upon to produce components for long-running contracts using long "frozen" drawings and plannings.

One alternative to CFC-113 which is effective as a defluxing agent, a cleaner and a dewaterer, is 2-propanol or isopropanol. However, this solvent suffers the considerable disadvantage of high flammability. At British Aerospace we are developing a process jointly with two other companies in which this flammability is completely suppressed by the use of a perfluoro hydrocarbon. This solvent, although immiscible with the alcohol, vaporizes with it form a vapor mixture which is completely non-flammable.



**Practical substitute methods for CFC solvent cleaning in electronics**

# **ELECTRONICS CLEANING IN DEVELOPING COUNTRIES**

**Mr. Brian Ellis**

**General Director, Protonique, S.A.**

**Switzerland**

## Some ideas concerning electronics cleaning in developing countries:

Assumptions: at present prices, a wave soldering machine + in-line CFC-113 machine for medium-large production of medium professional quality (e.g. computer, telecomms etc.) costs \$120,000 in capital and an index of 1 to run.

Following figures are very approximate average estimations, based on average European figures for capital costs of middle-of-the-range equipment, solvent costs, salaries, social charges, rent, energy and other overheads.

Indices: lowest figure best, highest figure worst.

Process type	Capital costs k\$	Running costs Index	Overall costs Index	Ease of use Index	Space Index	Reliability Index	Comments
CFC-113 solvent (reference)	120	1	1	1	1	1	OK for most professional usage <sup>1,6</sup>
No-clean conventional rosin flux	20-50	.2-3	.1-25	0.5	.6	3-5	Not OK for truly professional use <sup>1</sup>
No-clean low-solids flux	30-80	.5-8	.4-8	3	.6	2-4	OK for some professional usage <sup>2</sup>
No-clean inert-gas soldering	>300	1-2	1.5-3	3	1.5-2	2-5?	OK for some professional usage <sup>3,4</sup>
Water-sol. flux + water cleaning	150	.5-7	.7-1.1	1-1.2	1	.8-2	OK for most professional usage <sup>1,8</sup>
Rosin flux + saponifier cleaning	150	.6-8	.75-1.2	1-1.3	1	.9-2.5	OK for most professional usage <sup>1,7,8</sup>
Rosin flux + HC/surf. + water	350	2-3	>2	2	2	<1?	OK for most professional usage <sup>3,4,5,6,7</sup>
Rosin flux + HC deriv. (alcohol)	400	.5-1	>2	1.8	1.8	1-1.2?	OK for most professional usage <sup>3,4,5,7</sup>
Rosin flux + HCFC, HCC, CC	120	.9-1	.95-1	1.1	1	1.1	OK for most professional usage <sup>1,6,7</sup>

1 Established method: technology & equipment easily available

2 Recent method: technology and equipment available

3 New method: technology still partially under development

4 Massive nitrogen installations required

5 Important fire and explosion precautions required

6 Major potential or real environmental problems

7 Potential operator health & safety problems

8 Overall quality is very process-dependent

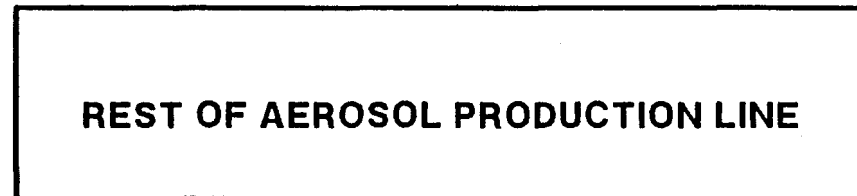
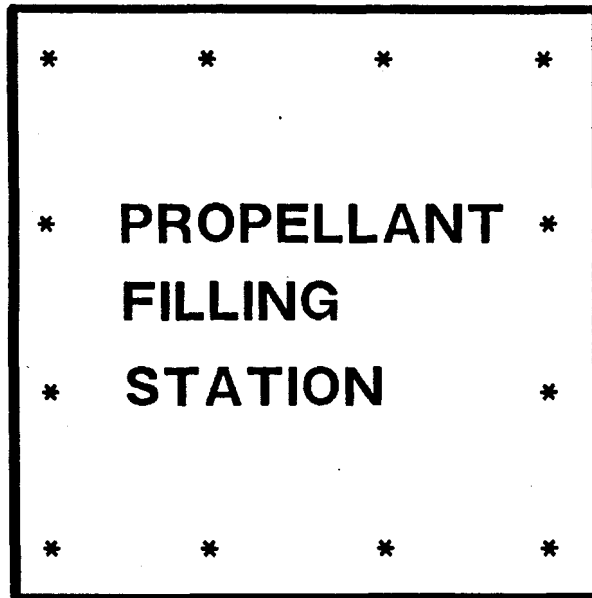
### *Danger VOCs!*

#### *Los Angeles syndrome.*

*Where weather can be dry, sunny and with long periods of little wind, some substitute solvents, known as Volatile Organic Compounds (notably some chlorocarbons and hydrocarbons) can react with local air pollution from industrial, domestic, transport or a few natural sources, to produce dangerous levels of ozone and smog.*



## CONVENTIONAL TECHNOLOGY

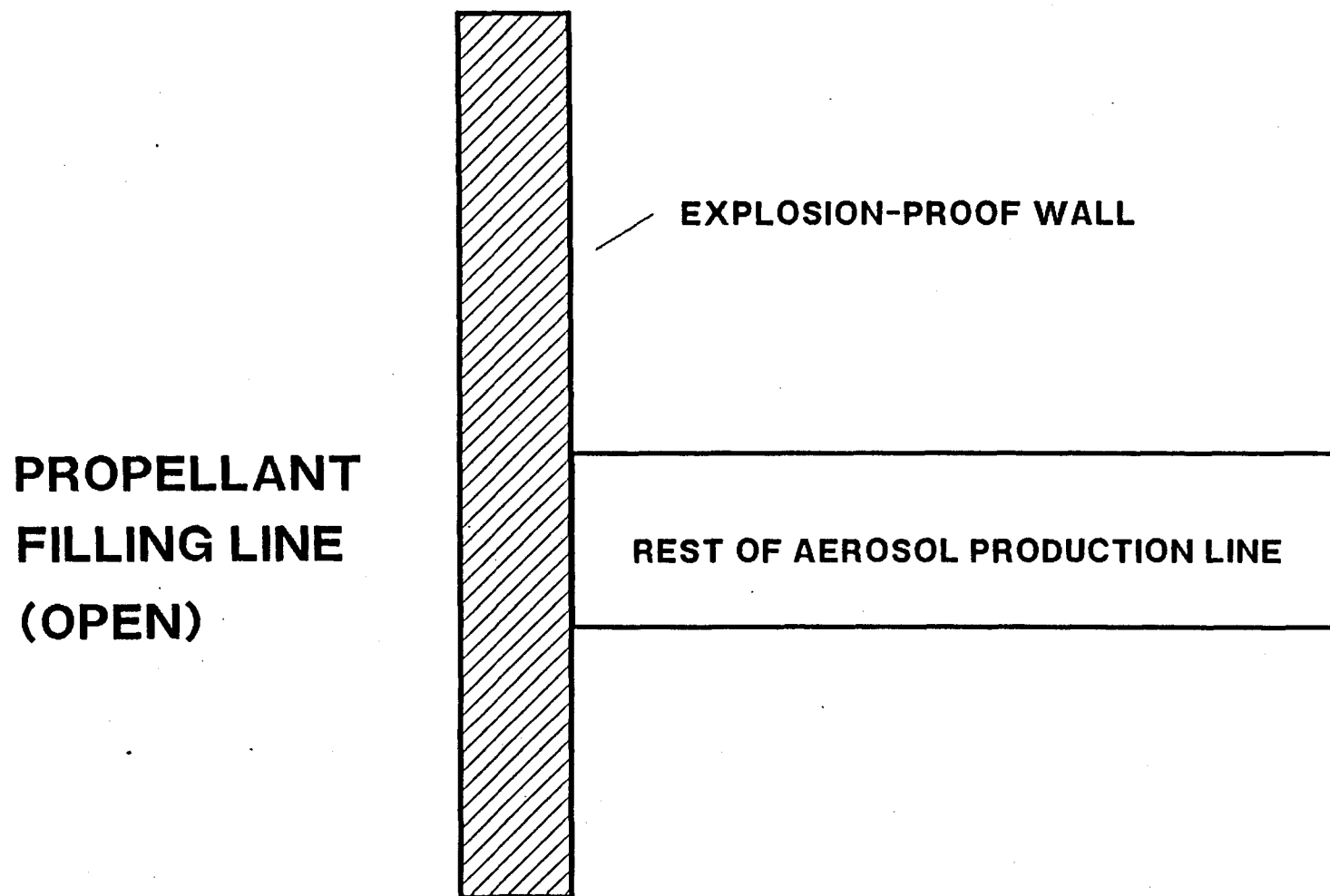


**\* = Leak detectors, alarms, & devices for shutting down gas supply lines.**

**COMPARATIVE CHARACTERISTICS OF ALTERNATIVE PROPELLANTS**  
**(BASED ON CFCs AS STANDARD)**

	Cost (Raw Material)	Environmental ODP	GWP	Flammability	Toxicity	Simplicity/ Reliability
Hydrocarbon	-	0	-	+++	=	=
CO <sub>2</sub>	-	0	+	=	=	(-)
N <sub>2</sub>	-	0	0	=	-	(-)
DME/HCFC-22	+	--	?	+/-	=	(-)/=
HCFCs	+	--	--	+	?	=

## TECHNOLOGY ADAPTED TO MILD CLIMATE AREAS



## **HYDROCARBON PROPELLANT CHARACTERISTICS**

---

- Propane/Isobutane (Different Blends)
- DRY
- Deodorized (Usually by Removing Sulphur Compounds, Aromatic and Non-Saturated Hydrocarbons)

**EXAMPLE OF INFORMATION REQUIRED  
FOR ADAPTING TECHNOLOGY TO LOCAL CIRCUMSTANCES**

---

- Present Plant Design
- Pneumatic or Electric Instruments
- Location (Distance to Inhabited and/or Industrial Areas)
- Climate (Maximum and Minimum Temps; Humidity)
- Prevalent Wind Direction
- Present Layout
- Propellant Storage Tanks (Design, Location)
- Availability of Hydrocarbons

## ALTERNATE TECHNOLOGIES FOR CFCs USES IN AEROSOLS

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### 1. Substitute Propellants

- Hydrocarbons
- CO<sub>2</sub>; N<sub>2</sub>; Other Compressed Gases
- DME; DME/FCFC-22
- HCFCs (142a; 152a)

### 2. Alternative Delivery Systems

- Pumps
- Pistons
- Mechanical Pressure Dispensers
- Non-aerosol Alternatives (e.g., roll-on, sticks, brushes...)
- Airless Sprayers (paints)

## **DIFFERENCES IN PLANT DESIGN REQUIREMENTS**

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### **For Non-Flammable Propellants**

---

- No special explosion-proof equipment needed

---

### **For Flammable Propellants**

---

- Special explosion-proof equipment installations and instrumentation needed
- Sophisticated leak detection required
- Plant shut-up equipment
- Alarms
- Escape routes
- Location (far from existing industries and urban areas)

## **CFCs AS PROPELLANTS**

---

### Advantages

- Stability
- Inertness
- Compatibility
- Non-reactive
- Non-toxic
- Non-flammable
- Odorless
- Proper Pressure Ranges

### Disadvantages

- Deplete Stratospheric Ozone Layer
- High Global Warming Potential
- Price



**I. INTRODUCTION**

**II. BEST COST-EFFECTIVE ALTERNATIVE TECHNOLOGIES FOR CFC USE IN AEROSOLS**

**A. Available Alternatives**

**B. Selection Criteria for Alternative Propellants**

**III. ADAPTING TECHNOLOGY TO DEVELOPING COUNTRY NEEDS**

**A. Switch From CFCs to Hydrocarbons in Mexico**

**B. Cost Effective Open-Air Hydrocarbon Filling Platforms**

**IV. EXAMPLE OF INFORMATION REQUIRED BY TECHNICAL EXPERTS FOR ADAPTING TECHNOLOGY TO LOCAL CIRCUMSTANCES**

(i.e., additional space and ventilation are available) the total investment required to adapt plants to safely handle these flammable propellants may be recovered in one or two years due to raw material savings.

### **Selection Criteria for Alternate Propellants**

The selection criteria for alternative propellants include raw material costs, ozone depletion potential (ODP), global warming potential (GWP), flammability, toxicity, and simplicity/reliability of use. Using CFCs as the basis for comparison, hydrocarbon propellants, carbon dioxide, nitrogen, mixtures of DME/HCFC-22, and HCFCs are ranked based on these criteria, as shown in slide 5. Hydrocarbon propellants and the compressed gases are less expensive than CFCs; however, hydrocarbons are flammable, and the technology needed to effectively use compressed gases is more complex. The newer options, DME/HCFC-22 mixtures and HCFCs, are more expensive than CFCs have low ODPs and GWPs, may be flammable, and the current filling technology may be adequate to use them effectively. Except for HCFC-22, which has been used in the refrigeration industry for a number of years, the toxicity of the HCFCs is under review.

Most of the modifications needed to switch from CFCs to hydrocarbons are related to safety, that is, dealing with the flammable products. This requires considerable additional investment, depending on the plant circumstances.

### **III. Adapting Technology to Developing Country Needs**

#### **Switch from CFCs to Hydrocarbons in Mexico**

Currently, only 12 percent of all aerosols produced in Mexico contain CFCs. The Mexican aerosol industry has committed to phaseout the use of CFCs by 1991 by signing a voluntary agreement with the Mexican environmental agency, SEDUE. The agreement does not apply to medicinal aerosols, electronic cleaners, and aircraft aerosols, for which no substitutes are currently available. The Mexican aerosol industry has reduced its CFC consumption and switched to hydrocarbons by adapting conventional technology to local circumstances.

When switching from non-flammable propellants to flammable propellants (i.e., hydrocarbons), various plants design requirements must be met. The plant needs special explosion-proof equipment and instrumentation, sophisticated leak detection systems, plant shut-up equipment, alarms, escape routes, and finally, the plant must be located far from populated areas.

#### **Cost Effective Open Air Filling Platforms**

An example of how all of these new plant design requirements can be adapted to local circumstances is the use of open air filling platforms. In developed countries where winter conditions are harsh leading to potential gas line freezing and clogging, it

is common practice to construct filling areas (gas houses) in a closed room with concrete walls. For safety reasons the room is isolated from the rest of the aerosol filling line (see slide No. 7). The room is equipped with leak detectors, alarms, and devices for shutting down gas supply lines in case excessive concentrations of hydrocarbons accumulate. The cost associated with such gas house construction design is high. Mexico, as many other developing countries has relatively mild and uniform weather year-round. Filling lines are positioned outside the plant building with an explosion proof wall separating the filling line from the rest of the aerosol production line (see slide No. 8). The design approach is inherently cheaper and with adequate ventilation (either natural or from explosion-proof fans) the open air filling platform is also safe. This design approach has been used in Mexico for many years with no reported incidents to date.

This is only one example where developing country engineers have used ingenuity and common sense to adapt conventional technology to local circumstances.

#### **IV. Example of Information Required by Technical Experts for Adapting Technology to Local Circumstances**

Mexican technical experts welcome the opportunity to assist other developing countries in eliminating the use of CFCs and adapting aerosol plants to safely use hydrocarbon propellants. An example of the information that these experts would require to evaluate the specific circumstances of an aerosol plant include:

- present plant design,
- use of pneumatic or electric instruments,
- plant location (distance to populated and/or industrial areas),
- climate (minimum and maximum temperatures, humidity)
- wind direction,
- present layout,
- design and location of propellant storage tanks, and
- availability of hydrocarbons.

# **ADAPTING AEROSOL TECHNOLOGIES TO DEVELOPING COUNTRY NEEDS**

**Mr. Jorge Corona**

**Cámara Nacional de la Industria de la Transformación**

**Mexico**

## **ADAPTING AEROSOL TECHNOLOGY TO DEVELOPING COUNTRY NEEDS**

Mr. Jorge Corona de la Vega, CANACINTRA, Mexico

### **I. Introduction**

In the past Mexico followed the worldwide trend of developing an aerosol industry based on CFCs as propellants. CFCs are still the most suitable chemicals for propellant applications, due to a number of technical advantages and no technical disadvantages. However, CFCs have great environmental disadvantages, namely their Ozone Depletion Potential.

When news came that CFCs had the potential of affecting world ecosystems by depleting the stratospheric ozone layer, it became clear that the efforts made to develop an aerosol industry in Mexico were in serious jeopardy, and that something had to be done immediately. Looking for a suitable substitute proved to be a difficult task.

### **II. Best Cost-Effective Alternative Technologies for CFCs in Aerosols**

The alternative technologies that may be used to substitute CFCs in aerosols can be classified into two groups: substitute propellants and alternative delivery systems. A number of materials may be used to replace CFC propellants including hydrocarbons, compressed gases (e.g., carbon dioxide and nitrogen), dimethylether (DME) and mixtures of DME with HCFC-22, and HCFCs (e.g., HCFC-142b, HCFC-152a). The alternative delivery systems replace the traditional metal container with pumps, pistons, mechanical pressure dispensers, non-aerosol alternatives (e.g., roll-on, sticks, brushes, etc. for deodorants and personal products) and airless sprayers (for paints.)

Not all these alternatives match the numerous advantages that made CFCs the preferred propellants for aerosol applications worldwide. CFCs are stable, inert, compatible, non-reactive, non-toxic, non-flammable, odorless, and possess the pressure ranges ideal for aerosol applications. Nevertheless, the globally recognized disadvantages of CFCs are their high ozone depletion, global warming potential, and high price.

Although some of the above technologies are adequate as substitutes for CFCs in certain applications, the aerosol industry in Mexico has opted to use of the most cost-effective technology: hydrocarbon propellants. Hydrocarbon propellants include different blends of propane and isobutane. For the effective use of hydrocarbons as replacement for CFCs, the supply of these gases must be free of moisture, sulphur compounds, aromatic, and unsaturated hydrocarbons. In Mexico, hydrocarbons are five times less expensive than CFCs, and in cases where plants are flexible

There are continued pressures to completely phaseout CFCs from the U.S. aerosol industry; however, some products such as the Metered Dose Inhalant (MDI) products do not lend themselves to substitution. If toxicological studies are positive, HFCs may be feasible alternatives.

In addition to a total phaseout of CFCs, the U.S. aerosol industry faces a number of environmental pressures associated with other materials used in the industry. These include potential restrictions on Volatile Organic Compounds in states such as California and New Jersey, and the potential addition of methyl chloroform to the list of regulated compounds under the Montreal Protocol.

# GLOBAL WARMING POTENTIAL (GWP) AND OZONE DEPLETION POTENTIAL (ODP) OF GASES

JANUARY-1990

NUMBERING SYSTEM	CHEMICAL IDENTIFICATION	GWP, COMPARED TO CFC-11	GWP, COMPARED TO CFC-12	GWP, COMPARED TO CO <sub>2</sub>	ODP, COMPARED TO CFC-11
(CC-10)	CCl <sub>4</sub> Carbon Tetrachloride	0.36	0.12	3,600	1.11
CFC-11	CCl <sub>3</sub> F	1.00	0.34	10,200	1.00
CFC-12	CCl <sub>2</sub> F <sub>2</sub>	2.99	1.00	30,000	1.00
CFC-13	CClF <sub>3</sub>	9.6	3.20	96,000	0.45
CFC-113	CCl <sub>2</sub> F·CClF <sub>2</sub>	1.42	0.48	14,500	0.80
CFC-114	CClF <sub>2</sub> ·CClF <sub>2</sub>	4.19	1.42	43,000	1.00
CFC-115	CClF <sub>2</sub> ·CF <sub>3</sub>	8.24	2.80	84,000	0.60
HCFC-21	CHCl <sub>2</sub> F	0.30	0.10	3,100	0.04
HCFC-22	CHClF <sub>2</sub>	0.29	0.10	3,000	0.05
HCFC-31	CH <sub>2</sub> ClF	0.30	0.10	3,100	0.05
HCFC-123	CHClF·CClF <sub>2</sub>	0.019	0.0065	190	0.02
HCFC-124	CHF <sub>2</sub> ·CClF <sub>2</sub>	0.093	0.032	950	0.02
HFC-125	CHF <sub>2</sub> ·CF <sub>3</sub>	0.42	0.14	4,300	--
HCFC-132b	CH <sub>2</sub> Cl·CClF <sub>2</sub>	0.06	0.02	600	0.05
HCFC-133a	CH <sub>2</sub> Cl·CF <sub>3</sub>	0.07	0.024	700	0.05
HCFC-141b	CH <sub>3</sub> ·CCl <sub>2</sub> F	0.085	0.029	870	0.10
HCFC-142b	CH <sub>3</sub> ·CClF <sub>2</sub>	0.06	0.02	600	0.06
HFC-134a	CH <sub>2</sub> F·CF <sub>3</sub>	0.22	0.075	2,250	0.00
HFC-143a	CH <sub>3</sub> ·CF <sub>3</sub>	1.00	0.34	10,200	0.00
HFC-152a	CH <sub>3</sub> ·CHF <sub>2</sub>	0.019	0.0065	190	0.00
HFC-161	CH <sub>3</sub> ·CH <sub>2</sub> F	0.01	0.03	100	0.00
(HCC-110)	CH <sub>3</sub> ·CCl <sub>3</sub> 1,1,1-Trichloroethane	0.022	0.0074	200	0.11
(HCC-20)	CHCl <sub>3</sub> Chloroform*	0.00	0.00	-	--
--	CO <sub>2</sub>	0.000097	0.000033	1	0.00
--	CH <sub>4</sub> Methane	0.0024	0.00083	25	0.00
--	CH <sub>3</sub> ·CH <sub>3</sub> Ethane	0.0065	0.0022	67	0.00
--	CH <sub>3</sub> ·O·CH <sub>3</sub> Dimethyl Ether*	0.00	0.00	-	0.00
--	N <sub>2</sub> O Nitrous Oxide	0.0017	0.00058	18	--

# **SWITCH FROM CFCs TO HYDROCARBON PROPELLANTS**

**Mr. Montfort Johnsen**

**Montfort Johnsen and Assoc., Ltd.**

**United States**



## **SWITCH FROM CFCs TO HYDROCARBON PROPELLANTS**

### **AN INDUSTRY PERSPECTIVE**

**Mr. Montfort Johnsen, Technical Consultant.**

The aerosol industry worldwide produced approximately 8.3 billion units in 1989 of which 3 billion were produced in the U.S. The use of CFCs in the U.S. was banned in 1978 and today only few products exempt from this regulation, continue to use CFCs. The U.S. aerosol industry has adapted to the use of hydrocarbon propellants as the predominant replacement for CFCs. When countries evaluate this substitution option, a number of technical and economic factors must be considered:

- Hydrocarbons propellants are much less expensive than CFCs. In the U.S., hydrocarbons cost approximately \$0.11/lb or \$0.24/kg, whereas CFCs cost more than \$1/lb or \$2.2/kg.
- Hydrocarbon propellants (primarily propane, isobutane, and butane) are flammable; therefore, gas houses must be adapted to safely handle these materials, and employees must be trained to ensure that potential hazards are mitigated.
- In some cases the risks to a neighboring urban community may be too high, and thus, total relocation of the manufacturing plant should be considered.
- CFCs are compatible with many active ingredients and substances due to their good solvency power. Compared to CFCs, hydrocarbons have inferior solvency power and are incompatible with certain materials. In the U.S., the switch to hydrocarbons required extensive reformulation and product re-development which included the use of co-solvents to aid hydrocarbon solubility.
- The availability of hydrocarbons for aerosol use must be carefully evaluated. Aerosol propellants must meet high purity standards. In addition, different gas mixtures yield different pressures needed for product formulation flexibility. Some countries have supplies of natural gas, but lack the infrastructure to purify and separate the various hydrocarbons.
- For safety reasons, some countries require that hydrocarbons be stented with sulphur derivatives so that leaks are detected during transportation. The technology to purify these gases may be costly.

## **Other Solvents**

A proposed CFC-113 substitute, methyl chloroform (1,1,1-trichloroethane), will likely become a controlled substance under the Montreal Protocol. HCFCs and chlorinated solvents are under review for environmental safety as well. If they do contribute significantly to ozone layer depletion or to global warming, restricted use will result. Northern will, therefore, not knowingly recommend substances that could become restricted materials.

## **Purchasing Practices**

Northern Telecom will cease buying, by the end of 1991, products containing CFCs or Halons. Vendors will be encouraged, through correspondence from Northern Telecom Purchasing, purchase orders and such, to stop using CFCs to manufacture products. This will help vendors develop their own programs to end the use of CFCs and Halons.

[illegible]

1

1

100

1

1

1

1

100

L

100

1,000,000 kg in 1987

## NORTHERN TELECOM'S POSITION on CFC AND HALON ELIMINATION

Northern Telecom's goal is to cease buying CFCs and Halons by or before the end of 1991.

### CFC-113

CFC-113 will not be purchased after 1991. For circuit board cleaning, the focus will be on selecting low solids, no-clean fluxes and on choosing new technologies that do not require cleaning. Alternative solvents and other cleaning processes would be considered only if no clean options prove impractical.

With the industry wide drive to eliminate CFCs, our circuit board cleaners will have low resale values. The cleaners will be scrapped after removal from service.

Miscellaneous uses of CFC-113 will be replaced with environmentally safe alternatives.

**Halons** - *Protected facilities that have value less than \$1 million in value (hardware & business interruption) do not need Halon.*

Corporate Standards 9001.14 and 9001.15 detail Halon needs and use. We believe that the need for Halon hand held extinguishers and Halon 1301 total flood systems is minimal.

Halon hand held fire extinguishers will be replaced with recommended alternate extinguishers. Halon 1301 total flood systems will be decommissioned where appropriate before the end of 1991.

### Refrigerants

Conservation programs are emphasized for cooling, refrigeration and air conditioning installations. Corporate Standard 14017.00 details equipment, leak testing, service, system operation and preventive maintenance procedure. Cooling and air conditioning equipment will be converted when new alternate chemicals are available.

### Miscellaneous uses of CFCs

We believe that all purchased products containing CFCs can be replaced with environmentally safe substitutes before the end of 1991.

- 4 -

The Cooperative expects other companies that use CFC solvents to join in their effort. The first meeting of the new organization will be held in November.

###

## BASIC Q & A

**Q. When was ICOLP founded?**

**A. In October 1989. Its formation was announced at the International Conference on CFC and Halon Alternatives held in Washington, DC.**

**Q. What makes ICOLP a "unique" association?**

**A. ICOLP is a repository and "clearinghouse" for technical and research information. It is not an advocacy group and does not lobby government. Among its chief aims is to distribute information on CFC alternatives to smaller firms and to engage in technology transfer internationally.**

**Q. What is the biggest challenge facing ICOLP?**

**A. Adapting manufacturing processes to CFC alternatives is an extremely complex and costly undertaking. To meet this challenge, companies belonging to the ICOLP cooperative are willing to pool their resources and share research.**

**Q. What are members' responsibilities?**

**A. ICOLP members are expected to:**

- 0 Commit to a CFC elimination plan as soon as safe, affordable alternatives are available**
- 0 Cooperate in identifying, testing and publishing non-proprietary information on alternatives**
- 0 Demonstrate new alternatives to companies internationally whenever and wherever possible.**

**Q. What kind of projects will ICOLP engage in?**

- A. 0 The cooperative testing of alternatives**
- 0 Demonstrations of new technologies and processes that reduce usage of CFC solvents**
- 0 Technology and trade missions, including sponsoring and participating in international conferences on CFCs**

- work with existing industry, technical and government organizations to develop the most efficient means of gathering and distributing information on alternatives worldwide, particularly to developing countries. The new Cooperative plans to work closely with existing information-sharing programs such as the one being conducted by the American Electronics Association.

The announcement was made here at the International Conference on CFC and Halon Alternatives by representatives of the new group: David Chittick, environment and safety vice president for AT&T, and Margaret Kerr, vice president of environment, health and safety for Northern Telecom. The International Conference is co-sponsored by the U.S. Environmental Protection Agency, the Alliance for Responsible CFC Policy, Environment Canada and the National Institute for Emerging Technology.

CFCs solvents are man-made chemicals commonly used in manufacturing as a component degreaser or as a cleaner for electronic circuit boards and precision mechanical parts. These man-made compounds are suspected of depleting the protective ozone layer that shields the earth from the sun's harmful ultraviolet radiation as well as contributing to global climate change.

(more)

- 3 -

CFC use is now regulated under an international treaty called the Montreal Protocol, which has been ratified by 45 countries. Under the Protocol, CFC use is scheduled for a 50 percent reduction by 1998. In response to new scientific data about ozone layer depletion, President Bush, major United States companies and many other countries have called for the complete phaseout of the use of CFCs by the year 2000 or sooner providing safe substitutes are available. But even a complete phaseout will not return the ozone layer to natural levels.

The work of the cooperative will be valuable because it will not be easy or inexpensive to eliminate the use of CFC solvents around the world before the year 2000. No single technology or substance can replace CFCs. These solvents are used in a wide variety of cleaning processes that are dependent upon the type of manufacturing, the materials to be cleaned and the contaminants to be removed. Cooperation among these companies will also help to ensure that new alternatives to CFC solvents are safe to use in the work place. Furthermore, customer requirements, such as military specifications, sometimes encourage or require use of CFC solvents. The Cooperative will work to overcome these types of problems.

Developing countries have special needs for information on new technologies to replace existing CFC solvent uses. The Cooperative is committed to working with solvent-using manufacturers worldwide to speed the protection of the ozone layer.

- more -



1. 2

**THE BOEING COMPANY**

# Industry Cooperative Ozone Layer Protection

## News Release

For further information:

Lydia Whitefield, AT&T  
(201) 771-3260

Art Fitzgerald, Northern Telecom, Ltd.  
(416) 566-3048

For release Tuesday, October 10, 1989 -- 1:00 p.m. (EDT)

Washington, D.C. -- AT&T, The Boeing Company, Digital Equipment Corporation, Ford Motor Company, General Electric, Honeywell, Motorola, Northern Telecom and Texas Instruments today announced the formation of a new organization to work with the Environmental Protection Agency in a world-wide effort to reduce and eliminate chlorofluorocarbons (CFCs) used as solvents.

Members of the new organization, known as the Industry Cooperative for Ozone Layer Protection, will join forces to:

- encourage the prompt adoption of safe, environmentally acceptable alternative substances and technologies to replace current CFC solvent uses,
- act as a clearinghouse for information on new alternatives to CFC solvents,

(more)

## TABLE OF CONTENTS

ICOLP Mission Statement	p. 1
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Basic Q&A	p. 3
Contact List	p. 4

- 0 To encourage the prompt adoption of safe, environmentally acceptable, non-proprietary alternative substances, processes and technologies to replace current industrial CFC solvents.
- 0 To act as an international clearinghouse for information on alternatives.
- 0 To work with existing private, national and international trade groups, organizations and government bodies to develop the most efficient means of creating, gathering and distributing information on alternatives.

**TECHNOLOGY TRANSFER PROJECTS  
BY THE INDUSTRY COOPERATIVE  
FOR OZONE LAYER PROTECTION**

**Mr. A.D. FitzGerald**

**Director, Environmental Affairs**

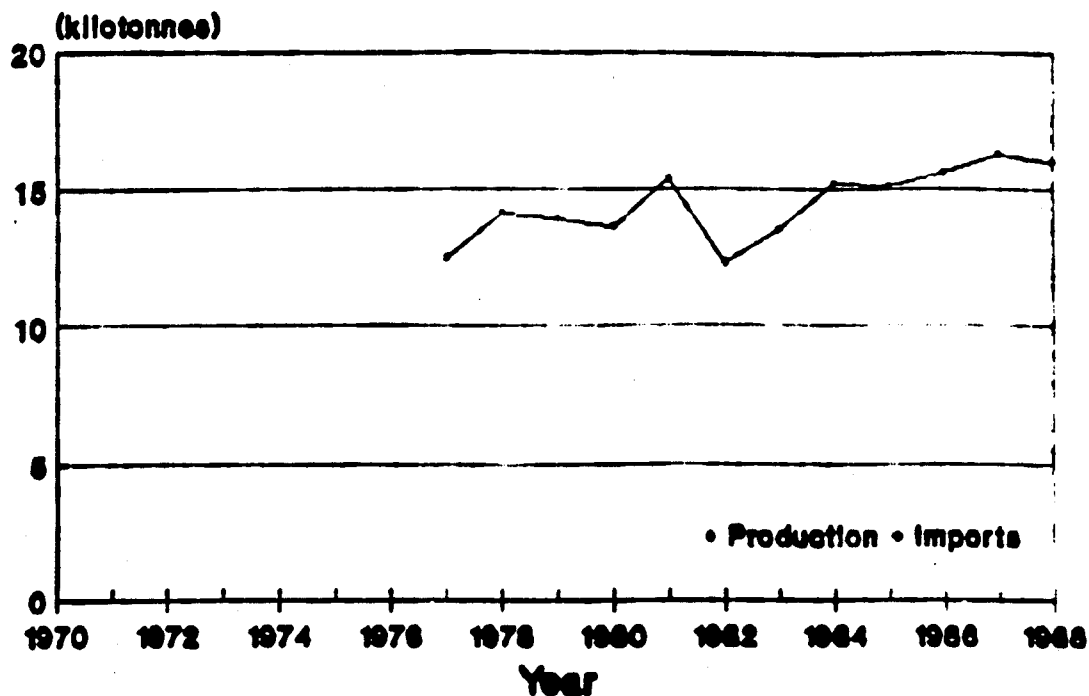
**Northern Telecom, Canada**

# Industry Cooperative Ozone Layer Protect

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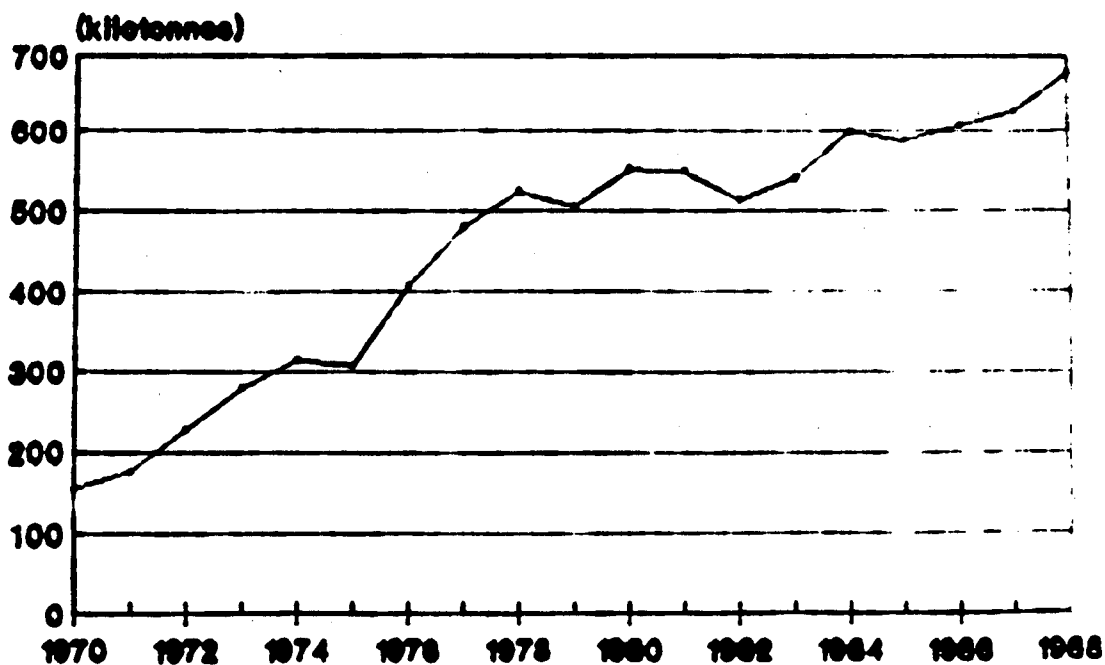
## BACKGROUND INFORMATION

# **Estimated Consumption • (methyl chloroform)**

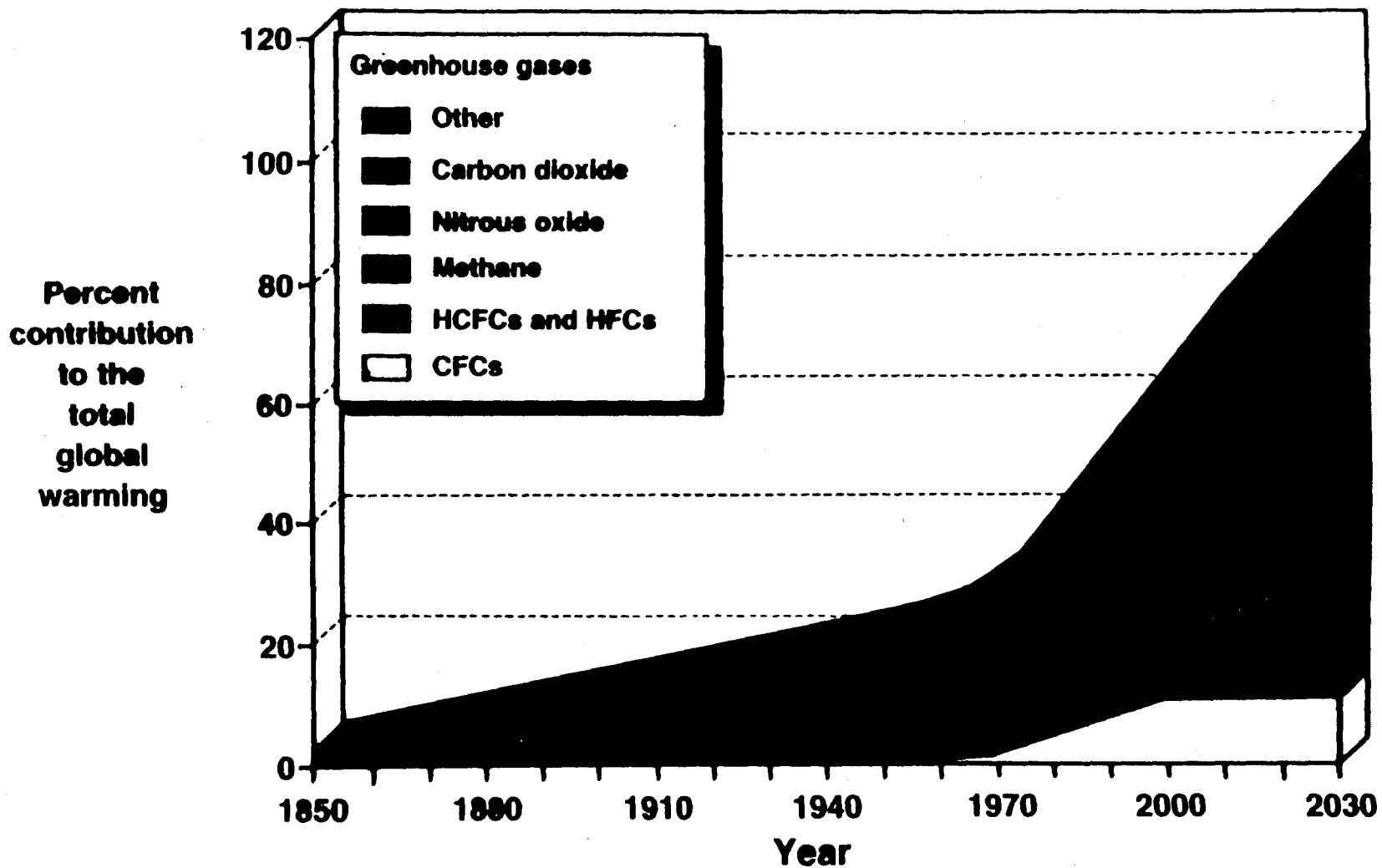


Source: Corps Information Services

# **World Production (methyl chloroform)**

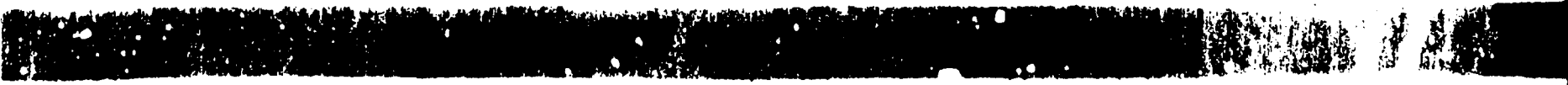


## Relative Contributions to Greenhouse Effect



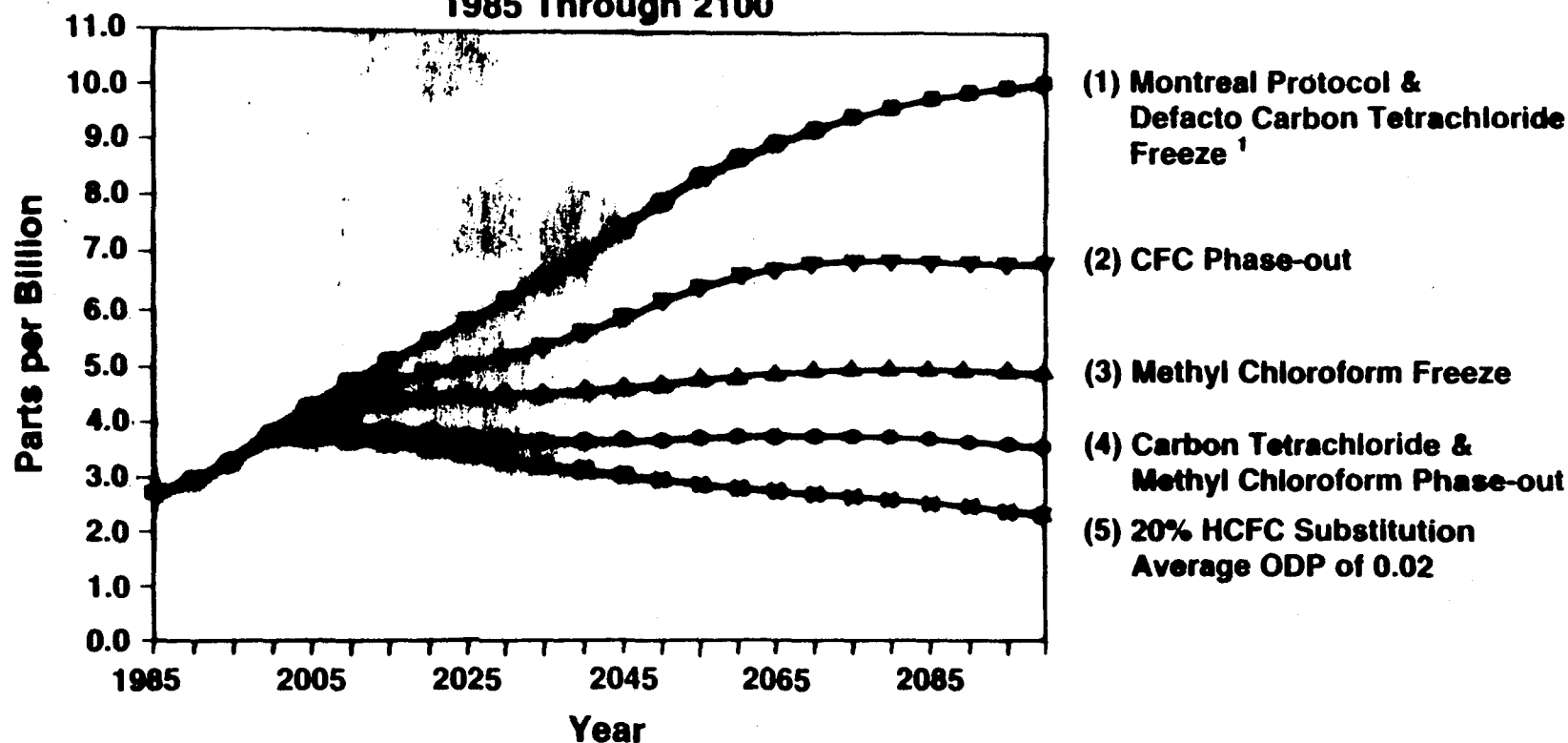
Source: Presentation by AFEAS based on WMO Report of 1985



- 
- **IT IS TECHNICALLY FEASIBLE TO REDUCE CONSUMPTION OF THE 5 CONTROLLED CFCs BY APPROXIMATELY 75% BY 1995 AND VIRTUALLY PHASE OUT CFCs, BY THE YEAR 2000**
  - **IT IS POSSIBLE TO REDUCE HALON (1211,1301, 2402) BY 50 - 60% ALMOST IMMEDIATELY THROUGH CONSERVATION MEASURES. A TOTAL PHASEOUT COULD BE ACHIEVED WITH INCREASED FIRE DAMAGE RISK. HALON IS CURRENTLY USED IN AREAS WHERE OTHER FIRE PROTECTION TECHNIQUES OR CHEMICALS WILL SUFFICE.**
  - **IT IS TECHNICALLY FEASIBLE TO PHASE OUT METHYL CHLOROFORM AND EMISSIONS OF CARBON TETRACHLORIDE ALMOST IMMEDIATELY SINCE SUBSTITUTES ALREADY EXIST FOR THE MAJORITY OF THEIR USES**
  - **WE WILL NEED TO CONTINUE TO USE CARBON TETRACHLORIDE AS A FEEDSTOCK FOR PRODUCTION OF HCFCs AND HFCs (IT IS TECHNICALLY FEASIBLE TO REDUCE OR ELIMINATE EMISSIONS)**

- **USE OF HCFCs IN ACCORDANCE WITH EXPECTED MARKET DISPLACEMENT (BY DU PONT) AT THE YEAR 2000 WILL ALLOW FOR AN ACCELERATED PHASEDOWN SCHEDULE AND WILL NOT ADD SIGNIFICANTLY TO GLOBAL WARMING OUT TO 2030**
- **THE SUBSTITUTION OF CFCs BY HCFCs WILL HAVE THE NET RESULT OF SIGNIFICANTLY REDUCING THE  $CL_x$  CONC. IN THE ATMOSPHERE UNTIL SUCH TIME AS CFC EMISSIONS HAVE BEEN ELIMINATED**
- **THE PERMISSIBLE USE OF HCFCs IN THE NEAR AND MEDIUM TERM IS CRITICAL TO THE ACHIEVEMENT OF THE EARLY PHASEOUT OF CFCs SET OUT IN THIS REPORT**

# **Total Cl<sub>x</sub> Concentrations 1985 Through 2100**



## **Assumptions:**

2000 Phase-out of Fully Halogenated CFCs (Except Curve 1)

HCFCs Capture 50% of What CFC Market Would Have Been Without Regulation (Except Curve 1); Assumed Annual Average Growth Rates for Fully Halogenated CFCs, Baseline HCFC-22 (non-substitute) and Methyl Chloroform are Approximately 3% for the Period 1986 to 2050. After 2050 Use is Assumed to be Constant.

Average ODP of Substitutes is 0.05 (Except Curve 5)

100% Global Participation

## **Notes:**

While possibilities exist for an increase in carbon tetrachloride use, such growth is unlikely given the awareness of carbon tetrachloride's potential contribution to stratospheric ozone depletion.

**[REDACTED] (PROGRAMME FOR ALTERNATIVE FLUOROCARBON TOXICITY TESTING)**

- 14 COMPANIES PARTICIPATING
- CHEMICALS ARE HFC-134a AND HCFC-123
- COMPLETION EXPECTED LATE 1992 - EARLY 1993

- [REDACTED]**
- 8 COMPANIES
  - HCFC-141b
  - RESULTS 1992 - 1993

- [REDACTED]**
- 7 COMPANIES
  - HCF-124 AND 125
  - COMPLETION DATE NOT KNOWN

**[REDACTED] (ALTERNATIVE FLUOROCARBON ENVIRONMENTAL ACCEPTABILITY STUDIES)**

- 14 COMPANIES
- INVESTIGATING ODPs, GWPs, AND OTHER PROPERTIES
- RESULTS EXPECTED BY LATE 1989

**● CATALYTIC INCINERATION**

**● PYROLYSIS**

**● ACTIVE METALS SCRUBBING**

**● WET AIR OXIDATION**

**● SUPER CRITICAL WATER OXIDATION**

**● CORONA DISCHARGE**

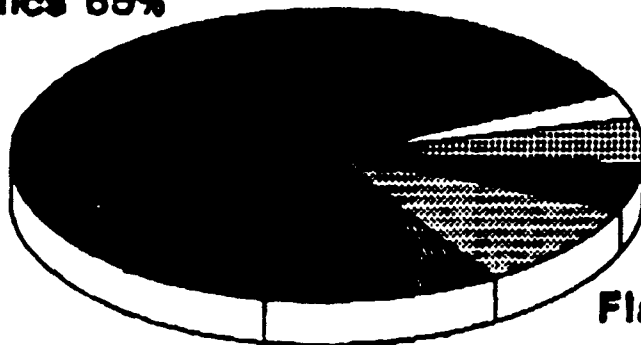
**● ZEOLITE CATALYTIC REDUCTION  
(JAPAN - CFC-113)**

**● WE NEED A WORKING GROUP OF RELEVANT EXPERTS TO  
RECOMMEND CRITERIA ON A "PER TECHNIQUE" BASIS**

**● WE NEED TO HAVE PREPARED A UNEP DOCUMENT "GUIDELINES FOR  
THE CRADLE-TO-GRAVE MANAGEMENT OF SUBSTANCES WHICH  
DESTROY THE OZONE LAYER"**

# ESTIMATED USAGE OF HALONS BY APPLICATION

**Electronics 65%**



**Miscellaneous 3%**

**Records storage 5%**

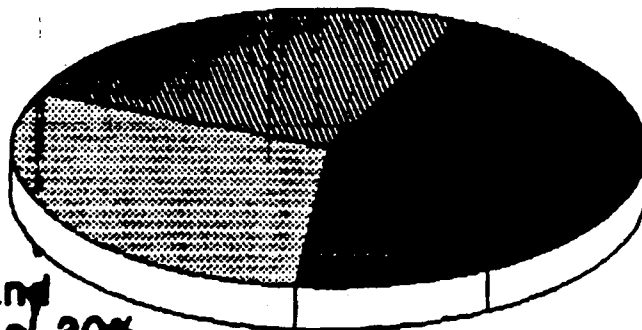
**Cultural heritage 5%**

**Flammable liquids 10%**

**Transportation 12%**

## HALON 1301

**Transportation 25%**



**Electronics 35%**

**Industrial and  
institutions 30%**

**Residential 10%**

## HALON 1211

**Source: Halons Technical  
Options Committee**



- **VERY LITTLE RECOVERY OF CFCs CURRENTLY**

- **DRAMATIC INCREASE EXPECTED SHORTLY DUE TO:**

- **PUBLIC DEMAND**
- **REDUCED CFC SUPPLY**
- **INCREASING CFC COST**
- **TECHNOLOGY NOW AVAILABLE**

- **PROBLEMS ARE INFRASTRUCTURE RELATED**

- **IMPORTANT TO CREATE RECYCLE INFRASTRUCTURE NOW  
BECAUSE WE WILL NEED IT FOR HCFCs AND PERHAPS  
OTHER CHEMICALS**

---



- NO EQUIVALENT PERFORMING SUBSTITUTE FOR HALONS IN CERTAIN APPLICATIONS

- HALONS CURRENTLY USED WHERE DRY CHEMICALS OR OTHER TECHNIQUES WILL SUFFICE

- 50-60% REDUCTIONS ARE ACHIEVABLE BY CONSERVATION AND BANK MANAGEMENT ALONE

- MAJORITY OF HALON COMMITTEE IN FAVOUR OF A PHASEOUT

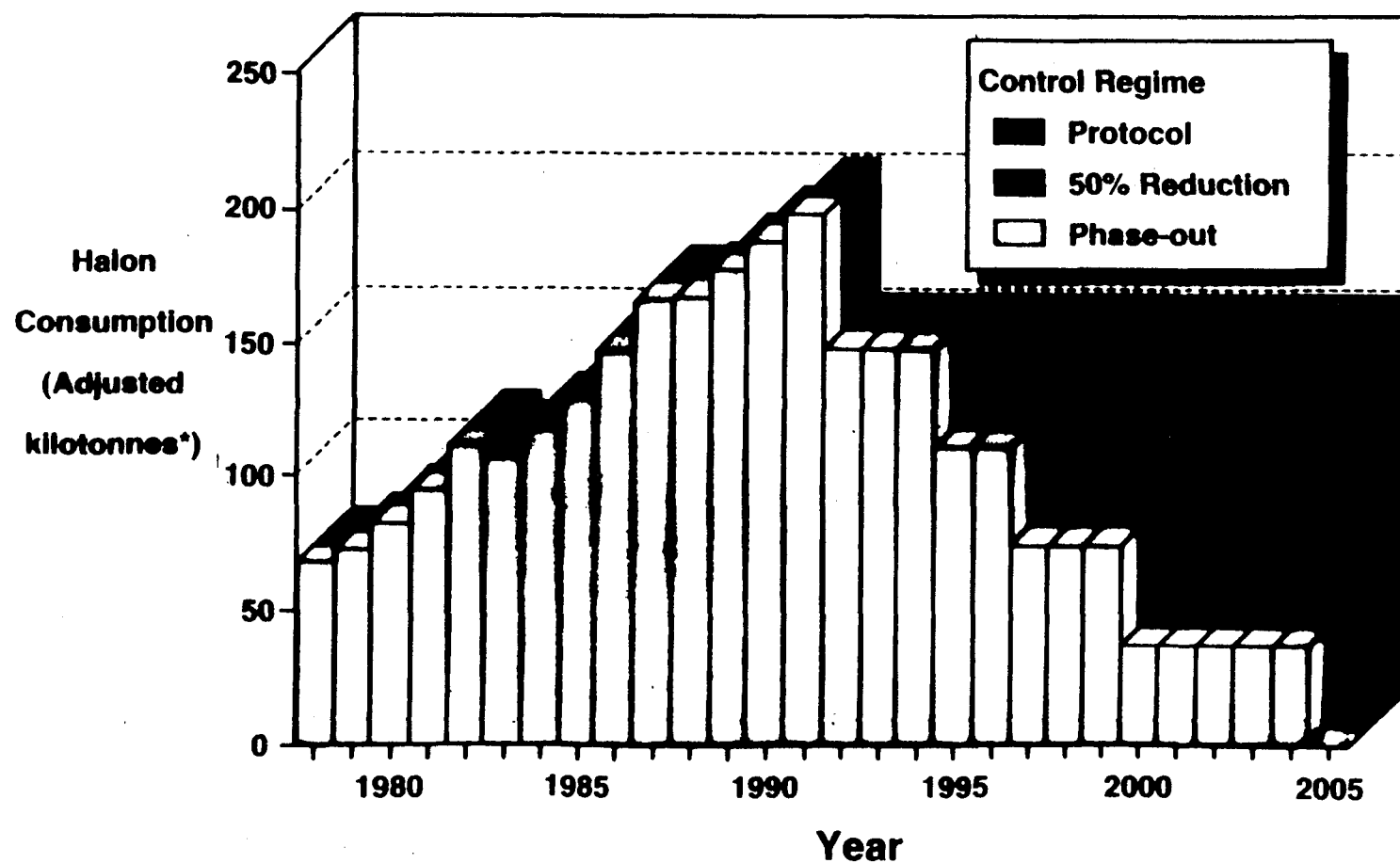
1992 .....	CAP AT 1986 LEVELS
1995 .....	75% OF 1986
1997 .....	50% OF 1986
2000 .....	25% OF 1986
2005 .....	0%

- QUESTION OF PHASEOUT OR NOT RELATES TO ACCEPTABLE RISK

- SOME COMMITTEE MEMBERS PREFER TO AWAIT SUBSTITUTES BEFORE DECIDING ON A PHASEOUT

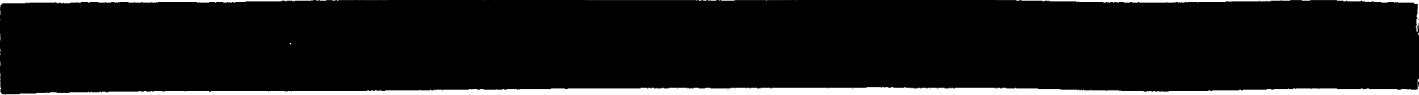



## Projected Halon Consumption



\* Sum of kilotonnes of each Halon multiplied by its respective ozone depletion potential (ODP).

- **25% OF WORLD CONSUMPTION (POLYURETHANES, POLYSTYRENE, POLYOLEFINS, AND PHENOLIC PLASTICS USED FOR BUILDING AND APPLIANCE INSULATION, CUSHIONING FOAMS, PACKAGING, FLOTATION, SHOE SOLES ETC.)**
- **CFCs ARE USED TO: COOL EXOTHERMIC REACTION, GIVE "R" VALUE TO INSULATING PRODUCTS, CONTROL DENSITY IN FLEXIBLE FOAMS**
- **TECHNICAL OPTIONS VARY WITH EACH FOAM TYPE**
- **TECHNICALLY FEASIBLE TO REDUCE GLOBAL CONSUMPTION OF CFCs 11, 12, 113 AND 114 BY 60-70% BEFORE 1993**
- **30% OF THESE REDUCTIONS RELY ON HCFCs**
- **TOTAL PHASEOUT IS FEASIBLE BY 1995**

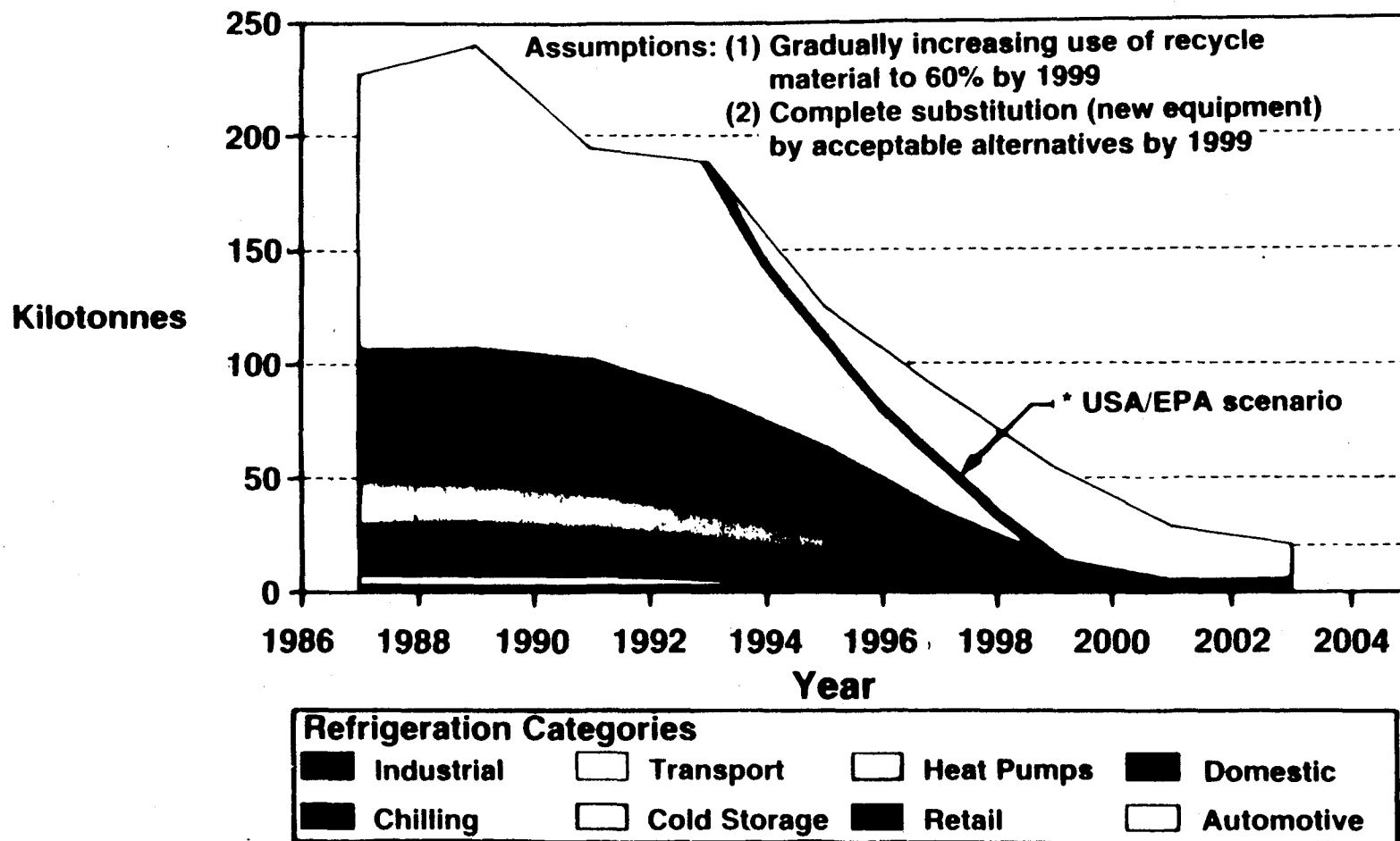
- 
- 
- 
- MAJOR USE OF CFC-113
  - NO UNIVERSAL SINGLE SUBSTITUTE
  - A SERIES OF ALTERNATIVES AND COMBINATIONS EXIST FOR SUBSTITUTION
  - 50% REDUCTIONS ARE ACHIEVABLE THROUGH CONSERVATION ALONE

- 
- CONSERVATION AND RECOVERY CAN REDUCE CFC-113 CONSUMPTION SUBSTANTIALLY IN NEAR TERM
  - AQUEOUS, CHLORINATED AND TERPENE-BASED CLEANERS ARE ALSO ALTERNATIVES

- 
- VERY SMALL USE
  - WHITE SPIRITS, HCFCs 225ca AND 225cb ARE PROMISING ALTERNATIVES

**IT IS TECHNICALLY FEASIBLE TO PHASE OUT ALL CFC-113 SOLVENT USE BY THE YEAR 2000**

# Technically Feasible Phasedown for the Various Refrigeration Uses






\* USA/EPA scenario for reductions resulting from recycling, retrofitting blends (still under carcinogenicity tests) and use of HFC-134a.


Source: Technical Options Report

# **REFRIGERATION, AIR CONDITIONING AND HEAT PUMPS**

- **25% OF WORLD CONSUMPTION, 5-8% BEING FOOD PRESERVATION, 1% DOMESTIC REFRIGERATORS**
- **MUST DISTINGUISH BETWEEN NEW AND EXISTING DESIGNS**
- **CURRENTLY AVAILABLE SUBSTITUTES INCLUDE: NH<sub>3</sub>, HCFC-22, HYDROCARBONS, HCFC-142b AND HFC-152a**
- **MEDIUM TERM (WITHIN 3-4 YEARS): HFC-134a, HCFC-123, AND AZEOTROPIC MIXTURES**
- **LONG TERM (BEYOND 4-5 YEARS: HCFC-124, HFCs 125, 134, 32 AND 143a**
- **15-20 YEARS NEEDED FOR FULL PHASEOUT UNLESS CURRENT BLENDS PROVE FEASIBLE AS A DROP-IN (EG. HCFC-22/124/HFC-152a)**

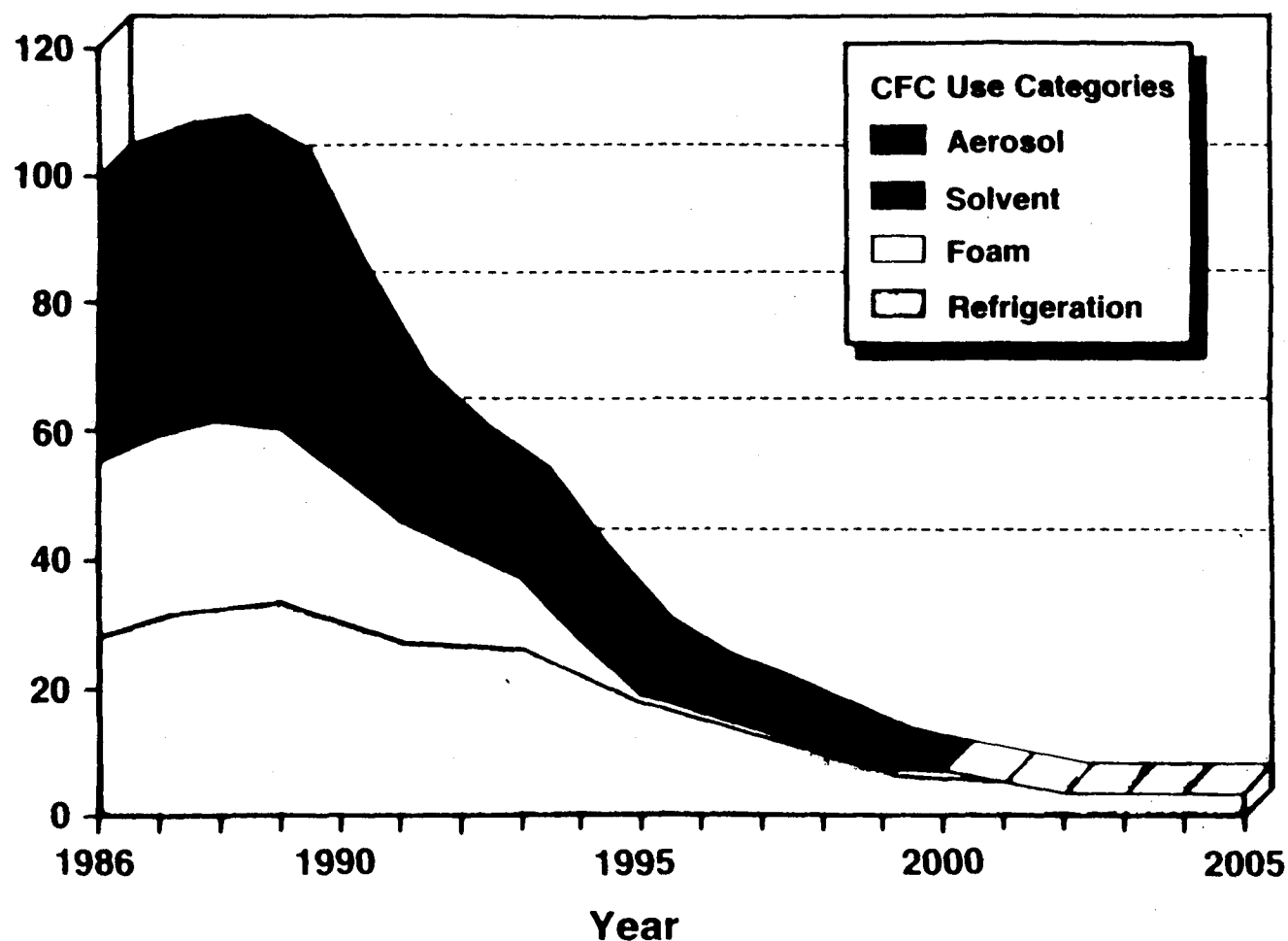
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- 
- APPROX. 27% OF GLOBAL CONSUMPTION (300Kt)
  - SUBSTITUTES INCLUDE HYDROCARBONS, COMPRESSED GASES, HCFC-22 AND VARIOUS BLENDS
  - NEW HCFCs ARE ALSO POSSIBLE SUBSTITUTES
  - "VIRTUAL" PHASEOUT IS POSSIBLE NOW
  - MEDICAL USES (10-12 Kt - 3-4 Kt BEING INHALANT DRUGS) MAY REQUIRE ANOTHER 5 YEARS

- 
- 12/88 (12% EO/88% CFC-12) IS MAJOR USER OF CFC-12 FOR STERILISATION IN HOSPITALS
  - 10/90 (10% EO/90% CO<sub>2</sub>) IS A POSSIBLE SUBSTITUTE BUT REQUIRES RETROFITTING (HIGHER OPERATING PRESSURES)
  - OTHER TECHNIQUES EXIST: STEAM, FORMALDEHYDE, GAMMA IRRADIATION, BUT ALL HAVE LIMITATIONS
  - MAIN PROBLEM IS HEAT SENSITIVE DEVICES (12/88 IS UNIVERSAL, STEAM USEFUL ABOVE 121 °C, FORMALDEHYDE - 85 °C)
  - PHASEOUT IS TECHNICALLY FEASIBLE BY 1995 (MAY TAKE LONGER IN THE DEVELOPING COUNTRIES)

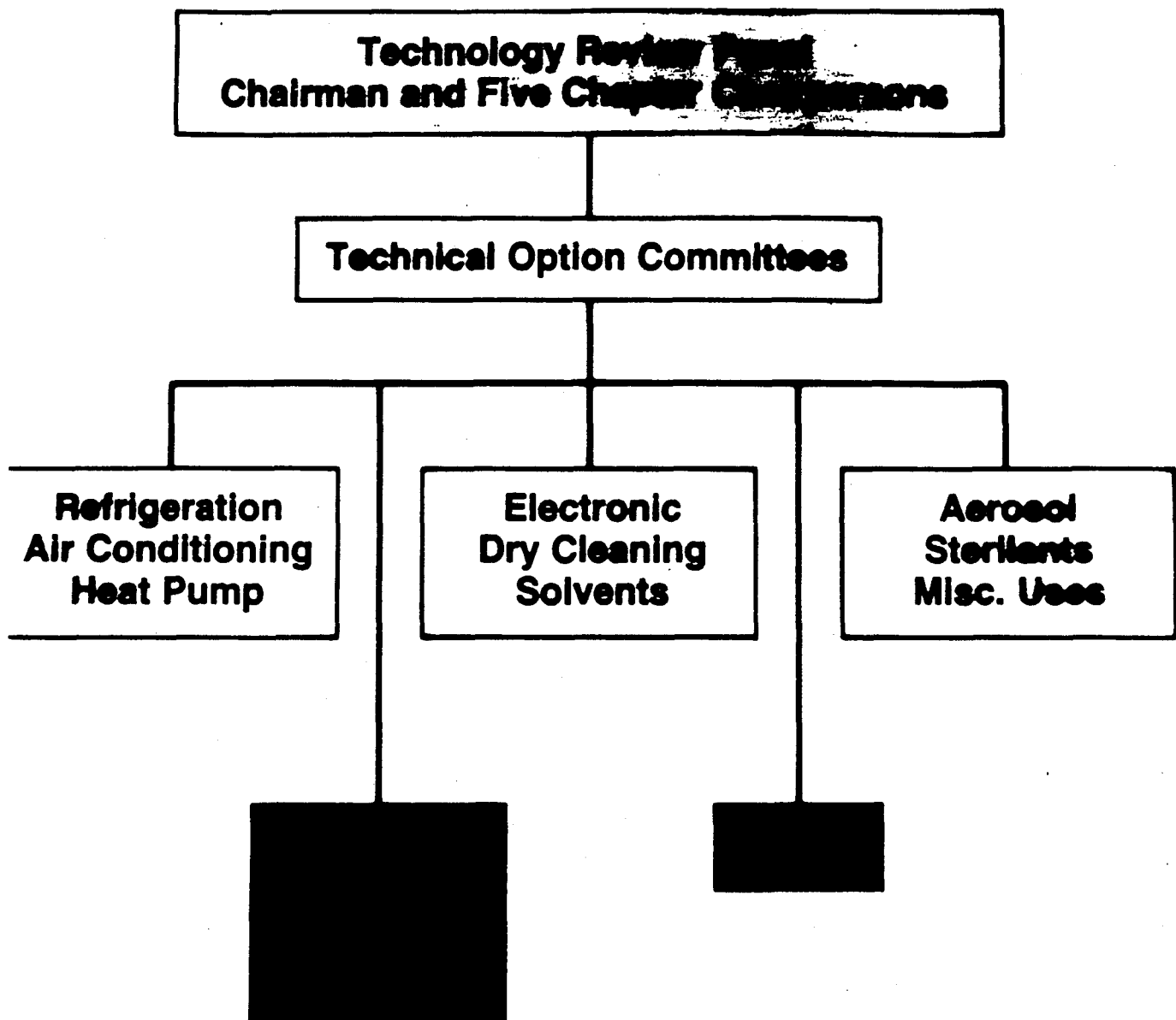
- 
- FAST FOOD FREEZING (SUBSTITUTE WITH CRYOGENICS)
  - OTHER MINOR USES INCLUDE: TOBACCO PUFFING, FUMIGATION, LEAK DETECTION, CANCER TREATMENT AND STANDARD LABORATORY PROCEDURES

## Technically Feasible Phasedown Projections for Major CFC Use Categories

Projected  
Consumption  
as a  
Percentage  
of 1986  
Consumption




## Organization



**110 Direct Participants**

**Even greater number involved in Peer Review**



- 
- **IT IS TECHNICALLY FEASIBLE TO PHASE DOWN THE CONTROLLED CFCs 70 - 75% BY 1995**
  - **IT IS TECHNICALLY FEASIBLE TO PHASE DOWN THE CONTROLLED CFCs BY 95 - 98% BY THE YEAR 2000 (A 98% REDUCTION WOULD DEPEND ON THE USE OF BLENDS AS "DROP-INS" FOR EXISTING EQUIPMENT)**
  - **REMAINING CFCs WILL BE NEEDED FOR SERVICING OF EXISTING EQUIPMENT (LARGE INDUSTRIAL REFRIGERATION UNITS, CHILLERS, AUTOMOTIVE AIR CONDITIONING) AND A SMALL AMOUNT FOR MEDICAL USES (INHALANT DRUGS)**

# **PURPOSES OF THE TECHNOLOGY REVIEW**

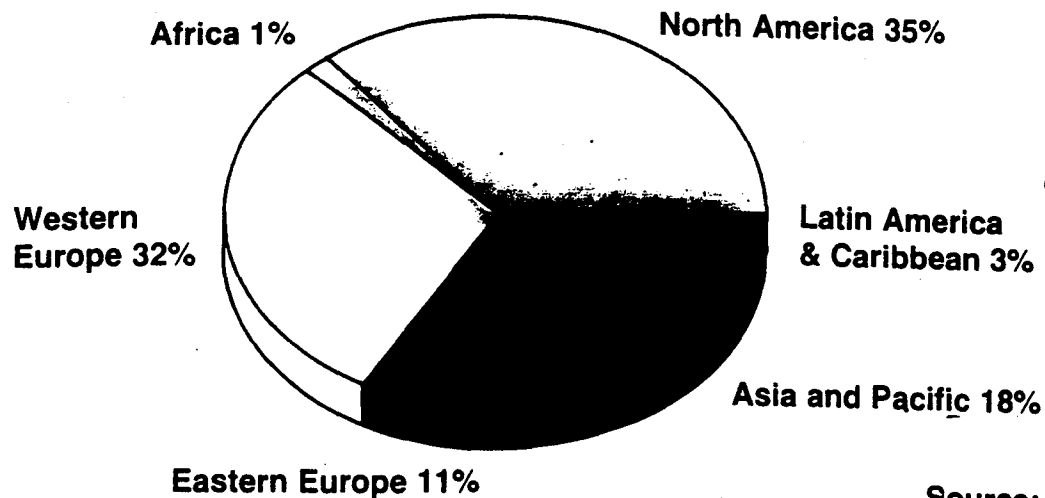
- **RESPOND TO MONTREAL PROTOCOL ARTICLE (6)**
- **DEFINE TECHNICALLY FEASIBLE REDUCTION SCHEDULES**
- **REVIEW RELEVANT TECHNICAL CONSIDERATIONS**

**SUBSTITUTES, FORMULAE, ODPs, GWPs  
STATUS OF TOXICITY TESTING  
STATUS OF COMMERCIALISATION  
RECOVERY AND RECYCLE  
DESTRUCTION TECHNIQUES**

- **REPORT ON METHYL CHLOROFORM, CARBON TETRACHLORIDE**
- **PROVIDE TECHNOLOGY TRANSFER AND DEFINE COMPLIANCE  
TECHNIQUES VIA THE 5 SECTOR-SPECIFIC TECHNICAL  
OPTIONS REPORTS**

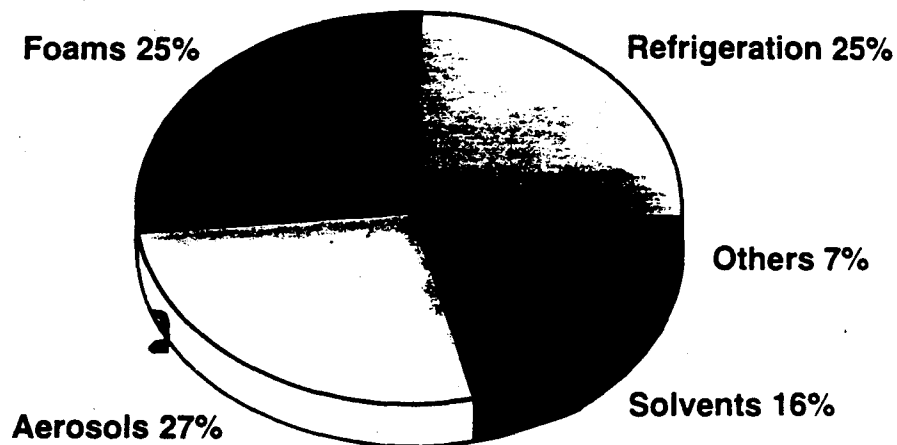
# 1986 World Usage of Controlled CFCs

(a) by Region



Source: UNEP

(b) by Use



Source: Sector data or best estimates

**OVERVIEW OF  
UNITED NATIONS ENVIRONMENT  
PROGRAMME  
TECHNICAL ASSESSMENT**

**Mr. G. Victor Buxton**

**Environment Canada**

# **REPORT OF THE TECHNOLOGY REVIEW PANEL**



**UNEP WORKING GROUP MEETING  
NAIROBI, KENYA  
AUGUST 28 - SEPTEMBER 5, 1989**

# **STATUS OF CASE STUDY: CHINA**

**Mr. Zhang Chongxian**

**Senior Engineer**

**National Environmental Protection Agency**

**China**

STATUS OF CASE STUDY: CHINA

Zhang Chongxian

National Environmental Protection Agency - China

Ladies and Gentlemen:

First of all I would like to take this chance to express my sincere thanks to our host -- USEPA -- for their hospitality and all the arrangements providing us with the chance to exchange experiences and discuss the background information relating to the progress of the country specific studies on ozone depleting substances.

China has indicated its willingness to cooperate with the international community to protect the ozone layer. To this effect China regularly participates in international meetings on the problems of the ozone layer and ozone depleting substances and signed the Vienna Convention in September of 1989.

Before the London Conference, about a year ago, almost no one who was involved in the production and use of ozone depleting substances in China knew of the destructive effect of ozone depleting substances on the ozone layer and the harmful consequences of the increased exposure to UV-B radiation. However, after the London Conference, NEPA used the opportunity of the World Environmental Day to launch a great number of educational activities on this concern. As a result of the work the Chinese government appointed NEPA as the coordinating agency for all monitoring and regulating activities relating to the issue of ozone depleting substances.

NEPA also represents China in international efforts on the ozone depleting problems based on discussions in such meetings. NEPA advises various Ministries of government of China on the scope of the problem, measures adopted by the international community to address the problem, the relevance to China's practice and so on with the aim of internal consensus on the work of protecting the ozone layer and agreeable necessary steps to be taken in China.

With limited resources available, NEPA has done some work and achieved certain progress. In this aspect I have to address our gratitude to USEPA missions headed by Dr. Eileen Claussen and Dr. Hoffman. They visited China respectively within the year and half. Their activities in China tremendously helped to raise the awareness of Chinese CFC producers and users on the importance of protecting the ozone layer and on the possible approaches to solve the problem.

Currently, China like other countries, is extensively producing and using ozone depleting substances for refrigeration, foam blowing, air conditioning, cleaning, disinfecting, fire fighting and protecting, propelling and other miscellaneous uses. Following the decentralization of ministerial power in 1984, all the industries mentioned above are managed separately and scattered in terms of investment decisions, production planning and so on. Local and provincial administrations usually put local interests and development plans ahead of central planning directions. Therefore, the government needs to know the details of the production and use of ozone depleting substances in China,



the costs for converting to non-ODS and very importantly the international assistance and aids that would be required.

NEPA does not currently have the capacity in financial resources, expertise and management capability to independently undertake the study. Moreover, because of the political and commercial sensitivities of the issues involved, NEPA and other Ministries want an unbiased body like UNDP which is also the representative of UNEP in China along with donor countries to provide assistance.

From November to December 1989, an international expert team invited by UNDP visited China for the establishment of the project. The aim of the project is to provide the decision makers of China as well as the UNEP Working Group with a feasibility study and policy options concerning the control and final elimination of the ozone depleting substances including production and use, the costs involved in conversion to other non-ODS and products, as well as the international aids required and to propose a plan of action including projects to be launched and assisted by multi- or bi-lateral aids.

After 20 days of hard work, the basic findings are as follows:

1. China currently produces three of the controlled CFCs: they are CFC-11, CFC-12 and CFC-113. Production is under the administration of the Ministry of Chemical Industry. At present China has 30,000 tonnes CFCs production capacity and the practical production was about 20,000 tonnes in 1988 and 1989 respectively. However, China also imports CFCs, especially CFC-11 and CFC-12. The total amount

of import CFCs reached approximately 20,000 tonnes in 1989. That means China's average consumption of CFCs is about 0.04 kilogram per capita per year in 1989.

2. Currently about 44% of total CFC consumption is in refrigeration, air conditioning manufacturing and servicing. More than 40% of the total consumption of CFCs are used as blowing agents in manufacturing rigid and flexible foams. Almost 90% of the total CFCs are used for manufacturing refrigerators, air conditioners, and other refrigeration equipments suggesting that the future trend of the growth of CFC use will remain high following the modernization of the nation's industry and people's living conditions.
3. Until 1988 the possession of household refrigerators was about 20 million units. And the 1988's refrigerator production stood above 8.8 million units, plus 2 million imported refrigerators, there was a big leap of overall possession of refrigerators between 1988 and 1989 alone.

The future trend of refrigerator production rate will fluctuate between 3-7 units a year. However, the production capacity will remain 12 million units a year. Compared with the total number of Chinese households this figure is still lower than the future demand. We could expect that the focal point of future CFC consumption in China will still be at the section of refrigerators, air conditioning and foam blowing.

Finding substitutes for CFC-11, CFC-12 will be essential for China to reduce the consumption of CFCs.

4. In addition to refrigeration and air conditioning, attention must be paid to foam blowing. For example, rigid polyurethane foaming for the purpose of insulation has big potential market in China following the reform of industries and energy efficiency, the flexible foaming will develop rapidly following the improvement of the household furniture, the development of packaging industries and so on.

In general, CFCs use is expected to increase 7-10% annually during the 1990s.

Referring to solvents, aerosols, cleaning agents, and halons, the application of CFCs will continue increasing at a rate of about 7% annually based on the present low level of consumption as a starting point.

5. CFC substitute production: China produces about 10,000 tons of HCFC-22 annually. At the present time most of the chemicals are used as a feedstock for "Teflon" production. The application of HCFC-22 for refrigeration needs to be further developed. China also produces about 100 tons of HFC-152a as refrigerant to apply for experiments. The preliminary results showed very promising

possibility to create a pilot project to apply the HFC-152a to household refrigeration.

Referring to the country specific study, what we are going to do next. After the preliminary study of UNDP export. Mission, the project design has been worked out in order to drive overall and more precise information on this regards.

The project is composed of three phases: in the first phase NEPA will collect statistical and substantive information on ODS production and use in compliance with the "national studies: proposed outline." I do think every country has its own specific condition, this outline will only provide the basic requirement needed for the consideration by the international community in order to gain assistance and aid. For the completion of the information collection NEPA has to cooperate with various Ministries and do a lot of organizational and standardizational work, for this purpose financial assistance is necessary for NEPA success.

The second phase is designed for the international expert team to arrive in China for additional information and evaluation of the technical feasibility and the step-wise strategy for phasing out the controlled CFCs and costs involved. This is really a very complicated process to complete in China.

In the third and last phase, the integration of respective reports will be completed and submitted to UNEP for financial and technical aid and assistance.

Finally, regarding the country specific study in China, I do think the Chinese situation is staying at a preliminary stage. Through our meeting I am able to learn a lot from your practice and experience. It is very valuable for implementing the study in China.

Thank you.

## II

# CASE STUDY COORDINATION WORKSHOP BRASIL

## SOURCES OF INFORMATION

### BUSINESS SURVEYS

- SUB COMMITTEES
- CFC PRODUCERS
- TRADE ASSOCIATIONS
- GOVERNMENTAL STATISTICS

### GOVERNMENTAL DATABASE / PROJECTIONS

### III

## CASE STUDY COORDINATION WORKSHOP BRASIL

### INDUSTRY INVOLVEMENT

- ☐ JOINT PARTICIPATION WITH THE BRAZILIAN DELEGATIONS  
TO THE PROTOCOL MEETINGS
- ☐ SUPPLY TECHNICAL EXPERTISE, GENERAL DATA AND  
OTHER RESOURCES TO DEVELOP TECHNICAL REPORTS
- ☐ CONFERENCES / WORKSHOPS  
SEMINAR "CFC's, ALTERNATIVES AND STRATEGIES"  
MARCH 08/09 - SAO PAULO
- ☐ MONTHLY TECHNICAL MEETINGS AT ABINEE  
SINCE MID-1987
- ☐ LIASON ACTIVITIES WITH GOVERNMENT AGENCIES

IV  
CASE STUDY COORDINATION WORKSHOP  
BRASIL

PROGRESS

- CFC GROUP WITHIN ABINEE
- CFC's ELIMINATED FROM COSMETICS AEROSOLS  
(BUTHANE/HCFC's)
- INTRODUCTION OF ALTERNATIVE BLOWING AGENTS FOR  
FOOD PACKAGING FOAMS
- EARLY STAGES OF DEVELOPMENT OF CFC  
RECOVERY SYSTEMS
- ELECTRONICS / REFRIGERATION INDUSTRY  
"QUEST FOR TECHNICAL DATA"
- RESOURCES AVAILABLE
  - COMPRESSOR DESIGN AND MANUFACTURING CAPABILITY
  - FLEXIBLE PRODUCTION FACILITIES
  - WELL ESTABLISHED COMPONENTS SUPPLIERS
  - ACCESS TO TECHNOLOGY FROM PARENT COMPANIES



# **STATUS OF CASE STUDY: BRAZIL**

**Mr. Alberto Carrizo**

**White-Westinghouse Climax**

**Brazil**

# I

## CASE STUDY COORDINATION WORKSHOP BRASIL

### ORGANIZATION

#### PROJECT TEAM

- LEADERSHIP

  - IBAMA (BRAZILIAN ENVIRONMENTAL AGENCY)

- GOVERNMENTAL AGENCIES;

  - FOREIGN AFFAIRS

  - HEALTH MINISTRY

  - INDUSTRY & TRADE MINISTRY

- ASSOCIATIONS;

  - ABINEE; ELECTRICAL AND ELECTRONIC INDUSTRY

  - ABRAVA; REFRIGERATION, AIR CONDITIONING AND HEATING

  - ABIPLAS; PLASTICS

  - ANFAVEA; AUTOMOTIVE MANUFACTURERS

  - IBF; INSTITUTE OF COLD TECHNOLOGY

- TECHNICAL ADVISORS:

  - Dr. SUELY CARVALHO; SAO PAULO UNIVERSITY, CNEN

Feron 11	4436 Tons
Feron 12	3453 Tons
Feron 22	446 Tons
Others (F 502 + F 114 +..)	453 Tons

-----  
Total 8788 Tons

4. The Eg. venture in limiting the emission of CFC which I already related in various international forums, is worth to be repeated for consideration towards application in other developing countries.
5. On February 23<sup>rd</sup> 1981, the Eg. Ministry Of Industry. (MOI) received an alert from the USEPA. through the Eg. Embassy in Washington as to CFC's and their harmful effects on human health and the restrictions to be imposed on their outlet uses particularly in aerosols.
6. MOI. appointed an adhoc committee, (Decree, MOI; 638/81) joining in its membership the chairmen and technical directors of the CFC consumer units in the fields of refrigeration, Air-conditioning, aerosols, foam Plastics, ....etc). The committee was reformed (Decree MOI; 446/86) joining to its membership representatives of other concerned bodies; Federation of Industry, Ministry of Health, General Organization for Standerzation. I should remember that I had the privilege to act as technical rapporteur of that committee.
7. The committee performed a number of technical and economical studies taking into consideration the probability of the difficulty of future importation of such substances. Also the probability that its procurement will be confronted with a rapid price escalation. (It its worth to declare that committee was totally right in its prediction, the price of importation of one kg of CFC increased from LE 0,9 in year 1985 up to LE 3.7 in 1989).

8. The committee performed a number of technical and economical studies, put forward a number of recommendations to MOI. inter-alia the following:
  - a) No new permits or licences should not be given to projects that depend in their production on the use of CFC as well as non agreement to extensions of such existing projects.
  - b) Introducing other substitutes for CFC that are locally available or abundant and easy to procure, as well as studying the possibility of introducing legislation banning the use of CFC's in such activities where substitutes are available and cost effective as well as the possibility of imposing taxes on CFC importations & incentives for substitutes.
  - c) Proposing the implementation of a procedural system that could enforce the disposal of salvaged equipment holding CFC and residuals thereof.
9. The committee found that LPG = liquified Petroleum gases (mainly propane & pentance) could be used as a cost effective substitute to CFC's in Aerosol industry. It is locally available and far cheaper than CFC's.
10. "Kafr El Zayat" Company for pestisides was the first company that changed over to use LPG in 1984. Other public sector companies have followed its example. Today (1990) all public sector companies use LPG as propellant in Aerosols. Also 3 of the private sector companies have changed over to LPG.
11. Here it is clear that LPG has succeeded as subsitute in Egypt because it was more cost-effective than its CFC's counterpart otherwise they would have not so quickly widespread.

12. This fact is in conformity with the report of the techn. committee chaired by Ms Ingrid Kokeritz (Sweden) <sup>(1)</sup> concerning the uses of substitutes for CFC's in aerosols such as hydrocarbons, propane and butane (page iii):-  
The Hydrocarbon cost per kilogram is however, substantially lower than that of CFC's (20-30% of the current cost of CFC's). In most cases, a conversion to hydrocarbons will therefore result in a net gain for the producer and a cheaper product for the consumer. The lower cost of hydrocarbons where suitable supplies of these propellants exists, may be especially important to developing countries.
13. It is also in conformity with the EPA report R & D N° 60012-89-062 <sup>(2)</sup> Page "5":  
In the U.S., hydrocarbon propellants cost less than 20% of the rapidly escalating costs of CFC's. Approximately 30% of U.S. aerosols are pressurized with propane, butane, isobutane or their blends.."
14. I think that a regulatory fee and auction system on the production of CFC halons are very well justified. This is contrary to the position of the U.S. council for International Business that cited in their publication of Sept. 89 <sup>(3)</sup> that their argument is that the outcome is likely to slow progress for U.S. companies towards development of alternative products and place them at a competitive disadvantage vis a vis production in other countries.
15. My own information is that Norway has already passed a bill to impose fees on CFC's & CFC products. Such Action should be well spreaded and introduced by all countries on equal bases so as to leave no space to competitive disadvantage. I strongly push for a global tax or fee or any auction system on all controlled substances so as to modify economic appraisals of the substitute (and weight their balance).

16. To phase out CFCs we should find and examine substitutes for its uses in all activities, not only aerosols but also, foam plastics, refrigerators, air conditioners .etc. It is estimated that our production capacity of refrigerators will reach about 750'000 units/yr of household units, 15'000 deepfreezers and 9'000 Exposition or commercial unit. The installed capacity of Air conditioning of various types will be equivalent to about 130.000 units window type 2½ HP. There is the argument that such units run in closed circuits but how about leakage and dissipation in repair & maintenance. Another problem is foam plastics and styropore. It is a rapidly growing sector, not only in Egypt, but also in all developing countries: Egypt's national output of foam plastic and styropore totals to about 10.000 tons/yr.
17. The world community is looking for a total phasing out of CFC's. All nations are consolidated to face this global challenge. In this respect I would quote EPA Administrator William Reilly in his memorandum <sup>(4)</sup> about the unbridled enthusiasm of the EPA international front for all the World solidarily towards CFC and climate change problem and in full support of the U.S. policy in that a field. He clearly stated that the President Bush 5 points on the international front, the first was committing the nation to the full phase out of CFC's towards the end of the century.

- 
1. Report by the technical options committee on Aerosols, sterilants and miscellaneous uses.
  2. E.P.A. Research & Development; Aerosols Industry success in reducing CFC propellants usage EPA-60012-89-062. November 1989. Prepared by Air & Energy Engineering Research Laboratory.
  3. Summary of International Environmental Issues and Positions of the US Council for International Business:- "Environmental Challenges for Industry" September 1989 1212 Avenue of Americas New York 10636-1689.
  4. Memorandum of USEPA Washington DC. dated September 7, 1989 Subject six Month Update by Administrator J.W.Reilly.

# **STATUS OF CASE STUDY: EGYPT**

**Dr. Ahmed Amin Ibrahim**

**Consultant, Egyptian Environment Affairs Agency**

**Egypt**

Facsimile (202) 382 6344

To: Eileen Clausen Director Office Of Air & Radiation EPA.

Some Remarks on Strategies of  
Limiting the uses of CFC's

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Presented by Ahmed Amin Ibrahim

To EPA Workshop January 15-17, 1990 Washington.

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1. Egypt was one of the first countries that signed the Vienna convention; March 22<sup>nd</sup> 1985 and the Montreal Protocol September 16<sup>th</sup> 1987; Egypt ratified both on August 8<sup>th</sup> 1988. In its consolidation with the International Community Egypt has taken initiatives in limiting the emissions of the controlled substances (which are the CFC's).
2. The Montreal Protocol came into force on January 1st 1989; and requires the following:
  - a) Freeze at 1986 consumption and production levels of the controlled substances (CFC 11, 12, 113, 114, 115) on the basis of their relative ozone depletion weights (O.D.P.)
  - b) By 1993 reduce the emission of controlled substance to 80 %.
  - c) By 1998, a further reduction by 20% to limit the controlled substance to 50%.
3. Egypt does not manufacture any of the controlled substances (CFC's) but totally depends on importation to fullfill its needs. The import figures ware 8788 tons in 1982 and dropped sharply to 2163 tons in 1985. This was due to the efforts undertaken to use CFC's substitutes in producing Aerosols with the following breakdown as to form grade classification as regards the 1982 figure:-



## **VI. CONCLUSIONS**

- 1. THE PROTECTION OF THE OZONE LAYER RULES OUT THE POSSIBILITY OF "FAIR" SHARES OF OZONE DEPLETING COMPOUND USE. ALTHOUGH MOST OF THE CHLORINE IN THE ATMOSPHERE IS DUE TO EMISSIONS FROM DEVELOPED COUNTRIES MUST ALSO STOP THEIR PRODUCTION AND CONSUMPTION OF THESE SUBSTANCES.**
- 2. IT IS NECESSARY TO TIGHTEN THE IMPLEMENTED MEASURES TO REDUCE OZONE DEPLETING COMPOUND EMISSIONS AND TO TAKE ALL NECESSARY ACTIONS TO ACHIEVE THE REDUCTIONS NEEDED.**
- 3. THE CASE STUDY UNDERWAY IN MEXICO WILL EVALUATE THE PRESENT AND FUTURE DEMAND OF OZONE DEPLETING SUBSTANCES AND THE ECONOMIC NEEDS ASSOCIATED WITH THE IMPLEMENTATION OF THE MONTREAL PROTOCOL. THE STUDY WILL ALSO PROVIDE USEFUL INFORMATION ON NEW TECHNOLOGIES AND APPROACHES USED IN MEXICO.**

# **ADAPTING TECHNOLOGY TO DEVELOPING COUNTRY NEEDS**

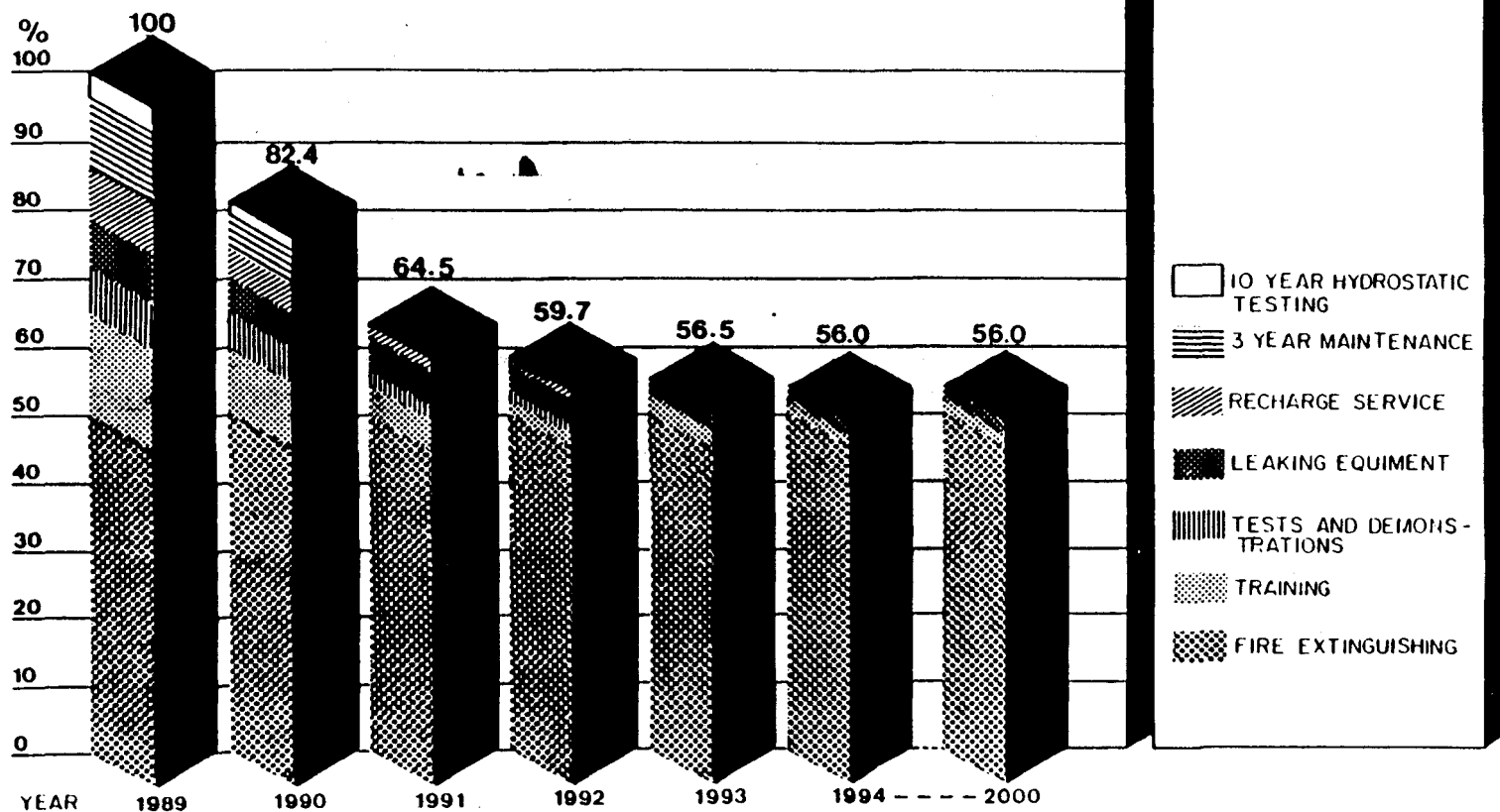
- . MEXICO CAN BE A SOURCE OF NEW AND ADAPTED TECHNOLOGY TO PROTECT THE OZONE LAYER**
- . THE MEXICAN DESIGN APPROACH HAS PROVED TO BE COST-EFFECTIVE AND SAFE**
- . THE MEXICAN KNOW-HOW MAY BE USEFUL TO OTHER DEVELOPING COUNTRIES**



# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL

## SOURCE AND REDUCTION OF AVOIDABLE HALON EMISSIONS

INDEX : 1989 EMISSIONS = 100 %





# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL

## SOURCE AND REDUCTION OF AVOIDABLE HALON EMISSIONS

### BASE EMISSIONS 1989=100 %

SOURCE :	1989	1990	1991	1992	1993	1994 ---2000
FIRE EXTINGUISHING	50.5	50.5	50.5	50.5	50.5	50.5
TRAINING	14.0	14.0	5.2	2.6	2.6	2.6
TESTS AND DEMONSTRATIONS	6.6	4.7	2.4	1.7	0	0
LEAKING EQUIPMENT	6.3	5.4	4.6	3.9	3.4	2.9
RECHARGE SERVICE	5.8	3.3	1.8	1.0	0	0
3 YEAR MAINTENANCE	12.8	6.4	0	0	0	0
10 YEAR HYDROSTATIC TESTING	3.4	1.7	0	0	0	0
TOTAL 1989 %	100.0	82.4	64.5	59.7	56.8	58.0

ELIMINATING TRAINING WITH 1201 AND 1301 EXCEPT FOR THOSE APPLICATIONS CRITICAL TO LIFE SAFETY.

COMPLETING ELIMINATION OF SALES TESTS AND DEMONSTRATIONS ALTERNATIVES MEANS, SUCH AS VIDEO TAPES, FILMS, TRANSPARENCIES, AND PHOTO - GRAPHS CAN BE USED.

STRICTLY COMPLYING WITH EXTINGUISHER QUALITY NORMS TO AVOID EMISSIONS FROM FAULTY EQUIPMENT.

IMPLEMENTING GAS RECOVERY SYSTEMS DURING RECHARGE OF EXTINGUISHING EQUIPMENT.

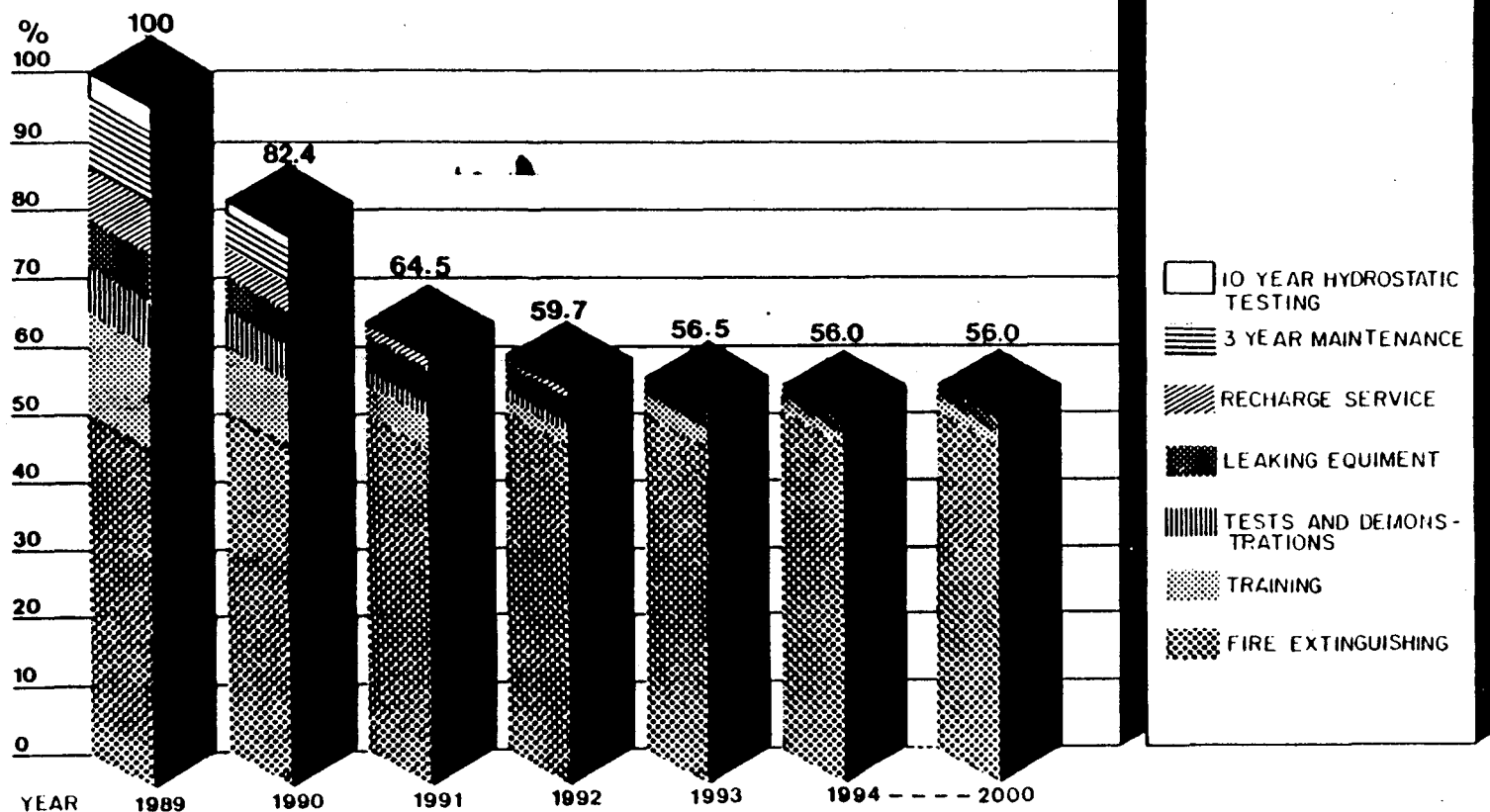
USING GAS RECOVERY DURING MAINTENANCE AND HYDROSTATIC TESTING OF EXTINGUISHING EQUIPMENT.



# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL

## SOURCE AND REDUCTION OF AVOIDABLE HALON EMISSIONS

INDEX : 1989 EMISSIONS = 100 %

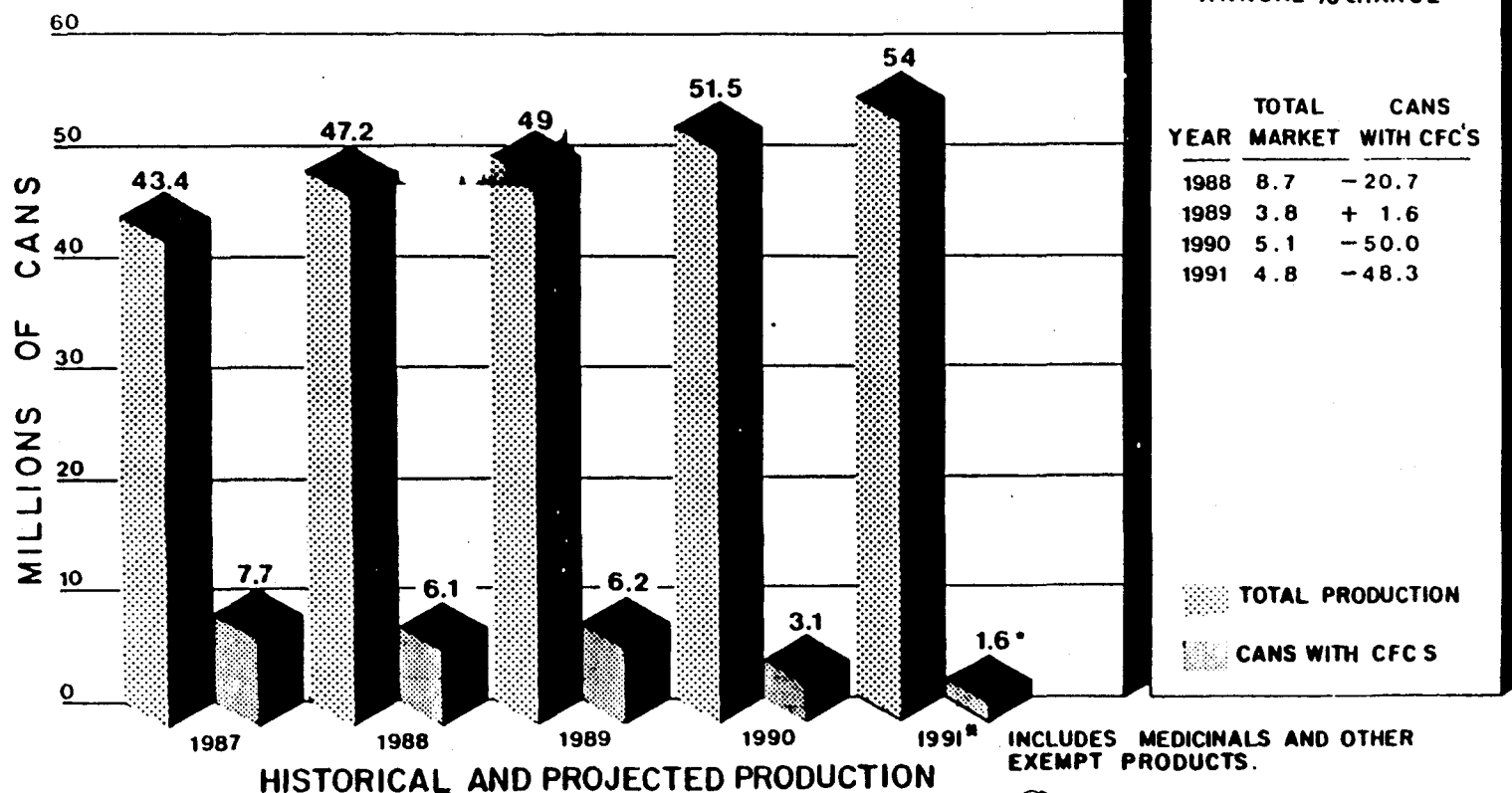




# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL

## REDUCTION IN CFC USE FOR AEROSOL PRODUCTS MANUFACTURING

### AEROSOL PRODUCTION



INSTITUTO MEXICANO DEL AEROSOL, A.C.



CAMARA NACIONAL DE LA INDUSTRIA DE PERFUMERIA Y COSMETICA



CAMARA NACIONAL DE LA INDUSTRIA DE TRANSFORMACION

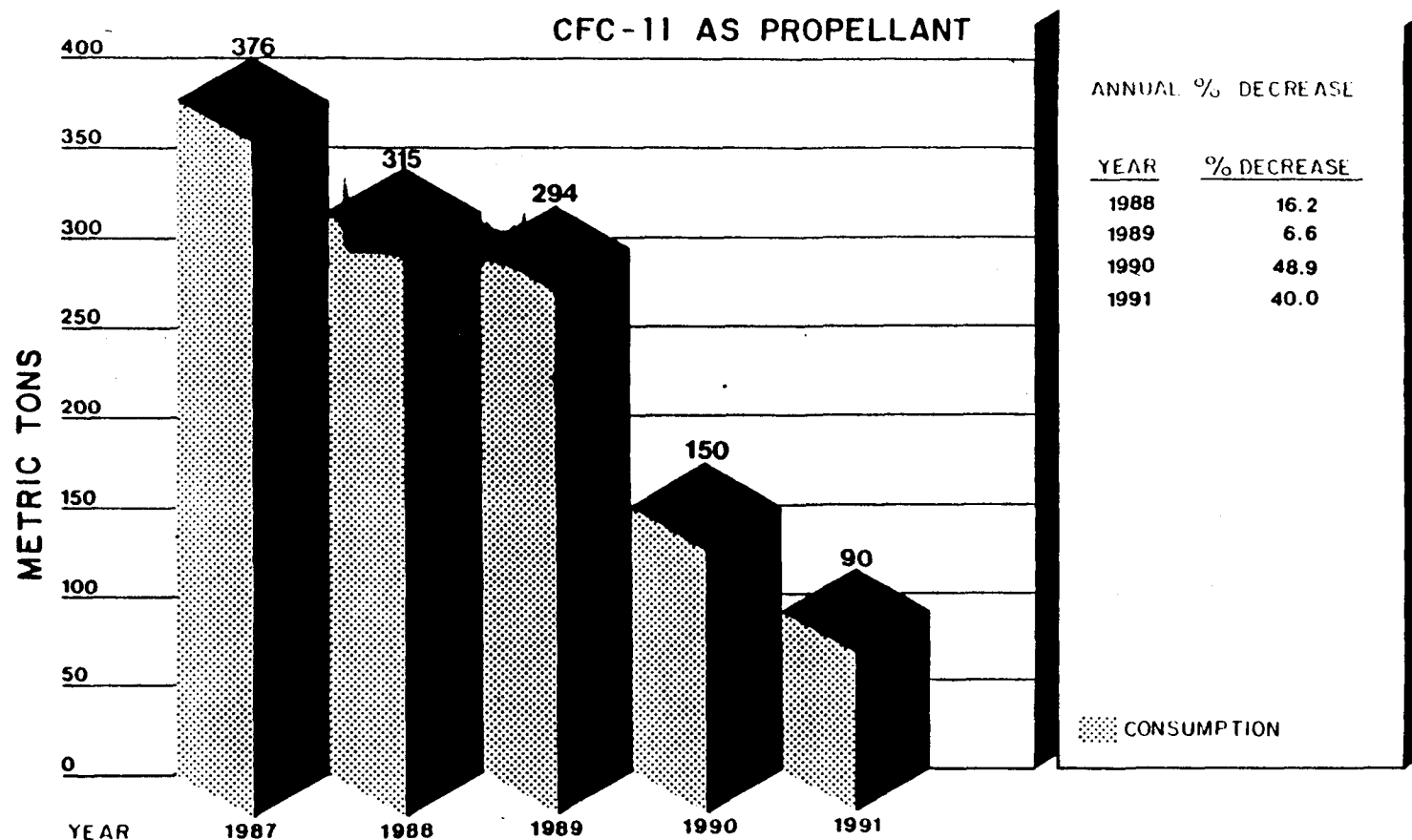
MEXICAN AEROSOL INSTITUTE

NATIONAL CHAMBER OF THE PERFUME AND COSMETIC INDUSTRY

NATIONAL CHAMBER OF INDUSTRIES



# MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL REDUCTION IN CFC USE FOR AEROSOL PRODUCTS MANUFACTURING



**HISTORICAL AND PROJECTED CONSUMPTION**

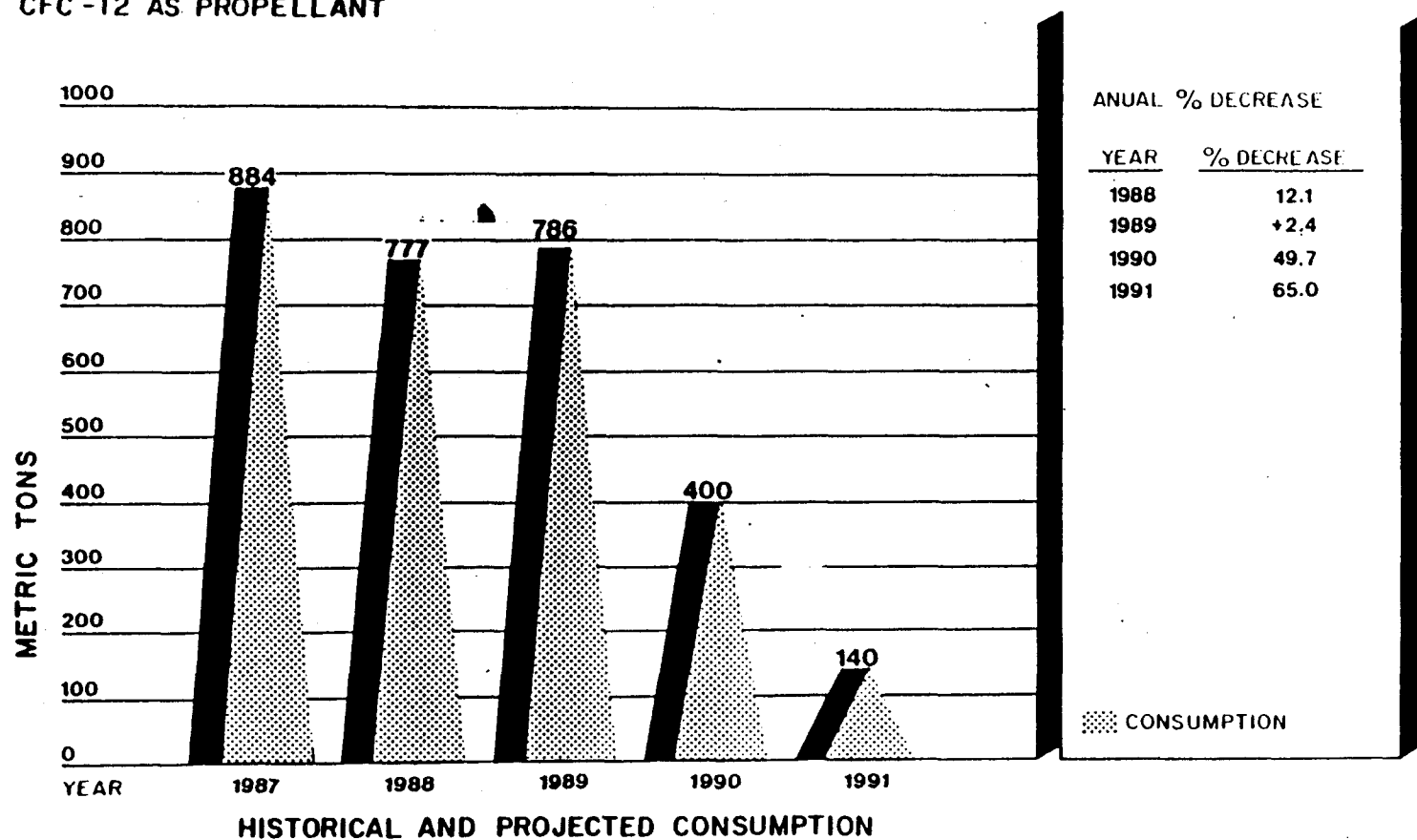
SOURCE: CFC PRODUCERS



## MEXICAN PROGRAM TO COMPLY WITH THE MONTREAL PROTOCOL

### REDUCTION IN CFC USE FOR AEROSOL PRODUCTS MANUFACTURING

#### CFC -12 AS PROPELLANT



SOURCE: CFC PRODUCERS



# **MEASURES TO BE IMPLEMENTED TO ADDRESS GLOBAL WARMING**

- . MEXICO WILL IMPLEMENT A PROGRAM TO PRESERVE AND IMPROVE THE EFFICIENCY OF FOSSIL FUEL UTILIZATION**
- . MEXICO IS WORKING TO IMPROVE ITS WATER SUPPLY MANAGEMENT**
- . ENERGY EFFICIENCY AND MEASURES TO ADDRESS AIR POLLUTION WILL BE ENCOURAGED**

# **ADAPTING TECHNOLOGY TO DEVELOPING COUNTRY NEEDS**

- . MEXICO CAN BE A SOURCE OF NEW AND ADAPTED TECHNOLOGY TO PROTECT THE OZONE LAYER**
- . THE MEXICAN DESIGN APPROACH HAS PROVED TO BE COST-EFFECTIVE AND SAFE**
- . THE MEXICAN KNOW-HOW MAY BE USEFUL TO OTHER DEVELOPING COUNTRIES**

**ATTACHMENT 4**

## TERMS OF REFERENCE FOR THE CASE STUDIES

### I. EXECUTIVE SUMMARY

#### STUDY METHODOLOGY

The feasibility study should be conducted in phases:

- 1) Generic Use Pattern Analysis (determine where and how, how much of these chemicals are used and their source of supply and distribution, i.e., produced locally/imported/exported, etc.) using published statistical summaries and estimates by chemical producers, distributors, and user association if possible or estimates based on estimates of production of products containing CFCs or products made with but not containing CFCs. Also, prepare an estimate of current and future needs (for the next ten years) taking into account national policies, economic plans or projected growth in demand.
- 2) Sector Specific Use Pattern Analysis (analyze how these chemicals are used within the sector and evaluate the options for: retrofitting plants to use alternative "environmentally friendly" technology; using alternative chemicals; manufacturing alternative products; maximizing conservation measures (recycle, recapture, re-use); or other mitigative measures (example no clean fluxes, etc.). Determine both the short and long-term alternatives and potential technological modifications for manufacturing processes, etc.
- 3) Assess the Cost Implications for country-wide compliance with the Montreal Protocol. (Determine costs on a sector basis for a 10 year period, including anticipated increases in costs for chemicals, servicing, maintenance, new products, etc.)
- 4) Develop a Feasible Compliance Schedule (taking into account the equipment acquisition times, etc.). Identify options to implement the report conclusions and recommendations including sources of new technology and financing. Develop a realistic timetable for achieving compliance with the Montreal protocol.

Capital Investment (including application engineering)

- New Facilities
- Retrofit
- Decommission
- Research, Pilot Plants, and Demonstration

Operating Costs

- Chemical Inputs and Labor
- Energy (including consideration of global climate change)
- Maintenance

## II. INTRODUCTION

- A. Purpose and Scope
- B. The Role of CFCs and Halons in Stratospheric Ozone Depletion
- C. The Montreal Protocol and Subsequent Developments
  - 1. The Montreal Protocol
  - 2. Ozone Depletion Potential (ODP) and Global Warming Potential (GWP)
  - 3. CFC and Halon Use in \_\_\_\_\_ (Country Name)
  - 4. Global and CFC and Halon Use
  - 5. Other Chemicals of Concern
- D. National Policy on Ozone Layer Protection
- E. National Advantage of Ozone Layer Protection
- F. National Circumstances Likely to Influence Technology Transfer
  - 1. Fire Codes
  - 2. Solvent Specifications
  - 3. Free Trade Zones/Off-shore Facilities and Ships
  - 4. Logistics
  - 5. Occupational Health and Safety
  - 6. Domestic Content Rules
  - 7. Import Restrictions
- G. National Case Studies as a Means to Facilitate Technology Transfer

## III. PRODUCTION AND CONSUMPTION OF CHLOROFLUOROCARBONS AND OTHER OZONE-DEPLETING COMPOUNDS

- A. Production Levels and Status of Current Production Capacity
  - 1. Historic, Current and Planned Production Levels
  - 2. Capacity and Location of Existing Facilities and Capacity under Construction
  - 3. Age and Flexibility of Existing Production Facilities
- B. Trade of Ozone Depleting Chemicals and Products
  - 1. Imports and Exports (with reference to Protocol Membership)
  - 2. Prices and Import Tariffs and other Regulations (such as CFC taxes)
- C. Consumption by End Use

## IV. TECHNOLOGY AND EQUIPMENT CHARACTERISTICS IN CURRENT END USES

- (Includes discussion of existing manufacturing facilities)
- A. Refrigeration, Air Conditioning, and Heat Pumps (including estimates of CFC contained in existing equipment)

B. Aerosols and Sterilants

C. Solvent Cleaning

D. Foams

1. Flexible Polyurethane Foams
2. Rigid Polyurethane Foams
3. Phenolic Foams
4. Extruded Polystyrene
5. Polyolefin Foams

E. Halon Fire Extinguishing Agents

1. Halon 1301 (including estimates of "banked" halon)
2. Halon 1211 (including estimates of banked halon)
3. Halon 2402

V. ESTIMATED FUTURE CHLOROFLUOROCARBON NEEDS

A. Methodology for 10-Year Projections

B. Projected Compound Demand by End Use

VI. OPTIONS TO REDUCE CHLOROFLUOROCARBON USE; RECYCLING, ALTERNATIVE COMPOUNDS AND TECHNOLOGIES

A. Recycling and Other Conservation Practices

B. Chemical Substitutes

C. Product Substitutes

VII. TRAINING AND INFRASTRUCTURAL REQUIREMENTS

VIII. STRATEGY FOR COMPLYING WITH THE MONTREAL PROTOCOL: THE CASE OF

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A. CFC Reduction Measures for the Short Term (1990-1995)  
(Best Available Technology from January conference)

B. CFC Reduction Measures for the Intermediate Term (1996-2000)

C. CFC Reduction Measures for the Long Term (2000-2010)

IX. COSTS OF TECHNOLOGY TRANSFER

APPENDIX A: SOURCES OF NEW TECHNOLOGY AND TECHNICAL ASSISTANCE

## Aerosols Workgroup - Terms of Reference

SUGGESTION TO INTEGRATE DISCUSSION OF TECHNOLOGY AND EQUIPMENT CHARACTERISTICS (SECTION IV) WITH OPTIONS (VI) AND RESPECTIVE COSTS (IX) WITHIN EACH SECTOR.

For example, the Outline for Aerosols would be:

### III. AEROSOLS

#### A. Technology and Equipment Characteristics in the Aerosol Industry

#### B. Substitutes and Costs

- i. Hydrocarbon Propellants
- ii. Non-flammable Propellants
- iii. Alternative Delivery Systems

For a projected mix of substitutes adopted estimate costs for Model Plant Scenarios including:

- Capital Investment and Other Fixed Costs, and
- Operating Costs

#### C. Summary (sector specific)

### Other Comments

CFC consumption estimates for aerosols obtained from CFC producers may be cross-checked if the volume and type of aerosols manufactured with CFCs is known. Even if this check cannot be performed, it is believed that uncertainties of  $\pm 20$  percent in this sector-specific consumption estimate are acceptable for the purpose of the case studies because conversion costs are insensitive to total CFC volumes consumed, but rather depend on the number and characteristics of aerosol filling plants.

**ATTACHMENT 5**



To be completed on industry, application, company or site basis (if possible)

**NATIONAL CFC STUDIES**  
**PROPOSED FORMAT FOR SURVEY QUESTIONNAIRE**

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**GENERAL INFORMATION**

Company Name: \_\_\_\_\_ Survey Respondent: \_\_\_\_\_

Address: \_\_\_\_\_ Position: \_\_\_\_\_

\_\_\_\_\_  
Voice Phone: \_\_\_\_\_

\_\_\_\_\_  
Fax phone: \_\_\_\_\_

Number of Employees (1989): \_\_\_\_\_

Sales (FY 1989): \_\_\_\_\_

Date Founded: \_\_\_\_\_

Estimated Annual Consumption of the following compounds (in Metric Tons):

CFC-12 \_\_\_\_\_ ; CFC-11 \_\_\_\_\_ ; CFC-113 \_\_\_\_\_

CFC-502 \_\_\_\_\_ ; CFC-500 \_\_\_\_\_ ;

Halon 1301 \_\_\_\_\_ ; Halon 1211 \_\_\_\_\_ ; Halon 2402 \_\_\_\_\_

Methyl Chloroform \_\_\_\_\_ ; Carbon Tetrachloride \_\_\_\_\_

Describe how the above compounds are related to your business (e.g., they form part of the final products produced in your company, they are purchased by your customers to operate existing equipment, etc.):

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Please indicate which of the following applications describes your current use of chlorofluorocarbons, and/or halons. Respond to this questionnaire at the indicated section:

- ☐ A. Refrigeration
- ☐ B. Aerosols
- ☐ C. Solvent Cleaning (includes use of CFC-113, Methyl Chloroform, and Carbon Tetrachloride)
- ☐ D. Sterilants
- ☐ E. Foams
- ☐ F. Halons

## REFRIGERATION

### I. DOMESTIC/HOUSEHOLD REFRIGERATION

#### A. General Description of the Sector

1. A short description of the history of manufacturing refrigerators
2. Which are the critical parameters for the country in this sector?
3. The size and the structure of the industry:
  - Numbers of factories (licensed/joint ventures)
  - Installed production capacity per shift
  - Age of production lines and lifetime
  - Types of products manufactured (static, frost-free cooling)
  - Size (inner/brutto volume) of typical products
  - Direct labor and total number of employees involved
4. How many refrigerators/freezers have been produced during the last ten years (specific data per year; imports and local data as well)?
5. How many refrigerators can be considered as "installed" capacity?
  - What is an estimate for an "installed" amount of refrigerant?
6. What is the production target for the year 2000 (as well as estimates for import data)?
7. How much refrigerant (type of refrigerant, probably CFC-12) is used in charging of the refrigerators, specifically the circuit of the appliances; typical values of products; and furthermore
  - Is the refrigerant produced domestically?
  - If not, why is it imported?What is the average refrigerant charge used (per unit of size)?
8. Which types of insulation are applied (type and quantity)
  - e.g., volume of insulation per product?

#### B. Components (compressors) Manufacturing

1. Are components (heat exchangers and valves, not the compressors) made in-site/locally or bought from external suppliers
    - information on the type of heat exchangers?
    - information on manufacturing techniques
  2. Are compressors made in-site/locally or bought from external suppliers?
- In case of domestic compressor production
3. The size and the structure of the compressor industry:

- Number of factories (licensed/joint ventures)

- Direct labor and total number of employees involved
- Installed production capacity per shift
- Age of production lines and lifetime
- Capacities of compressors produced (cooling capacity)

4. Are compressor electric motors made in-site or bought externally?
5. How many compressors have been produced during the last ten years (import and export data)?
6. What is the production target for the year 2000?

C. Other Topics

1. What is the future trend expected in manufacturing refrigerators:

- Manufacturing technology change
- Types of appliances
- Typical volume of a refrigerator

2. (Optional) Which standards are applied in tests (ISO, NF, DIN, own)

- Inner and ambient temperatures

Which responsibility belongs to National Manufacturing Organizations?

3. How efficient is the service organization?

- How many servicing operations
- Amount of refrigerant (typical) used in servicing
- Is servicing performed via factory/brand organization
- Education level of servicing engineers

4. (Optional) How many refrigerators are being disposed of and what is the future expectation? Will it be possible to collect disposed refrigerators? Now, or in the future?

5. What is the average lifetime of a refrigerator (reasons for disposal)?

II. RETAIL/COMMERCIAL REFRIGERATION

A. General Description of the Sector

1. A short description of the history of manufacturing cabinets, stores, etc.
2. Which are critical parameters for the country in this sector?
3. The size and the structure of the industry:
  - How many production sites.
  - Average size of a production site

- Status of manufacturing technology.
- Direct labor and total number of employees involved

4. How many:

- display cabinets
- Cold stores
- Ice makers
- Other equipment

have been produced during last ten years (specific data per year; also import and local data)

5. What is the production expected for the year 2000 (as well as estimates for import data)?
6. How much refrigerant (types, HCFC-22, CFC-12, 500, 502) is used in equipment manufacturing (first charge whether it concerns domestically produced refrigerant or import)? What is the charge used in the typical products?
7. Which types of insulation are applied (type and quantity) (e.g., volume of insulation per product)?
8. How many units have been installed (domestically produced or import)?
- Distribution with respect to age (10-20 years, 5-10, 0-5 years old)
  - Typical charges of these units
9. Engineers involved and their education level:
- Education level of engineers
  - National engineer societies (education level)
  - Training courses
10. What is the future trend expected in manufacturing this equipment?
- Manufacturing technology changes
  - Types and typical volumes
11. (Optional) Which standards are applied in tests (ISO, NF, DIN, own)?
- Inner, ambient temperature levels

Which responsibility belongs to National Manufacturing Organizations

B. Components (compressors) Manufacturing

1. Are components (like heat exchangers and valves, not compressors) made in-site/locally or bought from external suppliers?

- Information on the type of heat exchangers
  - Information on manufacturing techniques
2. Are compressors made in-site/locally or bought from external suppliers?  
  
In case of domestic compressor production
  3. The size and the structure of the compressor industry:
    - Number of factories (licensed/joint ventures)
    - Direct labor and total number of employees involved
    - Installed production capacity per shift
    - Age of production lines and lifetime
    - Capacities of compressors produced (coding capacity)
  4. Are compressor electric motors made in-site?
  5. How many compressors have been produced during the last ten years (also import and export data)?
    - Separate data for each of the refrigerant types
  6. What is the future production target (e.g., 2000)?
    - Quantity concerned
    - Shift from/towards other types
    - Shift from/towards other refrigerants

C. Servicing

1. How efficient is the servicing operation?
  - Amount of refrigerant (typical) used in servicing
  - How many servicing operations per unit
  - Amount of refrigerant used for servicing per year compared to the charge of the unit
  - Is servicing performed via factory/brand organization
  - General practice in servicing
2. What has been the amount of refrigerant used for servicing per year vs. charge of equipment (split up to types of equipment)
3. Which kind of engineers perform servicing?
  - Education levels (permanent education)
  - Training on the job/service manuals
  - Service engineers organizations
  - Number of engineers involved
  - Is there a shortage/surplus of engineers
4. Which are typical aspects of servicing and critical parameters (which components fail, leak detection available)?

5. Disposal:

- What is the average lifetime of a unit (reasons for disposal)
- How many units are being disposed of
- Future expectations

### III. TRANSPORT REFRIGERATION

#### A. General Description of the Sector

1. A short description of the history of manufacturing transport refrigeration equipment.
2. Which are the critical parameters for the country in this sector?
3. The size and the structure of the industry
  - How many production sites
  - Average size of a production site
  - Direct labor and total number of employees involved
  - Status of manufacturing technology
4. How many
  - Units in trains
  - Units in vans and lorries
  - Units in ships
  - Other equipment

Have been manufactured during the last ten years (specific data per year; also import and local data)
5. What is the production target for the year 2000 (as well as estimates for import data)?
6. How much refrigerant (types, HCFC-22, CFC-12, 500 or 502) is used in equipment manufacturing (first charge; whether it concerns domestically produced refrigerant or import)? What is the charge used in typical products (indications as to size)?
7. How many units have been installed (domestically produced or import)?
  - Distribution with respect to the age of the product (10-20, 5-10 and 0-5 years old)
  - Typical charges of these units
8. Engineers involved and their education level, some information on
  - Education level of engineers  
(equal questions as in retail refrigeration)
9. What is the future trend expected in manufacturing this equipment
  - Manufacturing technology change
  - Types and typical volumes
10. (optional) Which standards are applied in tests (ISO, NF, DIN, own...)



- Inner and ambient temperatures applied

Which responsibility belongs to the National Manufacturer Organization(s)?

**B. Components (compressor) Manufacturing**

1. Are components (like heat exchangers and valves, not the compressors) made in-site/locally or bought from external suppliers
  - Information on the type of heat exchangers
  - Information on manufacturing techniques
2. Who provides the compressors
  - Same structure as the retail refrigeration industry
  - Differences
  - What is the target for the near future

**C. Servicing**

1. How efficient is the service organization
  - How many servicing operations per unit
  - Amount of refrigerant (typical) used in servicing (separated to the refrigerant type of equipment)
  - The amount of refrigerant used for servicing per year compared to the charge of the unit
  - Is servicing performed via factory/brand organization
  - General practice in servicing
2. What has been the amount of refrigerant used for servicing per year versus new charging of equipment (split up to types of equipment)
3. Which kind of engineers perform servicing
  - Education levels
  - Training on the job/service manuals
  - Service engineers organizations
  - Number of engineers involved
  - Is there a shortage/surplus of service engineers
4. Which are typical aspects of servicing and the critical parameters (which components fail, leak detection available, etc.)
5. Disposal
  - What is the average lifetime of a unit (reasons for disposal)
  - How many units are being disposed of/future expectations

#### IV. AIR CONDITIONING

- a. AC by the use of small and middle-sized units
- b. AC by the use of large (reciprocal and centrifugal chillers)

(questions have to be answered separately for the two categories of equipment, small AC requirement and large chilling equipment)

##### A. General Description of the Sector

1. A short description of the history of manufacturing air conditioning units
2. Which are the critical parameters for the country in this sector?
3. The size and the structure of the industry
  - How many production sites
  - Average size of a production site
  - Direct labor and total number of employees involved
  - Status of manufacturing technology
4. How many AC-units have been produced during the last ten years (specific data per year; also import and local data)
5. What is the production target for the year 2000 (as well as estimates for import data)
6. How much refrigerant (types, HCFC-22, CFC-12, 500 or CFC-11) is used in equipment manufacturing (first charge; whether it concerns domestically produced refrigerant or import)? What is the charge used in typical products (indications as to size)?>
7. How many units have been installed (domestically produced or import)
  - Distribution with respect to the age of the product (10-20, 5-10 and 0-5 years old)
  - Typical charges of these units
8. Engineers involved and their education level, some information on
  - Education level of engineers
  - National engineer societies (education level)
  - Training courses
9. What is future trend expected in manufacturing this equipment
  - Manufacturing technology change
  - Types and typical volumes
  - Size of production sites
10. (Optional) Which standards are applied in tests (ISO, NF< DIN, own...)

- Inner and ambient temperatures applied

Which responsibility belongs to the National Manufacturer Organization(s)

**B. Components (compressors) Manufacturing**

1. Are components (like heat exchangers and valves, not the compressors) made in-site/locally or bought from external suppliers
  - Information on the type of heat exchangers
  - Information on manufacturing techniques
2. Are compressors made in-site/locally or bought from external suppliers (abroad)

In case of domestic compressor production (in-site or not)

3. The size and the structure of the compressor industry
  - Number of factories (licensed/joint ventures)
  - Direct labor and total number of employees involved
  - Installed production capacity per shift
  - Age of production lines and lifetime (when installed)
  - Capacities of compressors produced (cooling capacity)
4. Are compressor electric motors made in-site?
5. How many compressors have been produced during the last gen years (import and export data)
  - Separate data for each of the refrigerant types
6. What is the future production target (e.g., 2000)
  - Quantity concerned
  - Shift from/towards other types
  - Shift from/towards other refrigerants

**C. Servicing**

1. How efficient is the service organization
  - How many servicing operations per unit
  - Amount of refrigerant (typical) used in servicing (separated to the refrigerant type of equipment)
  - The amount of refrigerant used for servicing per year compared to the charge of the unit
  - Is servicing performed via factor/brand organization
  - General practice in servicing
2. What has been the amount of refrigerant used for servicing per year versus new charging of equipment (split up to types of equipment)

3. What kind of engineers perform servicing
  - Education levels
  - Training on the job/service manuals
  - Service engineers organizations
  - Number of engineers involved
  - Is there a shortage/surplus of service engineers
4. Which are typical aspects of servicing and the critical parameters
  - Which components fail, leak detection available, etc.
5. Disposal
  - What is average lifetime of a unit
  - How many units are being disposed of/future expectations

V. AUTOMOTIVE/MOBILE AIR-CONDITIONING

A. General Information

1. A short description of the history of Auto-AC; are cars normally equipped with AC units?
2. Which are the critical parameters for the country (comfort, humidity, etc.)
3. What is the number of cars equipped with AC:
  - Tendencies in recent years
  - Expected for the near future
  - What is the lifetime of a car and what is the average lifetime of the fleet equipped with air conditioning
4. Is there a significant amount of buses, railway carriages, etc. equipped with AC and what is the trend for the near future (are units produced domestically or imported)
5. Production figures
  - How many cars are being produced domestically (with and without AC)
  - How many cars are being imported/exported (with and without AC) (some data for the last decade)
6. What is the production target for the year 2000 (as well as estimates for import data)
7. How much refrigerant (type) is used for first charging the units and how much is used for servicing; what is the total amount involved and is it obtained from domestic sources.

What is the average charge used in the equipment
8. How many units are functioning (domestically produced or imported)
  - Distribution with respect to the age of the unit/car (10-20, 5-10 and 0-5 years old)
  - Typical charges of these units
9. What is the future trend expected in manufacturing this equipment
  - manufacturing technology change and types involved
10. In which way compressors are mounted in cars and what is the education of the workers.

11. Which standards are applied in tests (SAE, own...)
  - Inner and ambient temperatures applied
12. How many cars are being disposed of each year (percentage equipped with AC; can the refrigerant be collected)

**B. Components (compressor) Manufacturing**

1. Are components (like heat exchangers and valves, not the compressors) made in-site/locally or bought from external suppliers
  - Information on the type of heat exchangers
  - Information on manufacturing techniques
2. Are compressors made in-site/locally or bought from external suppliers
3. The size and structure of the compressor industry
  - Which percentage is licensed production
  - Installed production capacity per shift
  - Age of production lines and lifetime (when installed)
4. How many compressors have been produced during the last ten years (import and export data)
5. What is the future production target (e.g. 2000)
  - Shift from/towards other types

**C. Servicing**

1. Is servicing of the AC units performed by garages (percentage of total number of activities; do it yourself attitude)  
What is the amount of refrigerant used by garages for servicing compared to the total amount used for servicing/refilling (disposable cans)
2. Which kind of engineers perform servicing?
  - Standardized education levels
  - Permanent education
  - Training on the job/service manuals
3. What is the amount of refrigerant used for servicing per service center (average garage)? What has been the tendency in the years 1986-89?
4. Which are the typical aspects of servicing and the critical parameters
  - Which components fail, leak detection available, etc.
5. Is there a shortage/surplus of service engineers? Is there a service engineer organization?

## AEROSOLS

1. Indicate the aerosol product categories manufactured in your facility and the approximate wholesale value per unit (in local currency):

	Wholesale Value per Unit
[ ] Insecticides	_____
[ ] Personal Products	_____
[ ] Paints	_____
[ ] Medical Products	_____
[ ] Household Products	_____
[ ] Automotive and Industrial Products	_____
[ ] Other (please specify _____)	_____

2. Estimate the total number of aerosols produced in your company in 1988 and the percent exported to other countries:

- Approximately \_\_\_\_\_ million aerosol units were produced in 1988 and \_\_ percent of this was exported to \_\_\_\_\_.

3. Estimate the overall future annual growth rate in demand for aerosols over the next 5 years:

- The estimated annual growth (decline) in demand for aerosols is estimated at \_\_ %.

4. What is the basis for changes in production of aerosols:

- [ ] Purchasing power of the population
- [ ] Availability of alternative products
- [ ] Prospects of export markets
- [ ] Other (please specify \_\_\_\_\_)

5. Of the total number of units manufactured in your facility, estimate the percent containing chlorofluorocarbons and the type of these aerosol products:

- \_\_\_\_\_ percent of the total number of units manufactured contain CFCs. The product categories formulated with CFCs include \_\_\_\_\_.

6. What is the current price of aerosol-grade propellants in local currency:

CFC-11 \_\_\_\_\_/Kg      CFC-12 \_\_\_\_\_/Kg  
Isobutane \_\_\_\_\_/Kg      Butane \_\_\_\_\_/Kg      Propane \_\_\_\_\_/Kg

7. What would be the constraints for reformulating products using CFCs to hydrocarbon propellants? If capital investment is required to modify existing manufacturing facilities, please estimate the level of investment required? \_\_\_\_\_

## SOLVENT CLEANING

1. Of the total amount of CFC-113 consumed in the company, estimate the distribution of solvent use by application:

		Percent of Total Use		
		CFC-113	Methyl Chloroform	Carbon Tetra- Chloride
<input type="checkbox"/>	to remove flux from electronic assemblies	_____	_____	_____
<input type="checkbox"/>	metal cleaning	_____	_____	_____
<input type="checkbox"/>	precision cleaning (e.g., cleaning of disk drives)	_____	_____	_____
<input type="checkbox"/>	component drying	_____	_____	_____
<input type="checkbox"/>	other (specify: _____)	_____	_____	_____
100%		Total	100%	100%

2. Which end-products are involved in the above uses:

- ☐ Computers;                      ☐ consumer electronics;                      ☐ automotive components  
☐ telecommunications equipment;   ☐ avionic instrumentation;                      ☐ military equipment;  
☐ other (\_\_\_\_\_)

3. Estimate the number and type of solvent cleaning equipment produced every year and the approximate value. Estimate the percent of total production that is exported and the number of imported units (please include destination and origin of exports and imports).

	Number of Units produced annually	Value per Unit	Units % Exported--Destination	Imported-Origin
Cold cleaning				
Conveyorized Vapor degreasing				
Open top vapor degreasing				
Solvent recovery systems				

4. Provide the number and age of cleaning equipment in service:

	Number of Units in Service	Percent of Total Stock 1-5 years old	6-10 years	11-20 years	21+ years
Cold cleaning					
Conveyorized vapor degreasing					
Open top vapor degreasing					
Solvent recovery systems					



5. Consider all major solvents currently used for electronics and metal cleaning applications. What is the approximate distribution of consumption by solvent type?

- CFC-113 accounts for \_\_\_\_ % of the total solvent consumption.
- Methyl Chloroform accounts for \_\_\_\_ % of the total solvent consumption.
- Carbon Tetrachloride accounts for \_\_\_\_% of the total solvent consumption
- Other solvents account for the remaining \_\_\_\_ % of total solvent consumption.

6. Do you send out waste CFC-113 for recycle/recovery? If so, how much annually?

7. Are you aware of and for considering replacement processes/chemicals/technologies for the above applications? If so, please describe.

## STERILANTS

1. For each of the following end-uses estimate the total number and type of sterilization chambers in service and the approximate value of these units:

	<u>Number of Units in Service</u>	<u>Value per Unit</u>
Hospital sterilization.		
Commercial/industrial sterilization		
R&D laboratories.		
Other (please specify) _____		

2. Indicate the approximate number of sterilization chambers purchased every year and the expected growth in future sales:

	<u>Number of Units Purchased</u>	<u>Sales Growth</u>
Hospital sterilization.		
Commercial/industrial sterilization		
R&D laboratories.		
Other (please specify) _____		

3. What percent of the local market is supplied domestically: \_\_\_\_\_ percent.

4. What percent of local production is exported: \_\_\_\_\_ percent.

5. Of the total volume of sterilant gases used, roughly estimate the percent associated with mixtures containing CFC-12: \_\_\_\_\_ percent.

6. What other sterilization methods are used for heat-sensitive devices:

- ☐ Pure ethylene oxide
- ☐ Formaldehyde
- ☐ Ethylene Oxide and Carbon Dioxide
- ☐ Other (\_\_\_\_\_)

## FOAMS

1. Quantities and types of foam products manufactured and imported, blowing agents used, and extent to which CFCs or other blowing agents or product substitutes are now employed.
  - a. Polyurethane Foams
    - Rigid Appliance Insulation
    - Rigid Insulation: building, piping, slabstock, etc.
    - Flexible
    - Packaging and Other
  - b. Extruded Polystyrene
    - Packaging
    - Insulation
  - c. Phenolic
  - d. Polyolefin
2. Projected foam demand by year until 2000

Basis for growth in demand

  - Domestic Consumption
  - Exports

Projected sources for meeting future demand

  - Expanded domestic production
  - Increased imports (possible sources)
  - Infrastructure requirements for expanded manufacturing and/or production
  - Possible sources of technology
  - Possible quantum of capital
  - Government/private/international agency participation in expansion
3. Sources of current raw material for production
  - Domestic production
  - Imports and country of origin
4. Current domestic manufacturing facilities
  - Size and structure of industry (number of employees, sales, etc.)
  - Age and expected life time of production facility
  - Is the facility under a licencing agreement/joint venture
  - Source and type of technology used
5. What are the critical parameters, factors of the product that are essential to the country.

6. Characteristic of unorganized industry in the country
  - Small plants
7. Identify near term substitutes
  - Chemical substitutes
  - Process modifications or alternative technologies
  - Product substitutes
8. Availability of near term substitutes
9. Identify longer term options for both chemical substitution or process change.

## HALONS

1. Is there a government agency or trade association responsible for fire protection? If so, list name, address, phone number and fax number.
2. Are there any pieces of national legislation or regulations on fire protection that require halon? If so, please list.

3. Imports/Halon

When did you first import halon?

How much halon is currently being imported?

- bulk
- in equipment

How much has been imported each year from initial date of import?

- bulk
- in equipment

4. Production/Halon

If there is any production facilities in your country, please estimate volume.

5. Production/Equipment

Does your country manufacture any fire protection equipment intended to contain halon? If so, identify manufacturer, location, capacity and whether manufacturing

- 1301 systems
- 1301 portables
- 1211 portable extinguishers
- 1301 systems
- 2402 in any type of equipment?

6. Estimate bank of halon by examining use sectors. Specify use of -1301, -1211, -2402 within each sector.

- Transportation
- Communications
- Utilities
- Financial services
- Primary industry
- Manufacturing industry
- Natural resource industry
- Petro/chemical
- Government services/military
- Health care
- Other

TOTAL

To check estimated bank, compare total to quantity imported from date of initial import.

6a. What percent of halon applications are in areas where a fire would pose direct threat to human life and a large sector of your society and where no other extinguishing agent could be used effectively?

7. How much halon is used to:

1301

1211

2402

Fill new installations

Recharge existing installations

Testing/training

8. What major projects has your country committed to that will require halon?

8a. Provide a 5-year forecast of halon needs/commitments.

9. What national plans, if any, exist for reducing halon dependence?

10. Please provide any other information/suggestions for needed assistance.

## APPENDIX

# Replacement of CFC-113 in Industry

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## **Preface**

To protect the global ozone layer, the production and consumption of a series of chemicals, such as chlorofluorocarbons (CFCs) and halons, must be phased out. The great majority of industrial enterprises using CFCs and halons are prepared to renounce them, but there is an obvious lack of information on how to achieve this in practice. This booklet contributes towards filling in this gap. The author is a renowned expert in industrial cleaning and is recognised in the relevant international professional circles. He has actively participated in the evaluation of the possibilities for the substitution of CFC-113, within the framework of the United Nations Environmental Programme (UNEP). The Federal Office of Environment, Forests and Landscape is convinced that, by supporting this publication, an important contribution to the accomplishment of CFC replacement is being made.

Federal Office for Environment,  
Forests and Landscape,  
**The Director**

*Professor Dr. Bruno Böhlen*

## **French executive summary**

## Executive Summary

This booklet is intended primarily to guide Swiss industry away from the use of chlorofluorocarbon (CFC) and other polluting solvents, giving suggestions as to how these products may be replaced by less polluting ones. For the most part, it is a résumé of the Solvents Technical Options Committee Report of the United Nations Environmental Programme, modified to suit the Swiss context. Its structure follows a logical sequence.

The first chapter is an introduction giving brief indications as to why it is necessary to replace CFC-solvents, touching on both the technical and the legislative aspects with, obviously, a certain emphasis on the Montreal Protocol, as well as the official Swiss position, as defined by the Federal Council and probable future legislation. The mechanisms of ozone depletion and the greenhouse effect are also briefly discussed.

Chapter two examines most of the practical products that may be used for industrial cleaning, indicating their individual advantages and disadvantages. The first section discusses the two solvents which are restricted under the current (1979) provisions of the Montreal Protocol, CFC-11 and CFC-113. The next section examines those solvents that are not yet restricted even though there is every reason why they should be, namely, carbon tetrachloride, 1,1,1-trichloroethane (methyl chloroform), CFC-112 and certain HCFCs. All of these will probably be included in the next revision of the Protocol, scheduled for June 1990. Section 3 of this chapter looks at other halogenated and non-halogenated organic solvents. The last section exposes water-based cleaning methods, with and without diverse types of additives.

As CFC and other halogenated solvents become more difficult to obtain, and more expensive, it will become

increasingly important to practice conservation. It is shown in the third chapter that savings of 40-90% of the consumption are usually possible by simple, common-sense measures, particularly for the smaller establishments such as are common in Switzerland. The most important of these measures is to make both management and the operator aware of the problems, but simple machine modifications and enhancements are equally described. These conservation methods are obviously applicable to all volatile solvents, whether CFCs or not.

The final chapter gives specific recommendations as to how to go about substituting less-polluting products for halocarbon solvents in various applications. Over half the chapter is devoted to defluxing in the electronics industry, this being the principle use of CFC-113 in Switzerland. Six substitute methods are discussed, namely, the use of fluxes that do not require cleaning, water cleaning of water-soluble fluxes, saponifier and water cleaning of rosin fluxes, hydrocarbon/surfactant and water cleaning of rosin fluxes, hydrocarbon and derivative (e.g. alcohol) cleaning of rosin fluxes and, finally, the use of a few permitted halocarbon solvents for rosin flux removal. Further applications that are discussed are industrial degreasing, precision cleaning, drying by solvents, textile dry cleaning, particle removal, medical applications and, finally, the use of such solvents as a vehicle for lubricants and adhesives.

The booklet is completed by an appendix listing the usual halocarbons, with certain properties, that may be found in industry, a list of references for those wishing more detailed information and some lists of addresses of organisations that may help industry to eliminate the use of CFC-113. A comprehensive table of contents and index is provided.

## **Italian executive summary**

## **German executive summary**

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## D. Definitions

It is thought that some of the terms used in this booklet may be obscure to non-specialists. In view of this, it has been decided to include a glossary explaining the meaning of some of them, of a fairly general

application. It has been a deliberate policy to keep the definitions as simple as possible, to the extent that some of them, while practically explaining the meaning, may not be correctly scientifically defined.

- Aerosol** [F. aérosol, D. Aerosol] a colloidal dispersion of a liquid or solid in a gas
- Aerosol spray** [F. bombe aérosol, D. Aerosoldose, Spraydose] a loose term to designate a means of atomising a liquid by pressurising it with a liquified or compressed gas in which it is soluble. It is a misnomer
- Chelation** [F. complexage, chélation, D. Komplexierung, Chelatbildung] a process whereby a substance forms a water-soluble complex with an insoluble compound
- Chlorofluorocarbon** [F. chlorofluorocarbone, D. vollständig halogenierter Fluorchlorkohlenwasserstoff], (CFC), an organic substance where all the hydrogen atoms of a hydrocarbon are replaced by chlorine and fluorine atoms
- Conservation** [F. conservation, D. Rückhaltung] in this context, the prevention of evaporation of a solvent by improved housekeeping
- Defluxing** [F. défluxage, D. Flussmittelentfernung, Entfluxen] the elimination of soldering flux residues
- Degreasing** [F. dégraissage, D. Entfettung] the elimination of oils and greases
- Detergent** [F. détergent, D. Wasch-, Reinigungsmittel, Detergens] a product designed to solubilise oils, greases, etc. in water
- Dobson Unit** [F. Unité de Dobson, D. Dobson Einheit], (D.U.), a measure of the instantaneous total quantity of ozone in a column of the stratosphere expressed in the number of hundredths of a millimetre that the total column would occupy as a layer if it was at standard temperature and pressure (0°C and 1 atmosphere). The average "ozone layer" thickness is about 300-400 D.U. or 3-4 mm.
- Dry-cleaning** [F. nettoyage chimique, D. chemische Reinigung] the elimination of dirt from garments by the use of organic solvents, as opposed to water solutions
- Flux** [F. flux, décapant, D. Flussmittel] a product designed to facilitate soldering. Nearly all fluxes are acid and therefore their residues must be removed or cleaned off, in many cases
- Flux activator** [F. activateur (de flux), D. Aktivator] a substance added to rosin or other flux bases to increase its effectiveness. The most usual flux activators are either an organic hydrohalide which breaks down at soldering temperatures to release minute quantities of hydrohalic acid gas or stronger organic acids which remain more or less intact
- Global Warming Potential** [F. Potentiel de réchauffement global, D. Globales Erwärmungspotential], GWP, an index, referred to CFC-11 = 1, given to a substance and which indicates its potential for global warming (see Greenhouse effect). In absolute terms, Radiative Forcing Potential is expressed by the theoretical temperature rise in Celsius degrees per increase in parts per 10<sup>9</sup> of the substance (parts per milliard volume; USA, parts per billion volume)
- Greenhouse effect** [F. Effet de serre, D. Treibhauseffekt] a natural increase of global temperature due to radiation from the earth's surface to outer space being reduced by the presence of certain gases. The effect is probably intensified by the presence of, principally, man-made pollutants
- Halocarbon** [F. halocarbone, D. Halogenkohlenwasserstoff] generic term for all hydrocarbons where at least one atom has been replaced by a halogen atom (fluorine, chlorine, bromine or iodine)
- Hydrocarbon** [F. hydrocarbure (preferred to hydrocarbure), D. Kohlenwasserstoff] (HC) organic substance whose molecule contains only carbon, often in chains or rings, and hydrogen. In the Swiss legislative context, this is considered as synonymous with Volatile Organic Compound (q.v.).
- Hydrocarbon derivative** [F. dérivé d'hydrocarbure, D. Kohlenwasserstoffderivat] a hydrocarbon where one or more hydrogen atoms are replaced by another radical
- Hydrochlorocarbon** [F. hydrochlorocarbure, D. teilweise halogenierter Chlorkohlenwasserstoff] (HCC) a hydrocarbon where one or more hydrogen atoms, but not all of them, are replaced by chlorine atoms



- Hydrochlorofluorocarbon* [F. hydrochlorofluorocarbone, D. teilweise halogenerter Fluorchlorkohlenwasserstoff] (HCFC) a hydrocarbon where one or more hydrogen atoms, but not all of them, are replaced by chlorine and fluorine atoms
- Hydrofluorocarbon* [F. hydrofluorocarbone, D. teilweise halogenerter Fluorkohlenwasserstoff] (HFC) a hydrocarbon where one or more hydrogen atoms, but not all of them, are replaced by fluorine atoms
- Ionic contamination* [F. contamination ionique, D. ionische Kontamination od. Verunreinigung] residues on an electronics assembly which will ionise in the presence of water. The measure of ionic contamination is a standard procedure to determine cleanliness
- Lifetime* [F. durée de vie, D. Lebensdauer] in this context, the time, expressed in years, required for a substance in gaseous or vapour form to break down in the atmosphere. As the decay is exponential, it is expressed for convenience as the "folded-e" lifetime, that is until there is 1/e times the original quantity, approximately 37%
- Ozone* [F. ozone, D. Ozon] O<sub>3</sub>, an allotrope of oxygen. In the stratosphere, where it is generated by solar radiation, it forms a barrier to high-energy ultra-violet (UVB) radiation. In the troposphere, it is a highly toxic gas
- Ozone depletion* [F. appauvrissement d'ozone, D. Ozonabbau] an effect where stratospheric ozone is reverted to oxygen by a catalytic reaction with chlorine or bromine, mainly derived from human activities, faster than it forms
- Ozone depletion potential* [F. Potentiel d'appauvrissement de la couche d'ozone, D. Ozonschichtabbaupotential] an index, referred to CFC-11 = 1, given to a substance, indicating its potential to deplete ozone in the stratosphere. It is calculated by means of a small number of mathematical models from about twelve parameters and is necessarily approximate as there are other undefined parameters involved
- Ozone hole* [F. trou d'ozone, D. Ozonloch] a loose term to describe a phenomenon where a high degree of ozone depletion occurs over the Antarctic at the end of winter. It is caused by the combination of meteorological phenomena with, principally, chlorine atoms
- Ozone layer* [F. couche d'ozone, D. Ozonschicht] a loose term to indicate the ozone contained in the stratosphere, between 10 and 50 km altitude
- Perchlorocarbon* [F. perchlorocarbone, D. Perchlorkohlenwasserstoff] (CC) an organic substance where all the hydrogen atoms of a hydrocarbon are replaced by a chlorine atom
- Perfluorocarbon* [F. perfluorocarbone, D. Perfluorkohlenwasserstoff] (FC) an organic substance where all the hydrogen atoms of a hydrocarbon are replaced by a fluorine atom
- Petroleum ether* [F. éther de pétrole, D. Petroläther] a mixture of hydrocarbon petroleum distillates with boiling points from 40° to 80°C, often selected over a narrow range
- Petroleum spiritus* [F. essence de pétrole, benzine, D. Benzin, Petrolspiritus] a mixture of hydrocarbon petroleum distillates with boiling points from 80° to 150°C. Also used as a generic term for all fractions from about 30° to 300°C
- Precision cleaning* [F. nettoyage de précision, D. Präzisionsreinigung] cleaning of ultra-precise components or assemblies to defined limits
- Product* [F. produit, D. Produkt] a mixture of chemical compounds, often of a commercial nature, frequently of indeterminate or secret composition
- Rosin* [F. colophane, D. Kolophonium] a mixture of natural organic acids obtained from pine trees used extensively as a soldering flux. Its fluxing action is weak and activators are usually added
- Soldering* [F. soudage, brasage tendre, D. Löten] the joining of two metals by a third, usually of low melting point, whereby a chemical bond is formed at the interfaces by the formation of intermetallic compounds. Soldering requires clean surfaces, hence one of the reasons for fluxes
- Solvent* [F. solvant, D. Lösungsmittel] in this context, but not strictly correct, a liquid substance or a product designed to dissolve specific contaminants
- Stoddart solvent* a type of white spirits used for dry-cleaning garments
- Substance* [F. substance, D. Stoff] a single chemical compound of a specific composition, as opposed to a product
- Surface insulation resistance* [F. résistance de l'isolement de surface, D. Oberflächenwiderstand] (SIR) one of the qualities of a good insulator is a high SIR. As the presence of contamination may reduce the SIR, the measure of it is a standard procedure to determine cleanliness
- Surfactant* [F. agent de surface, D. oberflächenaktiver Stoff] a substance with long molecules, one end of which is lipophilic and the other hydrophilic. Surfactants reduce the surface tension of water with which they are mixed and they form micelles which can emulsify many oils and greases. Surfactants are the principal constituents of most detergents

- Terpenes** [F. terpènes, D. Terpene] a family of volatile, odouriferous, cyclic hydrocarbons with the empirical formula  $C_{10}H_{16}$ . There are tens of types of terpenes with various solvent qualities. The most familiar is alpha-pinene, the principal constituent of turpentine.
- Terpenoid** [F. terpène, D. Terpenederivat] a derivative of a terpene (see hydrocarbon derivative)
- Toxicity** [F. toxicité D. Giftigkeit, Toxizität] a measure of the harm that a substance may cause to any living species. Acute toxicity applies to the effect of a single dose, whereas chronic toxicity applies to the effect of repeated doses over a period of time. As far as man is concerned, the major access paths of toxic substances are oral, respiratory and cutaneous
- Volatile organic compound** [F. composé organique volatil (COV) D. flüchtige organische Verbindung] (VOC) a loose term to designate a compound whose vapours will react with pollutants and oxygen, in the presence of light, to form atmospheric ozone. In the context of Swiss custom, the term means any organic compound that is easily vaporised, synonymous with hydrocarbon (q.v.)
- Water-soluble flux** [F. flux hydrosoluble, D. wasserlösliches Flussmittel] a soldering flux, not necessarily containing water, but whose residues after soldering are easily removed by a simple water wash
- White spirits** [F. white spirit, sangayol D. white spirit] a mixture of hydrocarbon petroleum distillates with boiling points from 120° to 220°C

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# Chapter I. Introduction

## I. 1. Why?

This booklet is a short résumé of why Swiss industry must reduce its consumption of an environmentally dangerous product, CFC-113, a chlorofluorocarbon or CFC and popular as a cleaning solvent (plus some other uses not relevant to this work). It is meant as an introduction for industrialists as to means and methods of substituting relatively harmless products for CFC-113 with a brief discussion of the pros and cons for each, as applied to each broad industrial sector. A further utility will be to warn industry of what may well become future problem areas, so that any substitution methods adopted are chosen, as far as possible, from those which are least likely to cause other problems of an environmental nature.

## I. 2. Historical background

In 1974, two American scientists, Molina and Rowland, pronounced a hypothesis<sup>1</sup> that CFCs could provoke destruction of the ozone layer in the stratosphere. This layer is one of the determining factors for global climate and protects the biosphere from intense UVB radiation and, without it, life could not be supported on the earth's surface. It is very thin: if all the stratospheric ozone in a column of a given area was brought down to the earth's surface, it would form a layer of an average thickness of 3-4 mm at atmospheric pressure (300-400 Dobson Units). However, this danger appeared at the time very theoretical and only a few persons took it really seriously. The first resultant measure was that the Environmental Protection Agency of the USA was able to instigate legislation, passed in 1978, forbidding the use of CFC propellant gases in most aerosol sprays. Only a few other countries, notably Sweden, Norway and Canada, followed suit within a year or so and no other application was restricted.

In the mid 1980s, a British Antarctic Survey<sup>2</sup> discovered that the ozone layer was rapidly and progressively diminishing at the end of each winter. The immediate reaction of scientists was to revive the theory that CFCs<sup>3,4</sup> may be responsible for the ozone hole which was later confirmed independently to exist<sup>5</sup>. In 1987, an international meeting in Montreal, under the auspices of the United Nations Environmental Programme (UNEP), agreed on a Protocol<sup>6</sup> which defined the most dangerous products which were known to be causing a degradation of the ozone layer,

their respective potential for such depletion, and a programme for the reduction of their production and consumption. Up to mid-1989, this was signed by nearly 50 nations and ratified by over 30 of them (including Switzerland) plus the European Economic Community en bloc. It entered into force on the 1st January 1989. Since 1987, much effort has been made to confirm that the ozone layer is diminishing in thickness and not only over the Antarctic and that the main cause of this depletion is indeed the chlorine resulting principally from the decomposition of CFCs and other industrial chemicals in the stratosphere. This has now been scientifically proved and confirmed by independent methods. Equally, it has been shown that the situation is even more serious than was initially believed and that the provisions of the Protocol are woefully inadequate to stop future degradation, even on a long time scale (Figure I-1).

As a result, a meeting was held in The Hague in Autumn 1988, at which it was decided to set up international committees of experts to study the situation and its evolution and who would report on the state of the art to UNEP and the members of the Montreal Protocol. These committees would cover all applications of CFCs and similar chemicals and show how to implement changeovers from these products to other types of materials as painlessly as possible, identifying which substances and products are the principal "culprits" and whether any others should be restricted. These committees were formed very rapidly and produced their reports in the record time of six months. This is an indication of the urgency of the situation.

In Spring 1989, the British Prime Minister, Mrs. M. Thatcher, responding to "green" pressure, called an informal international conference of scientists and ministers at which it was confirmed that the situation was grave. During the address pronounced by Swiss Federal Councillor Mr. Flavio Cotti, he gave a warning that Volatile Organic Compounds (VOCs) would not be the most satisfactory substitutes for CFCs because of the problems caused by them in the lower atmosphere. At the same time, he announced that Switzerland would substantially eliminate CFC and halon usage by 1995 (85-90% reduction).

## I. 3. The Montreal Protocol

As stated earlier, the Montreal Protocol defines the substances subject to restrictions and dangerous for the

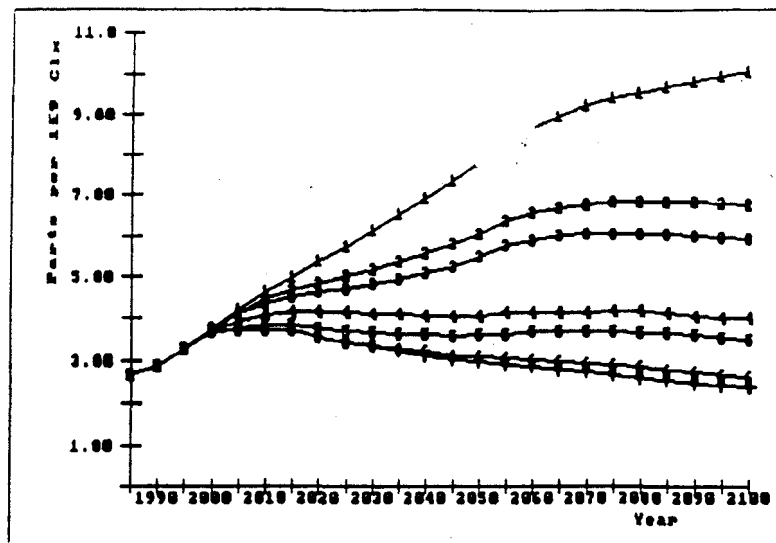


Fig. I-1. Forecast for Stratospheric Clx Progression

#### Key to Figure I-1

The above figure demonstrates the different scenarios, calculated according to the best information available and to possible reduction programmes of chlorine-containing substances. The Y-axis is in parts per milliard (U.S.A. parts per billion) of total Cl<sub>x</sub> concentrations in the ozone layer. As in all predictions, the premises on which the calculations are based can not be considered as infallible, but they are sufficiently accurate to give a broad visual representation.

Curve 1. CFCs (all types) reduced on a global scale according to the current provisions of the Montreal Protocol and no increase in production of carbon tetrachloride, 50% of the CFC market being replaced by HCFCs with an average ODP of 0.08.

Curve 2. As for curve 1, except for a total phase-out of all CFCs by year 2000.

Curve 3. As for curve 2, except for a total phase-out of carbon tetrachloride.

Curve 4. As for curve 3, plus no increase in production of 1,1,1-trichloroethane.

Curve 5. As for curve 3, except for a total phase-out of 1,1,1-trichloroethane.

Curve 6. As for curve 5, except for replacement of 20% only of the CFC market by HCFCs with an average ODP of 0.08.

Curve 7. As for curve 5, except for replacement of 35% of the CFC market by HCFCs with an average ODP of only 0.02.

Source: adapted from a presentation made by the U.S. EPA to the Parties of the Montreal Protocol at Helsinki (1989).

ozone layer and a programme for the reduction of their production and consumption. It is a long and complex document and only the essential points, as applied to solvents, will be discussed here. Only two CFCs mentioned are usable as solvents, CFC-11 with an Ozone Depletion Potential (ODP) of 1 and CFC-113 with an ODP of 0.8. The first-named is only rarely used for cleaning purposes due to a very low boiling point. It is estimated that at least 99.9% of the CFC solvents are products based on the substance 1,1,2-trichloro-1,2,2-trifluoroethane, C<sub>2</sub>F<sub>3</sub>Cl<sub>3</sub>, abbreviated to CFC-113. These two substances are included in a "basket" with other CFCs which are used for other purposes. This "basket" was agreed to be subject to a reduction of the production and consumption according to the following programme:

- 1 July 1989: reduction to the 1986 consumption level, a *de facto* reduction of about 21%
- 1 July 1993: reduction to 80% of the 1986 level
- 1 July 1998: reduction to 50% of the 1986 level.

Further clauses in the Protocol permit revision of the list of substances and the timetable of reductions.

It is therefore clear, as Switzerland ratified the Protocol on the 28 December 1988, that Swiss industry is committed to reduce its consumption of CFC-113.

In May 1989, the UNEP organised the first meeting of the parties to the Montreal Protocol in Helsinki at which it was agreed that further restrictions were inevitable.

#### I. 4. The Helsinki Declaration, May 1989

In substance, the Helsinki Declaration officially recognised that the Montreal Protocol was inadequate and it has paved the way to forcing the introduction into it of other substances that research has shown to be ozone depleters and to tightening the programme to a complete phase-out of CFCs by the year 2000. It has also foreseen the difficulties that under-developed countries may experience in reducing their consumption of the substances in question and is

forcing research into means of low-cost technology transfer into these nations.

### **I. 5. Solvents Technical Options Committee**

The main task of the committee, formed as a result of The Hague meeting, was to determine how to substitute less environmentally harmful substances or products for CFC solvents. This involved an examination of the secondary implications, such as the cost of capital equipment and exploitation, as well as the primary ones, such as the environmental impact. As far as possible, the objectives were to study all the known applications. The second task was to scrutinise solvents that were not restricted in the Montreal Protocol but were known to be ozone-depleting and to determine whether and where these, too, could be replaced by more benign products.

The committee was formed in January 1989 under the chairmanship of Dr. Stephen O. Andersen of the U.S. Environmental Protection Agency. Twelve persons (with three substitutes) contributed to the work of the committee, from Canada, Japan, Sweden, Switzerland, the United Kingdom and the United States of America. The combined experience of the members of the committee covers nearly every possible usage of CFC-113 solvents and their substitutes. Their report is being published in 1989 after five meetings<sup>7</sup>. Copies (in English) will be obtainable through the Federal Office of Environment, Forests and Landscape. It is an important work: the chapter headings are: Glossary, Executive Summary, Introduction/Worldwide Use of CFC-113, Electronics Industry Applications, Precision Cleaning Applications, Metal Cleaning Applications, Dry Cleaning Industry, Other Solvent Uses of CFC-113 and 1,1,1-trichloroethane, References and Appendices. Two accompanying documents include reprints of cited technical papers and commercial documentation concerning products and machines which may be considered for CFC-113 substitution purposes.

This booklet represents a short summary of the report of the Solvents Technical Options Committee, as applied to the Swiss context.

### **I. 6. Future Decisions of the Parties to the Montreal Protocol**

It is obviously impossible to forecast what the Parties will decide in the future. What is known at the time of writing is that the next Ordinary Meeting of the contractual parties will be held in London in June 1990 with the firm intention of tightening the provisions of the Protocol. As announced in the Helsinki Declaration, it is almost inevitable that a complete phase-out of CFCs by the year 2000 will be decided. What is probable is that further solvents will be restricted in one way or another, including carbon tetrachloride, 1,1,1-trichloroethane, other CFCs, including CFC-112, and some HCFCs.

### **I. 7. Swiss legislation**

It is clear that pollution knows no political frontiers. Switzerland, a small country with an annual consumption of CFC-113 of less than 2000 tonnes, is not a major polluter but it has taken a firm stance in favour of reducing this to a minimum, as part of a general programme towards a clean environment. As stated above, the official position is quite clear: a reduction of all CFC and halon usage by 1995 to a minimum (at least 85-90% phase-down plus a virtual phase-out by 2000). Any permitted exceptions to the complete elimination will be clearly defined and based on sound technical reasons, as opposed to purely economical or commercial ones.

Obviously, no specific legislation has yet been introduced concerning CFC solvents. A Federal Ordinance is intended, but it is unlikely that it will be approved before 1991. It will mainly cover usage restrictions and recovery obligations.

In addition, a further point that should not be ignored is that some substitute solvents, notably hydrocarbons and their derivatives classed as Volatile Organic Compounds (VOCs), are equally under attack for being causal of tropospheric pollution by their vapours being subject to photochemical reactions with other pollutants and oxygen, creating a risk of excessive ozone levels and smog under unfavourable weather conditions. Whereas legislation governing such emissions of Volatile Organic Compounds is still in its infancy, industry should be aware that such problems exist and that it is planned that polluters will be made to pay for the pollution they cause. If it is envisaged that a substitution process will use such a VOC (e.g. hydrocarbons, halocarbons, alcohols, terpenes, petroleum spirits, etc.), it would seem wise to include in the cost calculations a figure for some form of tax on unaccounted substances and products and the cost of means to prevent the emission of such VOCs into the atmosphere.

It is clear that any substitution method to replace the CFC solvents must not engender any other legal problems such as may be covered by other, existing, laws, notably the Federal Ordinances on water effluents<sup>8</sup>, on substances<sup>9</sup> and on toxic products<sup>10,11</sup>. In addition, it must conform to the requirements of industrial hygiene as laid down by the Swiss National Accident Insurance Fund. The appropriate Cantonal services should be consulted for further information on all these requirements.

### **I. 8. The Mechanism of ozone depletion**

It is not always clear why the presence of CFC molecules in the stratosphere is so damaging. One of the most frequently asked questions is why, if most of the CFCs are used in the Northern Hemisphere, are the most severe manifestations close to the South Pole? A very short explanation is felt to be necessary to help

readers grasp the fact that the phenomenon is, indeed, a global one.

If a CFC or a similar molecule reaches the stratosphere intact by diffusion and global convection currents, the ultraviolet radiation from the sun breaks it down, liberating one or more of the atoms of chlorine. Each of these acts as a catalyst (i.e. it enters into a reaction without itself being destroyed) in such a way that any atom of ozone it meets will break down into oxygen and chlorine oxide. Two molecules of the latter will break down, by radiation or contact with other types of molecules, to form another molecule of oxygen, thereby releasing the chlorine to restart the cycle. It is estimated that each atom of chlorine will destroy, on an average, 100,000 molecules of ozone before it diffuses back to the troposphere where it will be washed back to the earth by rain. How can a substance whose vapours are much heavier than air diffuse into the stratosphere? Why, if it does reach there, has it manifested itself near the South Pole, which is the farthest point from where it is used the most? These are valid questions and difficult to answer in just a few, simple words. First, time is on the side of the CFC molecules. Unlike most other chemicals, this type of solvent is remarkably stable. This means that it does not break down readily when it encounters other substances: it is exactly this quality that renders CFC-113 so non-toxic. It is estimated that the average "e-folding" (exponential decay) lifetime of CFC-113 is nearly 100 years. This means that, if 1 kilogramme of CFC-113 evaporates in 1989, about 370 grammes will still be intact in 2089, 135 grammes in 2189 and so on. It is also estimated that the whole of the tropospheric air mass only takes about a year to circulate vertically from ground level to the bottom limit of the stratosphere and down again, the mechanisms being diffusion, winds, storms, convection etc. It takes about five years to circulate horizontally over the whole of the global surface. Penetration into the stratosphere takes typically tens of years. The reason for the problem having been discovered initially at the South Pole is because of a particular meteorological phenomenon, called the polar vortex<sup>12</sup>, which, over the few months of the polar winter, prevents any admixture of renewed air and allows the temperature to drop to very low levels. The two phenomena together, combined with the presence of nascent chlorine, result in massive local ozone depletion. From an average of about 300 Dobson units, one observation post at a latitude of 76°S has measured a diminution to about half this figure over the last twenty-five years. The figures are even worse as the pole is approached. This explanation is very simplistic and reference may be made to an excellent description of the problem for those wanting more scientific explanations of these phenomena<sup>12</sup>. In any case, it has now been shown beyond all empirical doubt that the "ozone hole" is not confined to the Antarctic. The whole of the ozone layer is depleting, various estimates having been made at approximately 0.2% per annum at temperate latitudes, averaged over the last twenty

years<sup>13</sup>. The least depletion is in the tropics, where the more intense radiation tends to re-ionise depleted oxygen back into ozone more readily.

The above explanation has been given to show the mechanism when the solvents, along with other CFCs and similar chemicals, which we use almost without heed, have created the problem for which the Montreal Protocol was elaborated to provide an answer.

## I. 9. Greenhouse effect

Let it be quite clear. There is no scientific proof that the so-called greenhouse effect has caused or is causing any global climatic changes. There are, on the other hand, strong suppositions that the earth is warming and that this warming may be attributed to the greenhouse effect. If this is so, then measures should be taken to reduce it.

The media have published all kinds of alarmist figures "proving" that the sea level will rise by up to 8 metres and that at least half the land surface will be desertified before the end of the next century. If the greenhouse effect is proved to be real, there is no proof that these scenarios will take place, even if there may be an element of truth in them. The mathematical modelling of climatic changes is so complex that no algorithm exists that permit any but very approximate predictions. If such an algorithm did exist, it would probably take the fastest and most powerful computers longer to calculate them than the actual changes themselves!

What is the greenhouse effect? The sun may be considered as a black-body radiator with a temperature of about 5,300K. At any one moment, half the earth's surface is receiving the sun's radiation and is absorbing it at an average energy of about 1 kW/m<sup>2</sup>, the rest being reflected back to space. This causes the surface temperature of the earth to rise, the average being approximately 287K. The earth can be considered as a partial black body radiator and the temperature balance is achieved by the difference between the incoming and outgoing radiation (first approximation, ignoring geothermic and other terrestrial heat sources). The incoming radiation is at short wavelengths which penetrate most gases with very little attenuation. Because of the low surface temperature, the outgoing radiation is at long wavelengths. These are readily absorbed by many atmospheric gases and, if this happens, the energy can not be radiated out to space but is absorbed in the troposphere in the form of an increase in air temperature. From there, the transfer to water and earth is evident.

The gas that is most frequently accused of this is carbon dioxide, the balance of which may be upset by the combustion of fossil fuels, deforestation, etc. Fossil fuel combustion can act in two ways. First, there is the direct production of the gas in large quantities. Secondly, there are certain quantities of acid-promoting sulphur- and nitrogen-oxides which combine with rain to form quite low pH precipitations. If these fall on limestone or dolomitic rocks, these will break down to

produce even larger quantities of carbon dioxide. It is estimated that about 98% of global carbon is held in such rocks. The volume percentage of carbon dioxide in the atmosphere is about 0.034% but it is increasing and it is to this increase that the theory of greenhouse warming is ascribed.

It may be asked what all this has to do with solvents. The answer is simple: CFC-113, along with all other CFC gases, is an extremely powerful greenhouse gas, stopping much radiation from the earth's surface. One molecule of a CFC gas is estimated to have the same effect as about 14,000 molecules of carbon dioxide, varying slightly either way according to the composition. In terms of weight, it is even more dramatic: 1 kg of CFC-12, for example, is equivalent to 8 tonnes of carbon dioxide<sup>14</sup>. In other words, it is sufficient to have a concentration of  $0.034\% / 14,000 = 0.024$  ppvm to reach the same effect as carbon dioxide. In places, this figure has almost been reached and the

global tropospheric average is considerably less than only one order of magnitude from it. In other words, if the greenhouse effect is indeed shown to be causing increased global warming, CFCs would be responsible for well over 15% of it. Although a secondary reason, it is yet another valid one why their production should be reduced.

Many other solvents, halogenated or not, are also hypothetically contributory in greater or lesser degrees to this effect. One notable exception is 1,1,1-trichloroethane whose vapours have a comparatively small effect on radiation at the wavelengths concerned. Care should be taken that any substitutes, including those under development, will not be greenhouse gases. HCFC-141b, for example, which is one of the candidates for substitute solvents, has a relatively low, but not negligible, radiative forcing potential.

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Here in Switzerland, we can perhaps observe the effects of *local* climatic change better than in most other countries, by noting the changes in glaciers. As one example, over the last hundred years the bottom edge of the Furka glacier has risen from the level of the village of Gletsch to higher than the Furka hotel. It is emphasised that this example does not indicate that the causal conditions are necessarily global.



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## Chapter II. Products under question and others

### II. 1. Restricted solvents according to the Montreal Protocol (state of 1989)

#### II. 1. 1. CFC-113

This substance is the base for many popular solvent products used in many branches of industry. The pure substance is also used in some cases. In nearly all cases, the commercialised products are sold under trade names, the most well-known being Arkione, Delifrene, Flugène, Freon, Frigen, Kaltron etc. (alphabetical order). There are also a number of speciality chemicals manufactured in smaller quantities containing a certain quantity of CFC-113. These can often be identified by the figure 113 somewhere in the designation or some other indication on the label.

It is frequently blended with alcohols, ketones and other halocarbon solvents. Depending on the chemical composition of the blend and the use to which it will be put, the manufacturers also add stabilisers, such as nitromethane.

The ozone depletion potential has been calculated at a value of 0.8. This means that, if one kilogramme of the substance will destroy 8/10 of the weight of ozone that one kilogramme of CFC-11 or CFC-12 would, but possibly on a different time scale. It is not possible to visualise the importance of this ozone depletion from such figures. It has been calculated, as a graphic indication, that if one kilogramme of CFC-113 is allowed to evaporate, it will destroy over a period of time enough of the stratospheric ozone layer to cover the surface area of a football field.

#### II. 1. 2. CFC-11

As stated earlier, CFC-11 is occasionally used as a solvent for a few specific applications. It is somewhat better than CFC-113 for solvency and wets more surfaces than its heavier brother. It is fairly mild towards most thermoplastics. Its principal disadvantage is that its boiling point is as low as 23.8°C, which makes storage and transport problematic.

Its atmospheric lifetime is lower than that of CFC-113, almost eighty years. Its ozone depletion potential is 1.0 (in fact, the reference value), higher than CFC-113 as it contains more chlorine per mole.

CFC-11 is a solvent whose high vapour pressure makes it almost impossible to use without considerable losses, even if precautions are taken to prevent emissions. It is therefore to be highly discouraged.

### II. 2. Ozone-depleting solvents not yet restricted according to the Montreal Protocol (state of 1989)

#### II. 2. 1. Carbon tetrachloride

Carbon tetrachloride is another solvent which is a heavy ozone depleter, even worse than CFC-113 and CFC-11, as its ODP is about 1.18. However, its use is very strictly limited in Switzerland and the rest of the Western industrialised community, because it is a known carcinogen and liver poison. It has therefore come as a surprise when analyses of gas samples from the stratosphere have revealed that some 70,000 tonnes per annum are being released into the atmosphere, creating a significant part of the depletion. It is surmised that this cheap, easy-to-manufacture, solvent is still being used in a few under-developed countries as well as in some Eastern European nations. It is unlikely that it would be possible for this substance to be used as a substitute for CFC-113 in Switzerland as the industrial hygiene regulations<sup>15</sup> are so strict as to effectively preclude its use. Nevertheless it is good to mention it specifically to explain why it will probably be included in the next revision of the Protocol.

Carbon tetrachloride is used extensively as an industrial feedstock in chemical manufacture. Losses from this usage are believed to be very low, despite production figures in the USA and Europe in the hundreds of thousands of tonnes.

#### II. 2. 2. 1,1,1-trichloroethane

Although 1,1,1-trichloroethane (also known as methyl chloroform) has a relatively low ODP, variously quoted at values from less than 0.1 to 0.18 (usually taken as 0.15), the vast quantities used and emitted are the cause for a total depletion in absolute weight approaching that of CFC-113. For this reason, there is pressure being applied to have its production and consumption either limited to current levels or even more restricted.

Most of this substance is sold under a variety of brand names (e.g. Chlorothene, Genklene, Prelete, Propaklone, etc.). The commercialised products invariably incorporate stabilisers, usually of the amine type, and they are sometimes blended with hydrocarbon solvents or their derivatives to widen their dissolution spectrum.

At the moment, there are not effective substitutes available for all the applications of 1,1,1-trichloroethane based products, so it would seem

very unlikely that draconian restrictive measures will be taken in the immediate future. On the other hand, it is likely that the production will be frozen at, say, 1986 levels, so that expansion of its use will not be possible. For this reason, it is not considered as a valid substitute for CFC-113, quite apart from the moral aspect of only partially reducing the ozone depletion.

Over the last few years, both the European and global production figures have stabilised or even dropped slightly. This is because a number of heavily consuming processes have been modified (e.g., the development of dry film resists in the printed circuit industry) and equipment using it is better designed to reduce emissions of the vapour<sup>16</sup>. In a few countries, this tendency has completely reversed since early 1989 because the solvent is being increasingly used as a substitute for CFC-113. This is exactly what the Solvents Technical Options Committee has feared may happen and why they have made it quite clear in their report that they do not consider 1,1,1-trichloroethane to be a valid substitute for CFC-113.

Another factor that it would be wise to consider seriously before using or continuing to use 1,1,1-trichloroethane is that some industrial hygienists are posing serious questions regarding its safety. Like all other hydrochlorocarbons and chlorocarbons, it may cause liver lesions (cirrhosis) or can, at least, aggravate the formation of such lesions if the worker is predisposed towards them either through heavy drinking of alcoholic beverages or from a genetic history. It would seem likely that this solvent may attack the central nervous system, particularly if blended with methanol. There is also some discussion as to a possible carcinogenicity, even though this does not seem likely according to available evidence. The TLV in various countries has been progressively reduced from about 500 ppm some twenty years ago to 50-350 ppm today (Switzerland, 200 ppm) with tendencies to further restrictions in the offing.

Users of 1,1,1-trichloroethane would be well advised to start thinking in what measure they can reduce their consumption. This can be done by two methods:

- a. conservation (reduction of evaporated solvent)
- b. substitution (where possible, change to a non-polluting cleaning method).

It is almost certain that there will be restrictive measures, sooner or later, so that it is not too early to start thinking about how to go about replacing this solvent. In the meanwhile, every effort should be made to reduce the emissions by good conservation practices and recuperation (see Chapter III).

### II. 2. 3. CFC-112

CFC-112 is currently manufactured only in Japan and is used in relatively small quantities. It is rather expensive. However, it does present excellent properties, especially for defluxing applications. The only reason that it has not been manufactured and sold on a wider basis is a question of price, typically 2-3 times that of CFC-113 but, as the price of the latter

increases, demand for the former may also increase, causing the price to drop. At least one series of products containing it has been sold in Switzerland (Alpha 1000 series).

The ODP of CFC-112 is not known but an estimation puts it at about 0.7, slightly less than that of CFC-113. It was not included in the original Protocol "basket" because the usage was so small, but concern is now expressed because it will become more competitive. For this reason, it is probable that the Parties to the Montreal Protocol will include it in the next revision in June 1990.

### II. 2. 4. Hydrochlorofluorocarbon solvents (HCFCs)

There are hundreds of possible HCFC compounds of which about ten may be applicable to solvent cleaning. Molecularly, these substances are similar to CFCs, except that one or more of the parent hydrocarbon hydrogen atoms has not been replaced by a halogen atom or, more simply, they are not perhalogenated. This has a number of effects: firstly, the substances break down more readily in the troposphere, forming substances such as hydrochloric acid which are washed to earth by rain (another problem!); secondly, by the same token, they break down more readily in the body, so are inevitably more toxic; thirdly, no matter how short their lifetime, as the decay is exponential, a certain number of molecules will reach the stratosphere, so that they are all ozone depleters, but usually much less than pure CFCs.

For the moment, no HCFCs have yet been commercialised for solvent applications. About ten are being investigated in the hope of finding a "drop-in" replacement for CFC-113 which will have all its virtues and none of its vices. This is a pious hope because, even if a product is found that is technically and toxicologically acceptable, the purchase cost will be at least three times higher, possibly five.

The nearest ones, to date, have just been announced in Japan, being HCFC-225ca and HCFC-225cb<sup>17</sup>. It would seem that the physical properties are remarkably similar to those of CFC-113 in most respects. Their ODPs have been calculated as fairly low, certainly less than 0.1, possibly even 0.05. Their radiative forcing potentials and chronic toxicities are not yet known.

Other possible HCFCs include HCFC-141b and HCFC-123. These have estimated ODPs of 0.08-0.15 and 0.02-0.05 respectively, so the first-named can be considered as similar to 1,1,1-trichloroethane and, if it is put on the market, it must not be used indiscriminately. They have respective radiative forcing potentials of 0.037 and 0.045°C/ppvb (1 in 10<sup>8</sup>).

The ideal product would be a "drop-in" replacement for CFC-113, that is one that can be exchanged for it in all applications, used in the same equipment without any modification, with a zero ODP, zero VOC photoreactivity, zero global warming potential and zero toxicity. It is unlikely that such a solvent will ever appear and it would display a remarkable optimism to

wait for it! All the currently known HCFC candidates as CFC-113 substitutes have ODPs in the range of about 0.025–0.15. These are too high to be able to be considered as general substitutes. One source has suggested that 0.02 should be the tolerable maximum<sup>18</sup>. This same figure has been selected as a discussion base for the next Protocol revision.

Nevertheless, but *only for those applications where there is no better alternative*, these may present a certain utility. In any case, economic considerations must be taken into account. Even if these substances pass all the tests necessary before they can be put into production and are then produced at full scale, they will cost between SFr 25.-- and 50.-- per kg to the end user, not counting any potential taxes or recovery costs.

The acute toxicity of HCFC solvents under consideration seems acceptable, but it will be several years before we can learn whether they have an acceptable chronic toxicity. This is a subject that requires extreme prudence as the "safe" chlorinated solvents of a few years ago are now considered as much more dangerous, in the light of true experience. The symptomatic development rate of liver lesions and cancer is often a number of decades, so it would be wise not to adopt these substances widely until we have sufficient hindsight to give them a clean bill of health, especially as there is a molecular resemblance to chlorinated solvents. The real question lies in whether it is possible to determine the chronic toxicity and put these substances into production (assuming they pass the chronic toxicity tests) in time to replace CFC-113. This is doubtful.

At least two solvent manufacturers have announced experimental blends of HCFC solvents with alcohols. It would seem that these products fulfil some of the requirements of CFC-113 replacements, at least on paper. There is a specious argument applied to them: the cleaning qualities of halogenated solvents is related to the quantity of chlorine they contain. The ODP is also in relation to the quantity of chlorine, amongst other factors. By making the blends appear to have an overall low ODP by diluting the high-chlorine HCFCs with low-chlorine ones, HFCs (and their derivatives) and alcohols, it would appear to be, at first sight, beneficial. What is not mentioned is that it is probable that more solvent blend will be required to achieve similar degreasing qualities and quantities. For this reason, solvent blends should be considered as having the same ODP as the substance in it having the highest value.

## II. 3. Other organic solvents

### II. 3. 1. Fluorinated solvents

Generally speaking, organic substances not containing chlorine or bromine but containing fluorine are considered to have zero ODP. For hydrofluorocarbons (HFCs), this would seem reasonable as fluorocarbons have a very small light reactivity and hydrofluorocarbons mostly break down

in the troposphere. On the other hand, it is not certain whether some perfluorinated products, characterised by extremely high chemical stabilities with lifetimes of many hundred years, would not cause atmospheric damage, even if several centuries hence. On the other hand, these products are generally useless as solvents unless blended with chlorine-containing solvents. Nevertheless, they are extensively used for other non-solvent applications, some of which overlap the CFC-113 area.

Hydrofluorocarbons (HFCs) are generally poor solvents and perfluorocarbons even more so. One perfluorocarbon has been proposed by an American company to replace CFC-113 as the secondary blanket on vapour phase or condensation soldering machines. As its ODP is virtually zero and its stability higher, this is seen as a positive step towards the elimination of CFC-113 in a small application. It will certainly not save on cost. HFCs have been proposed to dilute other solvents in order to allow the blend to approach more suitable characteristics for specific cleaning applications or to render it more inert or to artificially lower the ODP. Others have been proposed as mild solvents for specific applications. For example, pentafluoropropanol (5FP)<sup>19</sup>, a new solvent under development in Japan, may have useful characteristics for degreasing delicate plastics, degreasing precision parts with fluorinated oils, for cleaning optical components, dry cleaning and a number of other applications. Its ODP is zero and it is non-flammable. Its spectrum of application is nevertheless narrow, but the substance may be blended with others to widen it.

### II. 3. 2. Chlorinated solvents

Perchloroethylene and trichloroethylene have both very low ODPs, probably less than 0.01. They can therefore be used with reasonable safety as far as the ozone layer is concerned. On the other hand, they are both considered as chronically toxic and an American rating as "probably carcinogenic" is under discussion. The TLVs are low in most countries, typically 25–50 ppm and it is not impossible that they be placed in a similar category to carbon tetrachloride, with a TLV of 10 ppm, in the future. This could be very restrictive for future use. They are both photoreactive VOCs, which may cause further restrictive and possibly fiscal actions to be applied in the future. It would seem to be unwise to adopt these products as a substitute for CFC-113 if there is any other choice, except as a very short-term palliative. If they are used, assume the worst concerning the toxicity and protect workers to the maximum. By conserving the solvent in the machine, rather than letting it escape, the environment, the workers and the company expenses are all protected to the maximum.

#### II. 3. 2. 1. Practical aspects of chlorocarbons and hydrochlorocarbons

As previously discussed, chlorinated solvents should not be considered as general substitutes for CFC-113.

They are stronger solvents and have similar applications to CFC-113 for degreasing most metallic parts, but they are less suitable for use on many synthetic polymers.

All these solvents are classed as non-flammable. This does not mean that they can not burn: a mist of some of the hydrochlorocarbons in air can even be explosive, although perchlorinated solvents do not suffer from this disadvantage.

It is to be expected that all chlorinated solvents will become increasingly regulated in the short and medium terms, either because of their ozone depletion or because more information is being acquired in respect of the health and safety properties (or both). Whereas no definitive information is yet available, it is probable that stricter regulation will be pronounced in the first half of the 1990s with some products. It would therefore seem most unwise to expand cleaning in this direction.

### *II. 3. 3. Non-halogenated hydrocarbons and their derivatives*

#### *II. 3. 3. 1. Hydrocarbons*

Light hydrocarbons are all toxic and flammable but some petroleum spirits may be applicable to certain degreasing operations. These are generally not substances but distillates with a range of boiling points. As a general rule and within any one family, the higher the boiling point, the higher the flash point, so that it is possible to choose the right compromise for each application. These mineral spirits are variously denominated, often arbitrarily, but usually go under the heading "White Spirits".

Heavier hydrocarbons with higher flash and boiling points can also be quite efficient solvents if handled correctly. Their low vapour pressure which renders them safer to use also makes drying problematic. One way round this problem is to use them as a solvent and then use a second, possibly less efficient, solvent but a better, non-polluting, dryer to finish off the process. Water is the obvious answer to this second phase.

For the lighter fractions, flame-proofing is required on all equipment where they are used. Furthermore, even if relatively low-toxicity types are chosen, they are all VOCs and liable to restrictions.

#### *II. 3. 3. 2. Alcohols and other hydrocarbon derivatives*

Alcohols are excellent solvents for many applications, including certain defluxing operations. However, they do require enormous and expensive precautions to be taken before they can be used for large scale industrial cleaning. First of all, they are flammable with flash points between 12° and 15°C (TAG closed cup). This implies extreme precautions against fire, such as nitrogen-purged, all-metal machines, oxygen detectors, in-machine sprinklers, flameproof electrics, intrinsically safe electronics, double air-lock entries and exits, special conveyor types, infallible drying of the parts, etc. If the alcohol is sprayed or jetted against

the parts, the rebounding will cause a mist and an aerosol to be formed. If this drifts, by any cause, into the air, it becomes explosive. None of these problems is insuperable but, together, they make capital equipment expensive and a certain risk is always inevitable if large quantities of alcohols are deployed.

Alcohols are also considered as VOCs, so that it is certain that some discouragement will be applied to their use in the future.

Which alcohols can be used as cleaning solvents? Methanol is far too toxic (OFSP Class 3) and is the most flammable. Ethanol would be ideal but for the fiscal problems, especially if it was purified by distillation. This leaves effectively the two propanols. Isopropanol (2-propanol) is cheap, easy to obtain and not excessively toxic. This is the natural choice. A propanol/water azeotrope is suggested for some applications by one manufacturer.

Other derivatives employed for cleaning purposes include various ketones, esters and, occasionally, ethers. These also require similar precautions to be taken.

#### *II. 3. 3. 3. Practical aspects of hydrocarbons and derivatives.*

Various hydrocarbons have been used for cleaning purposes for many years. Benzine (not to be confused with the highly toxic benzene) is such a well-known solvent. Others include various mixtures of aliphatic and aromatic petroleum distillates, usually fractions with a narrow range of boiling points between 50° and 220°C. Most of them are poorly defined and can not be classed as substances.

Some aromatic substances, the best-known being toluene and xylene, are also used as effective low-cost solvents although they are more toxic than many aliphatic spirits.

Hydrocarbon derivatives, such as alcohols, ethers and ketones, are popular solvents for certain applications. Another class of derivatives are mixtures of esters which are used in the manufacture of paint thinners and for other specialised applications. In fact, the range of possible halogen-free organic solvents is enormous.

It is a half-truth that all the good organic solvents are either flammable or contain chlorine. Another half-truth is that the better the solvent a hydrocarbon or a derivative is, so is its boiling point and flash point lower. A third half-truth is that the closer a solvent molecule resembles another molecule, the more the latter is likely to be soluble in it. Whereas these are not inviolable rules, they contain sufficient elements of truth to situate the usability of some products.

To dissolve petroleum oils, petroleum spirits are amongst the best solvents, but they are poor for dissolving rosin. On the other hand, the latter is soluble in light alcohols and some terpenes. Cellulosic resins are readily soluble in certain esters and so on. Some fluorinated oils and other fluorocarbons are only soluble in fluorinated solvents. In other words, the

solvent must be chosen according to the nature of the soil: there are no universal solvents.

All these products are flammable, most of them are highly flammable, often with flash points below ambient temperatures. This means that any means of ignition in their vicinity could cause a fire. Use of these solvents should be governed by the utmost prudence and only equipment designed for the solvent in question should be used with them. In truth, it is a wonder that there are not more industrial fires caused by the unconscientious use of organic solvents.

Furthermore, all these substances and products are toxic, to a greater or lesser extent. This should be even more reason why their vapours and aerosols should be contained, away from the nose of any operator.

Generally speaking, provided that the safety problems can be kept under control, most current CFC-113 applications could be replaced by some form of organic solvent of this nature. The solvent costs would generally be favourable but this would be offset by the increased capital equipment costs occasioned by the safety aspects.

In certain cases, drying off the clean solvents at the end of the process can present a problem. It is generally undesirable to simply allow the parts to dry off in free air, quite apart from the flammability difficulties, as the vapours are polluting (VOCs). In addition, it is a waste of solvent. Some alcohol machines avoid this problem by vapour phase drying, in a similar way to that used for halocarbon solvent degreasers, but this is usually done in closed, nitrogen-purged, machines. Otherwise, activated charcoal filters or water scrubbers may be used, the latter with a separator if the solvent is immiscible with water.

#### *II. 3. 3. 4. Hydrocarbon/surfactant blends*

If a suitable hydrocarbon or derivative can be found to dissolve the soil and it is relatively non-volatile, it could present certain advantages. If it is non-volatile, or nearly so, at the temperature at which it is used, the fire hazards are reduced. This is possibly conditional on no mist being formed during a spraying operation, as mists or aerosols of all hydrocarbons could be dangerous in the right proportions. At the same time, the reduced vapour content of the air round the cleaning equipment will reduce the toxicity problems for the operator (assuming the product is not inherently more toxic) and also the air pollution problem (VOCs). Obviously, there is a price to pay for these three important advantages and this price is that the parts being cleaned will be contaminated by a solvent that will not readily dry off and some means must be found to remove this solvent.

If the solvent is blended with a surfactant or detergent, then it can be washed off with water which, in itself, is sufficiently volatile that it can be dried off or, preferably, blasted off. This will then leave the parts being cleaned clean and dry. There are, nevertheless, a number of provisos before such a process could be practically admitted. The most important one is that the rinse waters are environmentally harmless. What

exactly does this mean? Waste water treatment is an extremely complex subject but, basically, the requirements are that water sent down the drain will not harm any bacterial water treatment plant nor, after passage through the plant, should it harm aquatic life or make water courses chemically unsuitable for consumption. To achieve these criteria, any heavy metals must be limited to extremely low levels, in most cases less than 1 part per million (1 mg/l). Many metals are toxic to the bacteria necessary for sewage treatment and will eventually be taken up in an alimentary chain (e.g. the famous case of mercury in fish from Lac Léman). The waste water must be neither too acid nor too alkaline, otherwise it, also, could destroy the bacteria in waste water plants. Large quantities of very hot water discharged close to a sewage farm could also kill the bacteria cultures. Finally, and probably most important of all, there is the notion of biodegradability. Very briefly, this means that anything sent down a public sewer must break down into harmless substances as quickly as possible. In this case in question, these waters from this type of cleaning process contain the hydrocarbon, the surfactant and probably small quantities of contaminants, often heavier hydrocarbons or derivatives. Many hydrocarbons, such as crude oil, may take years to break down: this is why accidents involving tankers are often dramatic. The fact that they can be mixed with detergents so that they become water-miscible does not cure the problem; it only displaces it to a less visible position. It is therefore essential that the hydrocarbons used in these products are readily broken down by natural means. The surfactant itself must also degrade, preferably at about the same rate as or slightly slower than the hydrocarbon, so that there is no preferential degradation, allowing the hydrocarbon itself to separate and rise to the water surface.

The majority of the biodegradable hydrocarbons are those found in nature, usually of direct vegetable or animal origin or synthetic look-alikes. Many mineral hydrocarbons are almost non-degradable. Many domestic detergents for floor cleaning, for example, contain hydrocarbons such as terpenes from pine or citrus trees, the smell of which is frequently disguised by added synthetic pine or lemon perfumes. This improves the spectrum of soluble soils and the dissolving power for greasy dirt. The housewife may believe, through poor advertising, that there is lemon juice in her dishwashing liquid and that this is an active ingredient, but it is only the small quantities of added limonenes that are helping her (but possibly not the skin on her hands)! These terpenes remain bound in solution by the detergents until they degrade. The degradation process is a combination of anaerobic (in sewage sludges), aerobic (in oxygenated treatment tanks) and photochemical (daylight falling on the contaminated water) processes. It requires a certain quantity of oxygen. The biological oxygen demand is the quantity of oxygen, expressed in milligrams of oxygen per litre of waste water, required to produce aerobic bacterial

#### II. 4. 3. *Drying*

Drying is the bugbear of all forms of water cleaning, especially for precision applications. There are several ways such as air blasting, evaporative drying, vacuum drying, solvent displacement and absorption, etc. Solvent manufacturers, aiming to sell their products, have always cited that drying is extremely energy-consuming, hence wasteful and costly. It certainly can be but is not necessarily so. It is evident that the energy required to evaporate 1 litre of water at 15°C is high (about 585 kcal or 2450 kJ). If the heat transfer is 10% efficient, this would require nearly 6.8 kWh. One of the main problems of evaporative drying is that, if a small quantity of solids remain in the water, they will be deposited on the cleaned part. This is not always acceptable, so that the implication is that pure water must be used in these cases with sufficient rinsing that no significant contaminants remain.

On the other hand, to use mechanical means to remove a similar volume of liquid from capillary spaces may require only 0.01–0.1 kWh, depending on the means and configuration. Drying is surely the most critical area of all types of aqueous cleaning and should be examined from case to case. The most usual means of mechanical drying are by air blasting and centrifuging, although a few other methods are occasionally encountered. Other than the purely energetic aspect, mechanical removal has a secondary advantage in that any residual solids are removed along with the water, reducing the tendency to form "water-marks". This means that a lower quality of rinse water can be used than would otherwise be possible, sometimes even ordinary tap water. Where air blasting is used, the design of the air knives is critical, especially with conveyerised machines where any single part being dried may be subjected to the air blast for only a second or two. The most successful systems depend on very high air velocities with a reasonably long attack time and variable angle attack. To illustrate the potential deficiencies of such a system, the most common air-knife drying encountered in everyday life is found in car-washing tunnels. Because a car is large, the air-knives are typically about 1 m 80 long and 25–30 mm wide. They act at about 10–100 cm from the surface being dried and usually vertically. To limit the power consumption, usually centrifugal ventilators of a total of 2–20 HP, the average air velocity is generally less than 50 m.sec<sup>-1</sup> at the car surface. As the typical speed of the vehicle through the tunnel is about 2 m.min<sup>-1</sup>, the impingement time at any one point is about 2–3 seconds, allowing for fan-out from the nozzles and deflected blast. Even under these conditions, about 90% of the residual water is removed for an energy consumption averaging well under 1 kWh. In industrial drying machines, the air velocity is often 4–5 times higher, the action lasts up to 20 seconds and the angle of attack is usually acute. Even with complex parts of dimensions up to 500–1000 mm in the three axes, mechanical drying up to 95–99% is commonplace. A

basket-load of assembled printed circuits, for example, can be blast-dried in about 20 seconds to 97% the remaining 3% being evaporative, for a total energy consumption of 500–700 Wh. As such a load may be about 2 m<sup>2</sup>, the total unit consumption would be about 3 Wh/dm<sup>2</sup>. If electricity costs are as high as 15 c/kWh, a standard Europa board (100 x 160 mm) would therefore be dried for under 0.1 centimes. In a conventional oven, the same drying would cost about 10–15 times as much in energy, not to mention time. Printed circuits have a low specific heat, so little energy is required for actually heating them. Massive metal parts may require much more, so that the difference between the two techniques would become even more significant.

Provided investment is made in adequate machinery, as part of the overall cleaning process, drying is not a severe problem. It can also be stated that it is not necessarily excessively energy-demanding. What is usually necessary, on the other hand, is that the machine be tailored to the job.

#### II. 4. 4. *Pure water cleaning*

The spectrum of soils that can be removed with pure water is very limited. However, it is, by far, the best possible solvent for water-soluble and polar soils. It is easy to use, presents no problems regarding operator health and safety, presents few environmental problems and is generally low cost.

Regarding the environment, it is evident that the water itself is harmless, but the soils dissolved in it may be very harmful. It is always good advice before adopting any aqueous cleaning method to carefully examine the effluent and to check whether it is acceptable without treatment. If not, how can it be treated? Is it economical (or even possible) to treat? Water cleaning has the great advantage that the effluent is easily contained for treatment, unlike volatile solvents.

#### II. 4. 5. *Water + detergents*

The action of detergents is well known, even if the theory of their operation is somewhat obscure to non-specialists. Under the name detergent, there are vast numbers of different types of product whose function is to widen the spectrum of dissolution of pure water. Many detergent mixtures are excellent degreasers. One document has cited that half of the degreasing applications in Europe is already being done by aqueous methods<sup>20</sup>.

It is worthy of mention that the U.S. Air Force has made a detailed study<sup>21</sup> of over 250 commercial detergents with a view to completely replacing halocarbon solvents in military aircraft maintenance. The reasons given for this were for environmental protection, worker protection and cheaper disposal costs of used solvents. The project was achieved in three phases: a performance evaluation of the various solvents used, as a yardstick; identification and evaluation of the detergents for cleaning, corrosion, biodegradability and the impact on waste water

digestion of the pollutants. It is usually expressed in the oxygen requirements over five days.

The anaerobic digestion in the sewage sludge at the bottom of the sedimentation tanks breaks the hydrocarbons down to lighter types, often producing large quantities of methane and other light organic gases. The sludge is periodically removed and a percentage is recycled back to ensure the continuity of the bacterial reproduction.

The organic solvents in this process must therefore not only be harmless to the diverse bacteria, they must also be active nutrients. All these requirements limit greatly the range of suitable products that can be employed as cleaning solvents. The spectrum of soils that can be removed is therefore limited, especially if the soils themselves must be essentially biodegradable, as well. There exist a number of industrial terpene and other hydrocarbon degreasing products of this type but their use is generally fairly specific. One such application that has created a certain controversy over the past few years is the removal of residues of rosin fluxes after soldering.

## II. 4. Aqueous systems

### II. 4. 1. General

Under the heading of aqueous systems, pure water and water plus additives are both treated. The term "semi-aqueous" is best avoided as it has been applied to various techniques bearing no relation with one another. The category of hydrocarbon/surfactant blends which require a water rinse after the solvent treatment has been partially discussed in the last section, but the actual water rinse belongs more to this one.

### II. 4. 2. Water quality

Tap water is usually sufficient for the first stages of a cleaning cycle. However, it is frequently necessary to employ better qualities for at least the final rinse. The main problem with tap water is the "hardness" or total calcium and magnesium ion content. Several different treatments are possible to render tap water more acceptable. The easiest is thermal decalcification. It can only be done where the hardness is due to bicarbonates and, to a smaller extent, hydroxides of calcium and magnesium. Heating the water will cause a certain proportion of the lime to precipitate, this being removed by filtration. It is not very effective, but can prevent excessive precipitation in the cleaning machine itself. At the same time, the hot water produced can be used directly by the machine.

Water softening is well known and consists of replacing the calcium and magnesium ions by sodium ones. For electrical or electronics applications, although there may be less visible residues on the cleaned parts, the contaminants are strongly ionic and very dangerous. This process is therefore restricted to non-electrical applications. The essential point with

water softeners is to regenerate them in time. This is usually done with simple salt which replaces the lime in the softener zeolites with a stock of sodium ions.

The next process is reverse osmosis. Although, strictly speaking, it is not a filtration, it appears to be one in that impure water, applied to a membrane, passes through as relatively pure, leaving the impurities on the inlet side. The real mechanism is beyond the scope of this work. Only softened and UV-sterilised water is suitable. The purified water is usually improved by a factor of 10-20 in a single installation. Water from reverse osmosis is usually adequate for most applications, including many electronics ones. For a single cleaning installation, the capital costs are usually too high, but the running costs are rather low.

Ion exchange is divided into two categories. Mixed bed ion-exchange consists of a single column which is sent to a specialist establishment for regeneration. It is cheap to purchase, but somewhat expensive to run if used for purifying large quantities of tap water. If used for "polishing" reverse osmosis or separate bed ion-exchanged water, the highest possible purity is obtained at relatively low cost. Separate bed ion exchange consists of two columns for removing anions and cations separately. As it can be regenerated *in situ* with low cost chemicals, it is the most economical deionising system in the long term and it provides a water quality adequate for nearly every application.

One question which comes up frequently is whether water should be used in open or closed circuits. *A priori*, it would seem attractive if rinse water could be repurified after use and sent back for reuse: there would apparently be no waste water disposal problem and the water (which may become a rare commodity) consumption would be negligible. Unfortunately, life is not so simple! In the first place, unless very sophisticated purification systems are used, it is possible that certain pollutants in the effluent may not be removed. This would mean that these pollutants would accumulate until the rinse quality became inadequate. Secondly, the pollutants removed by the purification system may be such that they would reach such high concentrations that they would present disposal problems. To take one example, products which have heavy metal contamination from cutting oils may be degreased in a detergent solution. The rinse water will have detergents and heavy metal salts dissolved in it. Some of the detergent surfactants will not be removed by a separate bed ion exchange installation, but the heavy metals will remain in it. When it is regenerated, the heavy metal ions captured by the column will be replaced by hydrogen ones from the hydrochloric acid and the effluent will become fairly concentrated metal chlorides, requiring special disposal. Depending on the application, recycling rinse waters should be limited to the range of 50-90% to avoid these problems and the question must be asked whether this partial advantage will justify the cost.



treatment plant; the third phase was a full scale changeover at one of the eight aircraft maintenance plants.

The first phase identified six different solvents in regular use for degreasing, cleaning, mask removal and paint removal and three were used for reference purposes.

For the second phase, samples of each candidate product were tested for solubility and then cleaning ability with four standardised "difficult" soils, namely, a petroleum wax, a carbonised oil, a hydraulic fluid/carbon mix and a carbonised molybdenum sulphide grease. About eighty products passed these two tests, including some which passed the cleaning test two or three times under different conditions of use. A standardised test method was developed to determine a biodegradability index, using ordinary sewer sludge with a 6 hour retention time and a measure of the COD. This reduced the number of candidate detergents to 32. Corrosion testing to a standardised method was then done with 15 common constructional metals including copper, nickel, various aluminium alloys, various steels and stainless steels, brass, inconel, monel, titanium and magnesium. After undergoing these tests, only six products were considered usable, of which five were suitable for all metals. Before the phase 3 testing, more extensive testing was done with two or three of these detergents in order to determine how to go about the practical work.

Phase three testing has been started and has been running for about six months at the time of writing. Full reports have not yet been made available, but interim information would seem to show an overall cost saving of the region of 10-15%, no worker health problems, adequate cleaning quality and no special water treatment problems. The Air Force Base concerned already had its own sewage treatment plant and no interference was observed from the technical cleaning on the biocultures.

Similar work is now starting on the paint stripping project.

This work is in the public domain and it is probable that the complete database will become available at the end of the solvent replacement project (a question of months). It is mentioned here as an example of the serious approach of this project and the fact that industrial degreasing, including precision cleaning, can be successfully done by aqueous methods.

Some detergents are restricted in their use. In Switzerland, there are some which are forbidden for use in household washing-up products but are, for the moment, permitted in industrial cleaners. It is not expected that this permissiveness will continue indefinitely as the degradation products of these detergents, octyl- and nonylphenoxylates, are much more stable and toxic to some forms of aquatic life. It is necessary to be aware that this differentiation of applications is a legal anomaly.

#### II. 4. 6. Water + saponifiers

Saponifiers<sup>22</sup> are chemicals that react with diverse fatty acids, rosins and other natural resins, etc. to form water-soluble soaps which are themselves somewhat detergent. Caustic soda, for example, has been used since time immemorial to solubilise vegetable and animal fats and oils. Commercial saponifiers are much more complex products, often based on aqueous solutions of monoethanolamine or ammonium hydroxide as well as the strong caustic alkalis, depending on the applications.

One well-tryed use is for solubilising wood rosin. Rosin consists of an indeterminate mixture, of which some 90-95% is a number of isomeric cyclic carboxylic acids, normally almost completely insoluble in water. These acids are easily saponified with monoethanolamine and commercial saponifiers have been available for this purpose for over 20 years. Their efficiency, used under the right conditions, is extremely good, producing residual contamination approaching an order of magnitude better than cleaning with CFC-113. If the rosin is used as an activated soldering flux, the cleaning efficiency is even better as the activators are readily neutralised and solubilised, which is not necessarily the case with halocarbon solvents.

Used for this kind of application, the rinse waters generally present no environmental problem. What is more, even the actual wash waters can sometimes be disposed of directly into public sewers under well-defined conditions (see section IV-2). If not, a very simple neutralisation is frequently the only water treatment that is necessary.

As a general rule, saponifiers are not suitable for mineral oil degreasing. However, saponifiers are sometimes added to other detergents to broaden their overall cleaning spectrum. Users are nevertheless warned to leave such blending to the manufacturers who, alone, are able to understand the reactions.

## Chapter III Conservation of CFC and other volatile solvents

### III. 1. General

As a short-term measure with CFCs and a long-term measure with all other volatile solvents, conservation is an important point to consider. If conservation had been applied to CFC usage since the beginning, the problem today probably would never have occurred.

Conservation is equally important with other solvents. Unfortunately, their very cheapness has not justified money being spent on preventing evaporation. After all, if it cost, say, SFr 50,000 to install a solvent recovery system with returns of less than 10,000 litres of isopropanol per year, most economists would agree that it was not worth it. But those 10,000 litres per year may cause untold other damage outside the factory walls. In Switzerland, high ozone concentrations in some towns and even in the open countryside are becoming commonplace under certain weather conditions and such VOC solvent evaporation is one of the contributory causes.

In terms of solvent usage, various figures have been proposed as to the fractions of CFC solvents that could be recovered if the equipment was better designed, maintained and used. The lowest is 40% and the highest 90% with an average of about 50–60%<sup>24</sup>. These figures seem to be borne out with practical experiences.

Consider the case of a small, open-top, vapour degreaser equipment used for manually defluxing printed circuits. Average CFC-113 consumption with a medium production rate may be 40 kg/week, of which 10 kg is recovered from the bottoms\*.

### III. 2. Bottoms recovery

This 10 kg in the bottoms is, at present, usually lost as the product is either sent for incineration (causing other pollution) or as a landfill where, sooner or later, it will escape. If a recovery still was used, 9–9.5 kg could be recovered and reformulated for reuse. In the case of our example, this would make typical savings of about SFr 1,500/annum including distillation costs.

If the total factory production quantities justified it, the recovery still could be internal. One American company achieved savings of over \$10,000,000 per annum just by installing their own still and another, smaller, one reached a savings figure of \$43,000 per annum by installing a secondary still uniquely for the recovery of solvents from the bottoms of two primary stills. If not, an external recovery service could do this.

In Switzerland, there is no well-organised redistillation service for small users available. This may be an excellent commercial proposition for an enterprising company willing to make the investment and set up the collection and redelivery infrastructure. On many occasions, small users have complained that no means exist to recover used solvents. One possible method is that a company could issue on loan specially painted 200 litre drums with the solvent type clearly marked. The user would undertake to put only that solvent type in the drum (if he used several solvent types, he would have a drum for each). When the drum was nearly full, he would telephone the service which would collect it the next time there was sufficient material to collect in that geographical area. The whole of Switzerland could be serviced with one truck on at least a monthly collection. At the same time, he would be issued with an empty drum. On arrival at the recovery centre, a sample of each drum would be analysed for solvent percentage and type. The corresponding quantity of recovered and reconstituted solvent would be delivered to him at the next delivery in his area. If it is found that solvent mixtures are, by accident, in his drum, the user would have to pay extra for recovery or destruction.

Economically, such a recovery service would possibly not have been viable up to 1989, but the rapidly increasing prices of CFC-113 based products should now render it feasible. It is probable that the recovered solvent could be sold to the users at about 90% of the cost of new products at the 1989 prices, but this will become increasingly attractive as prices rise further. For chlorocarbon and hydrochlorocarbon solvents, the economic viability can not be established at current

\* Bottoms: the residue in the boiling sump of a still or a vapour phase cleaning machine comprising the majority of the removed contamination plus a certain amount of solvent.

prices, but it is possible that a legal obligation will be declared necessary.

The real problem is for the user whose annual consumption of any one solvent type is less than, say, 100 kg per annum. In this case, the used solvent should be returned obligatorily to his supplier at the user's expense. The costs for this service could be levied as part of the sale price.

### III. 3. Equipment siting

All machines should be in a draught-free room, preferably dedicated to their own use. The floor should be level and covered with a solvent-resistant impermeable surface, so that the solvent is not lost in the event of spillage and can be recovered before it evaporates. Ventilation should be by extraction at floor level, but regulated for minimum throughput consistent with operator safety. For large installations, the ventilation should be equipped with activated carbon filters. Thought should be given to transporting fresh and used solvent to and from the room.

### III. 4. Equipment maintenance

All equipment should be maintained on a regular basis<sup>25</sup>. It is possible that up to 5-10% of all CFC-113 losses are due to almost imperceptible minor leaks. Seals and gaskets should be regularly checked and changed at least every year. Taps and valves are notoriously dangerous and drain taps should have solvent-tight plugs in them when not in use.

All equipment using halogenated solvents of all types should be checked annually with a sniffer. This is a small electronic device which sucks in air and indicates whether it contains halocarbon vapours of any type. A small flexible hose can be directed to every part of the machine to locate even the smallest leak. Every user of multiple or large installations should possess a sniffer. Users of small installations should ask their equipment or solvent supplier to do an annual sniffer check if it is felt that the modest cost of the instrument can not be justified.

### III. 5. Molecular sieves

Most vapour degreasers are equipped with molecular sieves for removing water from the solvent. It is essential that these are correctly maintained, to ensure maximum solvent life. The zeolite beads adsorb considerable quantities of solvents as well as water. A certain quantity of this solvent can be recovered by

initially placing the filter in a closed recipient immediately on removal. Put in the new filter and run up the machine. Transfer the filter rapidly from the recipient into the vapour phase of the machine and keep it there until it reaches the full vapour temperature. Transfer it to the freeboard\* zone and keep it there for several minutes to allow the vapours to "drain" from the filter. The recipient should also be emptied back (vapours and possible liquid) into the machine. Note that this technique is only usable where there is a sharp differentiation between the vapour pressures of water and the solvent, notably with CFC-113 and its blends.

Many machines are poorly designed and spillage is inevitable when removing the molecular sieve for maintenance. If it is not possible to modify the machine to avoid this spillage, try and recover as much as possible.

### III. 6. Solvent handling

CFC-113 solvents are usually delivered in 20 litres (30 kg) cans, 200 litres (300 kg) drums or in bulk containers. Bulk containers are of two types. Pressure containers present no problems provided they are never opened to the atmosphere while the pressure gauge is indicating a positive pressure. Other bulk containers have breather valves, often fitted with desiccators, but which let solvent vapours escape if the temperature rises. This creates losses amounting to about 2% of the stock per annum. Bulk tanks should never be situated where the sun can shine on them or where other sources of heat can cause solvent evaporation within the tank.

Drums and cans of all halocarbon solvents should always be stocked in the coolest place possible and never outside. When taken from the storage area for use, they should be opened before the temperature of the contents can rise. After use, they should be reclosed tightly and taken back to the storage area. Never transfer from the storage area to the usage area in an intermediate recipient, even closed: the transfer losses will be doubled. Drums should always be kept vertically, tightly sealed, and *never* horizontally with a tap.

Unless the equipment has special transfer pumps incorporated, transferring solvents from or to drums or cans should only be done with special pumps with outlet pipes extending to the bottom of the recipient. This ensures there is minimum solvent-air interface while filling and emptying. On no account should solvent ever be poured from one container into another. This applies also when dirty solvent is removed from a sump: drain taps are frequently placed where spillage is inevitable.

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\* Freeboard: this descriptive nautical term, frequently used in this application, is employed throughout this booklet to describe the distance between the upper level of the vapour in the vapour phase and the level of the upper surface of the opening.

### III. 7. Equipment enhancement

#### III. 7.1. Freeboard

A number of minor modifications of open-top vapour cleaning machines can reduce the solvent losses dramatically. Undoubtedly, the most important is an increase of freeboard height. This is defined as the vertical height between the top level of the vapour and the lip of the machine. With most degreasers of more than a few years age, this is woefully inadequate and often so on more modern machines. If the height is less than the width of the opening, then it is essential to increase it. If it is less than the length, or even the diagonal, of the opening, then it is desirable to do so. Various freeboard heights have been quoted as being ideal but the more, the better and the diagonal would seem to be a good compromise. At the very least, the freeboard should be at least twice the height of the tallest parts to be cleaned or the opening width, whichever is the greater. This improvement can be done with a simple stainless steel box-form structure on all four sides. It should be bolted down onto the original upper surface, not forgetting a good gasket in a material resistant to the solvent in use. A water-cooled serpentine round the interior is desirable. The water flow rate does not have to be high, so that the cost is only SFr 1–3/day, less than a gain of half a kilogramme of solvent. It should flow 24 hours/day, 7 days/week, as long as the machine is filled. The water temperature should be as low as possible and certainly less than 15°C for CFC-113 installations. If, in summer, the temperature rises slightly over this figure for a day or two, this is not a cause for alarm, but if it consistently rises, refrigerated cooling may be necessary. Of course, the same applies if water-cooled condenser coils are used, these being even more critical. The machine should never be opened until all condensers and freeboard coolers are at their minimum temperature.

#### III. 7.2. Lid

Most equipment is fitted with a lipped, lift-off lid. Every time this is lifted, most of the vapour in the upper half of the machine is wafted away. The original lid should be thrown away and replaced by a sliding lid that causes no draughts when it is opened. A motorised lid of a "Venetian blind" construction is ideal, as the speed can be regulated to ensure no vapour disturbance, the gas-tightness can be good and it can be made to close automatically if the operator has forgotten to shut it.

The lid must be kept closed at all times the machine is not in use. If the lid is a two-part sliding type, opening from the middle, only the half of the machine in use at a time need be opened. These halves can be automatically opened through the controller of an automatic transfer system.

If the machine is equipped with additional freeboard, it goes without saying that the lid should fit this new top.

#### III. 7.3. Cooling coils

If the machine has water-cooled or plain refrigerated coils, these should be kept cooled until all the solvent in the machine is cold. If the equipment has a heat pump, then additional water-cooled coils should be added for this purpose. If a water-cooled freeboard is added (see above), then the water flow rate may need to be increased until the solvent is cool.

In all cases, it is desirable to fit flat water-cooling coils along the side or bottom of each sump. This is so that the solvent is cooled as rapidly as possible when shutting the machine down and kept as cold as possible until the heating is switched on again. The solenoid valves controlling the water flow can be interlocked with the off position of the power switch.

#### III. 7.4. Parts baskets

It is usual for the parts to be cleaned to be placed in baskets. These should be constructed of an open wire mesh with as high an opening:wire diameter ratio as possible, never of perforated metal plates. The baskets should be of a size that their length and their width is never more than two-thirds the length and width of the smallest sump, to reduce the piston effect as they are moved in the vapour zone. When cleaning small parts, it is preferable to have only one layer in the basket, so that vapour can circulate freely in a vertical direction.

#### III. 7.5. Sprays

The use of spray lances in open-top degreasers is most undesirable. In the first place, they create turbulences in the vapour phase, causing additional losses. In the second place, they depress the vapour level, drawing air into the machine. As the vapour level rises again after the spraying is finished, air is pushed out, carrying with it some vapour. In the third place, the sprayed solvent increases the solvent/air interface area, exaggerating the evaporation.

### III. 8. Cleaning cycle

In most cases, the cleaning cycle should consist of lowering the basket containing the parts to be cleaned at a speed of about 50 cm.min<sup>-1</sup> directly into the boiling solvent. This lowering should therefore take 1–2 min in most machines. The parts are kept there for at least the length of time for them to reach the boiling point or until the scrubbing action of vapour bubbles ensures an adequate pre-cleaning. The basket is then hauled upwards at the same speed until the bottom is just clear of the overflow weir. It is then displaced horizontally at 100 cm.min<sup>-1</sup> until it is over the cold distillate sump and lowered in it at 50 cm.min<sup>-1</sup>. It remains there, with or without ultrasonic agitation, until the parts are uniformly at the same temperature as the cold solvent. The basket is then hauled upwards again at the same vertical speed until it is entirely in the vapour zone over the distillate sump. It remains there until the most thermally massive parts reach the vapour temperature.

when the basket can be pulled upwards again at the same speed, until the whole workload is in the middle of the freeboard. For most parts, 2 minutes in the freeboard is usually sufficient, to allow the vapour to drop off the assemblies, although complicated parts with deep, blind holes may require longer. A sniffer test of the parts coming out of the machine should reveal virtually zero solvent. It is to be appreciated that parts such as electronics assemblies or metallic components with small thermal masses will require a cycle time of, say, 1 min descent, 2 min boiling sump, 1/2 min ascent, 1/2 min lateral, 1/2 min descent, 2 min cold sump, 1/2 min ascent, 2 min vapour phase, 1/2 min ascent, 2 min freeboard, 1/2 min ascent or a total of about 12 minutes to clean successfully with minimal solvent losses. This compares to a typical 4 minutes in an uncontrolled situation. It should be mentioned that the cleanliness levels will also be better.

### III. 9. Automatic handling

There exist on the market many types of automats to manage the cleaning operation in this kind of equipment. These are usually gantry hoists with microprocessor control of many of the parameters. These generally cost about the same price as the cleaning machines themselves. If the use of one programmed to the cycle mentioned in the previous section can reduce the losses to half, which has been frequently documented, then 20 kg/week can be saved at a typical 1989 price of SFr 150.- per week. The equipment can therefore be written off in less than three years, especially if solvent prices rise even more, as is probable. It is still therefore economical to install if a decision to change to another cleaning method must be deferred for a few years, for any reason. This calculation does not take into account the labour costs of a 12 minute cleaning cycle otherwise done manually, bearing in mind that it is a boring job that is likely to be skimped if it is not automated: it is based purely on solvent savings.

### III. 10. Solvent type

One manufacturer of CFC-113 blends claims that the losses are dependent on which blend is used. This is of particular interest in cleaning electronics assemblies. It is claimed that ethanol blends, particularly with methyl acetate, evaporate at almost half the rate of methanol blends. The mechanism behind this is not clear.

### III. 11. Solvent vapour capture

This is the only practical method, other than maintenance and handling, of being able to recover solvent losses from large, closed, conveyorised machines (short of completely redesigning the machine). It consists of passing the whole of the air in the room in which the solvent is used through a suitably dimensioned active charcoal adsorption filter. This is

an expensive process, as the subsequent recovery of the solvent from the filter requires a complicated steam treatment, separation and reconstitution. It is only likely to be economical if the losses are over five tonnes of CFC-113 solvent per year. Even so, the cost would be put to better use to replace the old equipment with some other method of cleaning, in the short term.

Nevertheless, the actual cost of air extraction at floor level and passing the air through a charcoal filter is not, in itself, costly. It is possible that this could be another opportunity for a sound commercial operation for an enterprising company which could provide interchangeable filters to numbers of companies, with one central recovery plant. The essential minimum requirements to make it worthwhile would be:

- to have a clientele losing a total of at least about 100 tonnes of CFC-113 per year (about 5% of the Swiss consumption)
- that each user would be willing to install the extraction and filter, according to the technical requirements
- that each user would be willing to pay a few tens of francs per filter change, including collection and servicing charges
- that each user would buy recovered solvent at, say, 5-10% off the current market price for virgin solvent. This could be made up into any of the popular blends.

#### III. 11. 1. Other solvents

The same general remarks apply to other organic solvents. With the application of a little thought and a few small investments, it is usually possible to reduce losses dramatically. At this time, it may not be economically sound, but neither the biosphere nor the ozone layer have ever heard of the Swiss Franc!

### III. 12. Operator awareness and management

From the foregoing, it is evident that the most important gains can be made only if the persons in charge of and operating the equipment are aware of the problems involved and are trained accordingly. Management involvement is not confined to deciding on whether investments are needed: they must make all the echelons of industry aware that the problem exists. The ideal approach is for a corporate decision to be made by the full board of directors to phase out CFC solvents (and possibly other problem products) and to appoint a director to identify all CFC usage, to calculate a calendar of operations and to ensure the implementation of the decision. From there, communications are necessary, explaining why the decision is made and what is being done. If everyone is aware of the problem, it is already half-solved.

This technique has been used in a number of enterprises in North America, Europe and Asia, with great success. The operator cooperation has often exceeded all expectations. Some companies are even

extending the notion to beyond the corporate walls and are already warning suppliers that they may be expected to certify that their products do not contain CFCs or use them in their production. Obviously, there are very few Swiss companies large enough to carry the weight required to force major suppliers into changing the production methods, but preference can always be given to suppliers who voluntarily state that their

products are manufactured without the aid of CFCs. More important, Swiss industry is traditionally oriented towards subcontracting parts of manufacturing processes. Subcontractors can always be chosen from the ranks of those who do not use CFC cleaning processes and companies providing subcontracting services should inform their customers that they are "CFC-free" (when they are, of course!).

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## Chapter IV. Substitution

### IV. 1. General

Any substitution method or product must take into account numerous parameters. Some of these are:

- Soil to be removed
- Ease of use
- Operator health and safety
- Environmental problems
- Cost

Each application has to be studied entirely on its own merits. No single substitution method to replace CFC-113 can possibly be the answer to all the current uses of this solvent.

### IV. 2. Specific applications

#### IV. 2. 1. Defluxing

##### IV. 2. 1. 1. Industrial defluxing

Industrial defluxing is defined as the removal of flux residues after soldering using *ad hoc* equipment designed for that purpose. This is in opposition to artisanal defluxing which is frequently employed in small companies and even in larger ones for special purposes, where trays of solvent and a brush are the usual tools.

The most popular equipment in Switzerland for industrial defluxing is the open-top vapour degreaser with some commercial blend of CFC-113 with an alcohol. With very few exceptions, these machines are used for removing some form of rosin flux: very occasionally, a synthetic activated flux (type SA) may be used but this type will almost certainly disappear from the market in the near future, because they were developed to exploit CFC-113. This type of equipment is frequently badly designed and it is probable that at least 90% of the CFC-113 solvent losses from the Swiss electronics industry, which in itself accounts for 60-70% of the total losses, is derived from this usage. In the short term, as has been explained in the previous chapter, it is possible to reduce these losses by at least 50%, but it would be better still if they were reduced by 100% by simply replacing the equipment to profit from one of the substitute methods. A brief survey of open-top vapour degreasers in ten Swiss factories, taken at random from both the Eastern and Western sides of the country, has shown that twelve out of a total of thirteen machines are more than five years old, nine more than ten years old and one was even 22 years old. Furthermore, of these thirteen machines, three were

never designed for use with CFC-113 solvents, although they were sold for this purpose. It would seem that this kind of machine is kept in operation until it falls apart. It is therefore not very surprising that the Swiss electronics industry wastes something like SFr 6-7 million in solvents literally going into thin air, every year.

Larger factories are equipped with conveyors, in-line machines where the output flows directly from a wave soldering machine into the cleaning machine. These machines are frequently badly maintained and it is not unusual, even with new ones, for them to waste quantities of solvent through gasket leaks, badly closing taps or valves, etc. With this type of machine, the average age in industry being between five and ten years, relatively little can be done to prevent the inevitable operational wastage: the best that can be hoped for until such time as they are replaced by machines using other processes is that active charcoal filters are used to recover most of the losses. One of the tragedies is that this kind of machine also gives quite mediocre cleanliness results, as measured with either ionic contamination testers or surface insulation resistance analysers.

A handful of Swiss companies, both large and small, have already very successfully adopted more modern cleaning techniques such as aqueous and hydrocarbon derivative (alcohol) cleaning. One group, renowned for its quality, high-reliability products, has been continually using water-soluble fluxes and aqueous cleaning for defluxing since 1967 for most of its production. At least half-a-dozen other Swiss companies have been using it for over ten years. None of these has experienced problems in terms of soldering, cleaning or reliability of their products, rather the opposite.

On an international scale, aqueous cleaning has been the workhorse method for many large multinationals for up to 25 years. The first major company to put it into production was Hewlett-Packard, followed by IBM, ICL, Burroughs, NCR, Olivetti, Bull and many others. It is estimated that about 40% of the US electronics industry production is cleaned in water.

To date, relatively little hydrocarbon or derivative cleaning has been done. Three German companies have developed alcohol cleaners but these are mostly being used for evaluation purposes, as yet, one in Switzerland. The hydrocarbon/surfactant technique has not yet made any great penetration in Europe. Two chemical supply companies are experimenting with it and it is



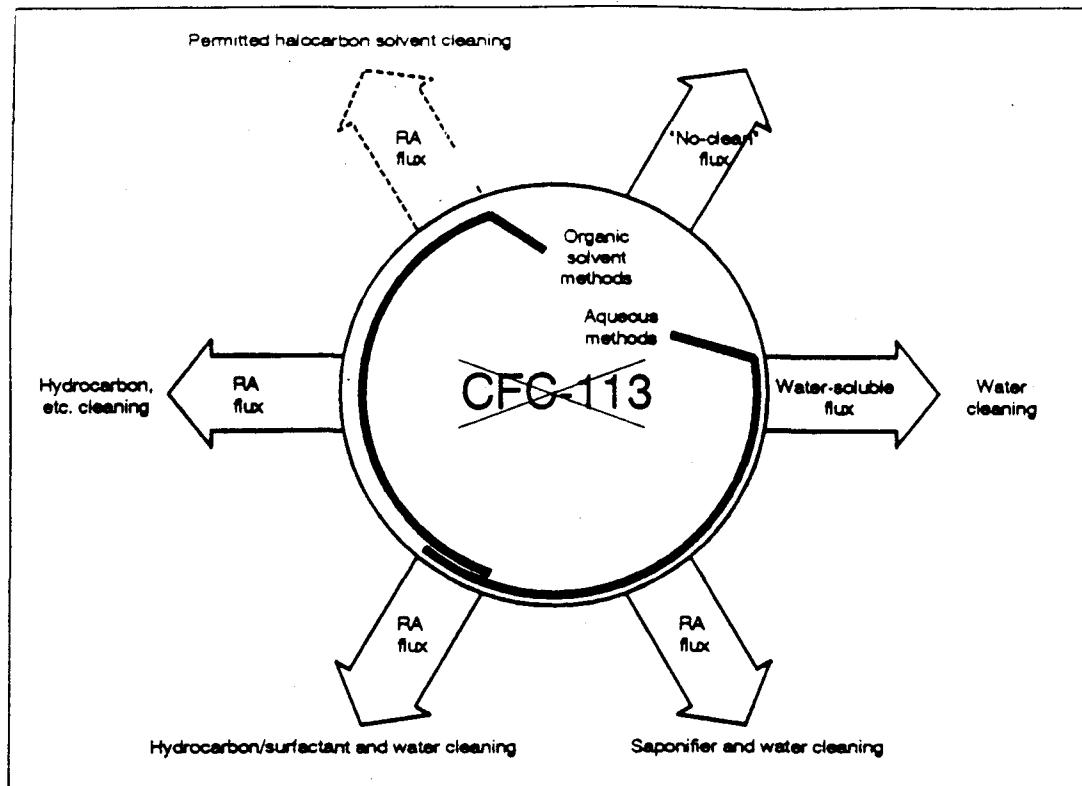


Fig. IV-1. Schematic of substitution for defluxing

anticipated that they will both become commercially available in Autumn 1989. It is known that two machine manufacturers in Europe are developing equipment for this method. The first is a French large-scale conveyorised machine and the other a Swiss batch machine for small and medium-sized applications (on the same scale as open-top vapour degreasers). Several North American companies are also developing machinery.

There are six substitution methods<sup>27</sup> (Figure IV-1) open to the electronics industry and these will be discussed in fairly full detail here, as it is in this sector that the most important reductions in CFC-113 and other ozone depleters can be made. At the same time, this industry, which is one of the most modern of Swiss industries, is paradoxically one of the most conservative and traditionalist, resisting change at all costs.

The six methods are:

- 1. Not to clean (using so-called low-solids or "no-clean" fluxes)
- 2. Water (using water-soluble fluxes)
- 3. Water + saponifier (using traditional rosin fluxes)
- 4. Hydrocarbon/surfactant + water (using traditional rosin fluxes)
- 5. Hydrocarbon and derivative solvents (using traditional rosin fluxes)
- 6. Permitted halocarbon solvent blends (using traditional rosin fluxes)

#### IV. 2. 1. 1.1 The "no-clean" solution

Up to the time when printed circuits were adopted for professional electronics, cleaning was required only for exceptional conditions. This was because assembly was done by soldering wires to discrete tags and both spacing and leakage paths were long. The situation changed dramatically with the advent of the printed circuit and, especially, of machine soldering when cleaning was deemed necessary for many applications. The Germans developed a special rosin flux type for those applications where cleaning was not absolutely essential. This was adopted in DIN 8511 under the designation F-SW32. Many users of this type of flux made the mistake of trying to clean off the residues using CFC-113 blends, forgetting that it was designed not to be cleaned. Not only was this difficult, even impossible, the residues after cleaning were frequently very dangerous.

One of the difficulties with this type of flux, and other rosin fluxes, was that automatic testing was rendered difficult as the residual rosin prevented contact from being made with the conductor pattern. In 1984, a flux manufacturer in Germany developed and patented a variant of this type of flux with solids as low as 2-8%, as opposed to the traditional 15-35%. Although slightly more corrosive than the older types, these fluxes did allow reliable contact to be made for automatic testing.

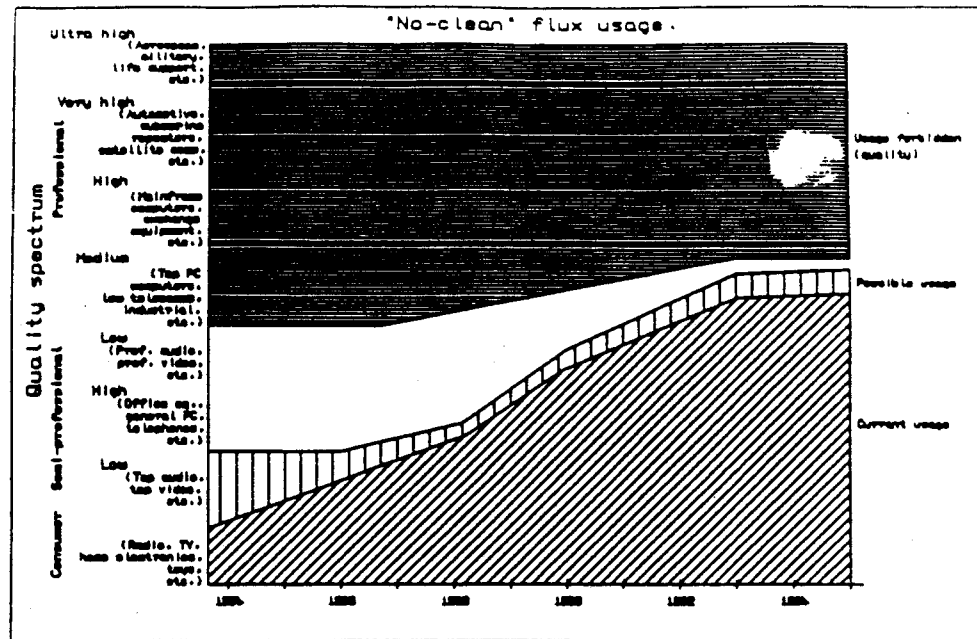


Fig. IV-2. Technical usage of "no-clean" fluxes

This figure and the following ones are meant uniquely to show the technical feasibility of the various techniques. They are neither a cost comparison nor a recommendation of one technique over another. However, if a technique is obviously too costly, this fact is shown and is taken into account under the heading of current usage.

This graph is based on the following assumptions:

1. that the technical progress between 1984 and 1989 may be extrapolated to at least 1992.
2. that no unforeseen problems occur from the use of these fluxes for medium-professional use and that correct contamination control is used for all professional uses.
3. that, as would appear likely, these fluxes will not be approved for any form of high-reliability electronics.

Since then, many other flux manufacturers have developed various formulations of fluxes that are variously described as "low-residue", "no-clean" and even, untruthfully, "no-residue". Other doubtful claims that have been made are that wave soldering washes off all the residues or that the residues sublime. These fluxes all have total solids of less than 10% and are activated mainly with strong mono- or dicarboxylic acids. The actual rosin or, in some cases, synthetic resin content is used as a matrix to encapsulate the dangerous activators. This confers reasonable insulation resistance to the residues. It must notwithstanding be realised that none of these fluxes is harmless and all leave large quantities of ionic contamination, measured from five to thirty times that permissible under military specifications (incidentally, this is another cause of doubtful publicity as some military specifications are worded in such a way that the less scrupulous flux manufacturers have used a loophole to promote their products).

Various mechanisms of breakdown of the old F-SW32 fluxes are known and these can all be applied to the newer fluxes, now known under the designations of F-SW33 and F-SW34. The most common is that rosin and some other resins oxidise on air contact (this is why that beautiful amber lump that some people used as paperweights became covered with a whitish powder after a year or so). When this happens, the

activator-holding matrix is destroyed and the released acids can cause damage. Even more dangerous is rosin hydrolysis caused by long-term contact with humid air. Another problem can be caused by prior contamination on the parts being soldered upsetting the matrix. Unfortunately, none of these effects is revealed by accelerated testing, except possibly the last-named in some circumstances.

The use of this type of flux is perfectly acceptable where long-term reliability is of little interest, particularly where the circuits are designed for use indoors in temperate climates or in air-conditioned rooms. It is doubtful whether they can be employed for most professional applications. They should most certainly be avoided for life-dependent applications (military, aerospace, automotive, life-supporting medical uses, etc.). They are not recommended for other high-reliability usage, especially if for use outdoors or in industrial locations. Figure IV-2 shows that usage of these fluxes is rising in the quality spectrum, but a ceiling is being approached.

One reason sometimes quoted for cleaning off flux residues is that the thick, sometimes sticky, residues of the more mildly activated fluxes were unaesthetic. The newer low-solids fluxes leave residues that can vary from visible but not especially unaesthetic to almost invisible to the naked eye. As a general rule, they are not usually sticky to the touch.

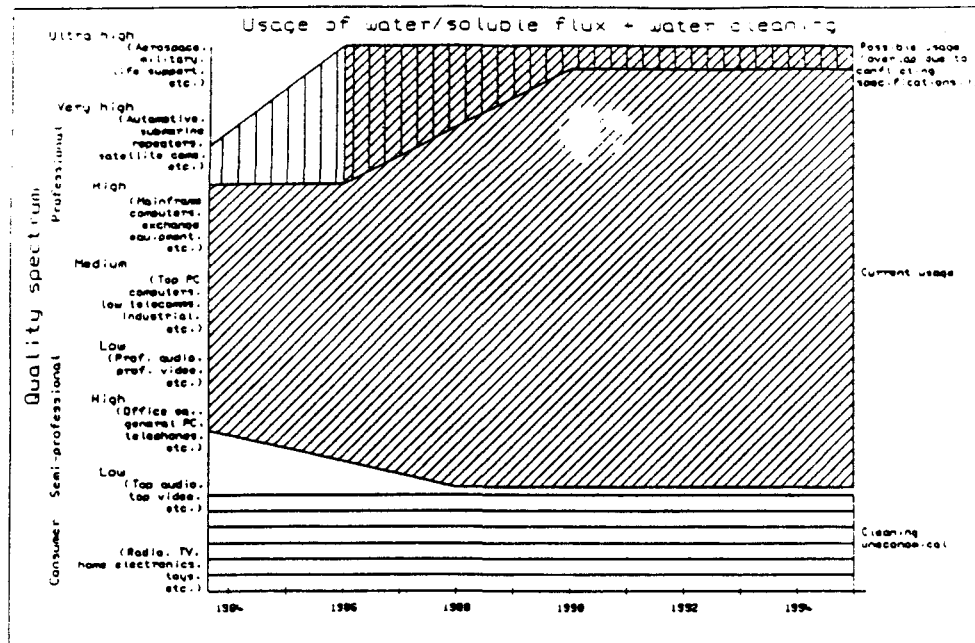


Fig. IV-3. Technical usage of water-soluble fluxes

This graph is based on the following assumptions:

1. that the military approve of them in DEF-STAN 00/10-3 (1986)
2. that the equipment used is suitable for SMD cleaning
3. that some other approvals will be accorded by 1990

The overlap area of "current usage" and "probable usage" is dependant on future approvals. At the time of writing, these fluxes are not approved for general use by the U.S. military authorities, but they will possibly be approved for limited use within a short period.

The actual *mise-en-service* of these fluxes requires a certain apprenticeship<sup>28</sup>, as they are not "drop-in" replacements for conventional types. In particular, foam maintenance and solids-contents adjustment are difficult and differ from traditional techniques. Machines may have to be modified. All soldering machine parameters are more difficult to optimise. Flux consumption will be greater and, being more expensive, the savings by not cleaning will not be as great as originally imagined.

Another variation on this same theme is being proposed in conjunction with a new wave soldering technique, inert gas soldering. This is similar to ordinary wave soldering except that the whole of the inside of the machine is nitrogen purged. As the solder itself does not oxidise under these conditions, the flux has less work to do and lower quantities are claimed to be necessary. It is being proposed to use small quantities of rosin-free carboxylic acids as flux in certain cases. This technique is interesting but certainly not safer: one company (telecommunications) experimentally using inert-gas soldering has reverted to "low-solids" fluxes in such a machine. As the machines are expensive and the running costs high, it is likely that this technique will be reserved for special applications.

In conclusion of this section, low-residue fluxes not requiring cleaning offer the ideal way of not causing pollution by a cleaning process. It is also the most cost-effective process. Under no circumstances should

these fluxes be solvent cleaned as the residues are partially insoluble. If necessary, some (but not all) types can be successfully saponifier-cleaned. Their use is restricted to relatively low-reliability applications or where a short life-time is acceptable. For fully professional applications, they should only be adopted with prudence and circumspection after lengthy field tests under real operating conditions for at least the expected life-time of the electronics. They should never be used for life-dependent applications. Above all, read manufacturers' data sheets and publicity with a sceptical mind as many of the claims made are either exaggerated or untruthful.

#### IV. 2. 1. 1. 2 Water cleaning with water-soluble fluxes

This is what most experts foresee as being the most likely to become the popular method for professional wave-soldering applications with small inroads into other soldering methods. It has a long and good track record and is thus a proven process. Its advantages are:

- very cost effective, especially for large systems
- the most reliable soldering process
- easy to obtain good ionic cleanliness levels
- machines for all sizes of lines available
- conforms to some military specifications
- often usable with SMT
- little or no waste water treatment required (machine dependent).

On the other hand, its disadvantages are:

- drying may be problematic, depending on machine design
- effective water-soluble flux solder pastes and wires difficult to obtain
- costs for small users may be slightly higher than 1986 CFC-113 usage (probably similar to projected 1990 costs)
- treatment of tap water usually required
- with a few flux and substrate combinations, degradation of printed circuit insulation resistance.

Figure IV-3 shows the increasing universality of this type of flux.

The choice of cleaning machines for all types of water cleaning is critical. There are four basic types of purpose-built machines available on the market:

- low-volume "dishwasher" types
- high-volume professional batch machines
- low-volume conveyerised machines
- high-volume in-line machines.

The "dishwasher" types, as the name implies, uses the principle of the domestic dishwasher modified for this application. As a general rule, standard dishwashers are not suitable for complete wash-and-dry cycles. For conventional assemblies, this type of machine gives excellent results, but very few are suitable for SM assemblies. Their principal disadvantage is that they take typically at least 1 hour for cleaning and drying a load of, say,  $1 \text{ m}^2$  of circuits, if they dry at all. They present no specific pollution problems as the wash water is completely renewed with each batch and there is no accumulation of pollutants. It is extremely unlikely that the wash water would ever fail to meet Federal requirements either in terms of heavy metal content, pH or biodegradability. On the other hand, these machines consume large quantities of water (typically  $20\text{--}40 \text{ l/m}^2$ ) which is expensive if deionised and they are quite energy-inefficient (drying is evaporative and the machine itself with all the residual water has to be dried as well as the circuits). The capital cost of a machine is typically similar to that of a small open-top degreaser (SFr 10,000-25,000). Some machines rinse in a closed circuit through a DI column, but their spray energy, hence cleaning quality, is reduced and the cost of column renewal is high as all the ionic rinse contaminants are ion-exchanged. On the other hand, the non-ionic contaminants are not eliminated. The successive rinse system is more efficient except for water consumption.

The high-volume professional batch machines (some of them are of Swiss manufacture) are suitable for all types of circuits, including SM types. They are characterised by low water and energy consumption and extremely efficient cleaning and drying. They can handle the full output of a wave soldering machine with typical throughputs of up to  $20 \text{ m}^2/\text{h}$  (about  $5 \text{ m}^2/\text{h}$  for SM assemblies). With water-soluble fluxes, the waste water is never likely to present a pollution problem as the wash water is constantly renewed by the rinse water and goes to waste while it is still very dilute. This type

of machine generally has high pump energies (typically 2 HP), making for efficient washing. The wash and rinse water circuits are completely independent, so that the open-circuit rinse water is totally unpolluted until it reaches the circuits being rinsed, making for small rinse-water consumption (typically  $5 \text{ l/m}^2$ ). Some machines have an optional feature of injecting a small percentage of isopropanol in the rinse water with several benefits. Drying with this type of machine is achieved in a separate compartment or machine. The best ones have rotary air-knife drying which blasts over 90% of the residual water from the circuits within a few seconds (even from connectors and from under SMDs), followed by an energy-conserving hot-air drying for removing the residual moisture. This results in the best drying of any system. These machines are more expensive than the previous type, usually within the price range of SFr 20,000-60,000, but the running costs are considerably lower, as well as being able to handle many times the quantity of circuits.

The low-volume conveyerised machines can not be used in-line with a soldering machine as their conveyor speed is too slow. They are typically capable of cleaning up to a maximum of about  $10 \text{ m}^2/\text{h}$ . The cleaning and drying efficiencies are usually mediocre. They are frequently based on redesigned printed circuit etching machines. One, American, design is custom-built with the conveyor inclined to give better draining flow. Some types may present a pollution problem: if the wash water is in a closed circuit without automatic renewal or with a low renewal volume, it is probable that heavy metals will accumulate in it to beyond Federal limits. In this case, the water must be treated before it is evacuated to drain. If this is not possible, then it must be sent to a specialist company for treatment. The usual way of reducing metal content is by precipitating the metal hydroxides in an alkaline medium, prior to neutralisation. This involves a large and costly installation and often causes difficulties in eliminating the sludge. An alternative method, suitable for small plants, is by recirculating the waste liquor through an electrolytic cell until all the metals are deposited on a stainless steel cathode, with a columbium (possibly titanium) anode. This method has been experimentally tried in the USA, by an EPA sponsored project. It is claimed that up to 90% of the metal (copper, tin and lead) is easily recovered (although for another application) but actual figures were not reported. Capital costs could be as low as \$3'500, not counting the installation costs. The water consumption of such machines is variable according to the design. Energy consumption is usually fairly high. Capital costs are reasonable in absolute terms, but perhaps high in relation to the quality of the results (SFr 35,000-60,000).

The high-volume in-line machines are usually very large, very expensive and not always efficient. The basic problem is that a large soldering machine may run at a conveyor speed of, say,  $2 \text{ m} \cdot \text{min}^{-1}$ . It is obvious that an in-line cleaning machine must run at the same speed.

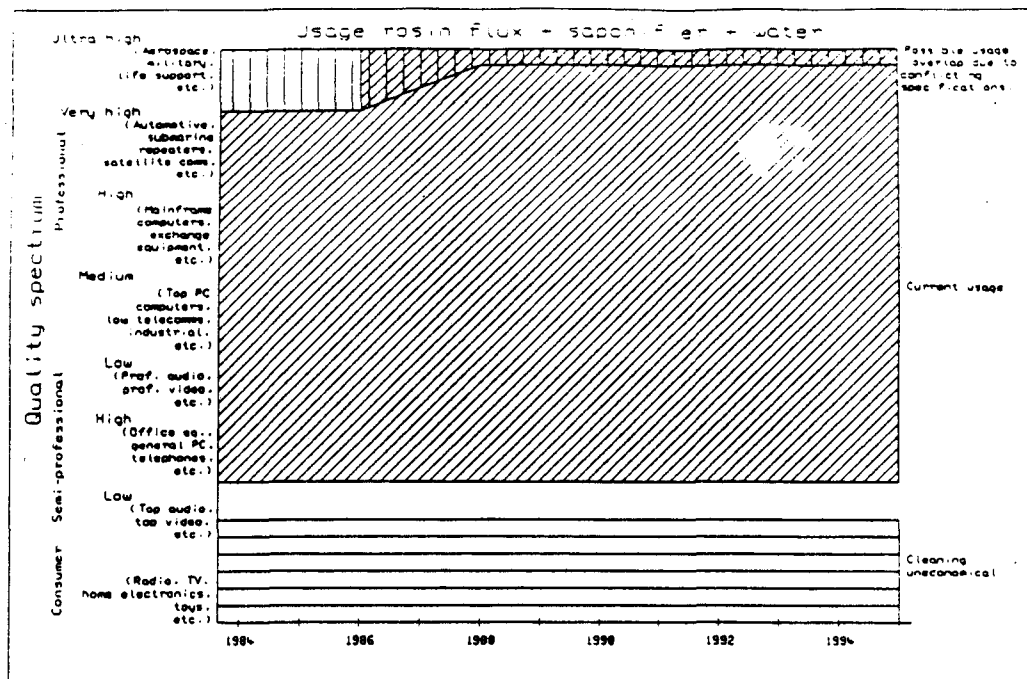


Fig. IV-4. Technical usage of saponifier cleaning

This graph is based on the following assumptions:

1. the approval to MIL-P-28809 is subject to interpretation.
2. that extended approval to MIL specifications will be accorded by 1990.
3. the approval to DEF-STAN 00/10-3 (1986) is normal.

The overlap zone is a function of the interpretation of current and future specifications.

If the cleaning process takes, say, 3–4 minutes, as may be required for saponification on SM assemblies, this means that the cleaning compartments must total 6–8 m long, plus the rinsing and drying modules. This makes for extremely expensive machinery. Obviously, if the conveyor speed can be reduced to  $1 \text{ m.min}^{-1}$  and it is known that the cleaning process can be achieved in, say, 1–2 min, as is usually the case with water-soluble fluxes, the problem can be resolved more easily. These machines give mediocre to very good cleaning results, depending on the machine design and conditions of use. On the other hand, it is rare for the drying to be very good and most users would be wise to consider it as a pre-drying. Pollution may sometimes be a problem and the same remarks as in the previous paragraph apply. The range of prices for these machines is very wide, typically from SFr 100,000 to over 500,000.

No matter which type of machine is used, one of the potential problems is foaming. This is more likely to occur if a water-soluble soldering oil is used in such a way that it comes in contact with the circuit to be cleaned. These water-soluble oils are readily biodegradable and are more economical than the non-degradable mineral oils but it is a fact that they do have this disadvantage. Foaming can usually be controlled with the addition of a few drops of octyl alcohol in the wash water (do not use silicone based foam-depressants). If not, a tap water pre-rinse to drain may be necessary.

Another problem that sometimes occurs with these fluxes when using batch machines is that the wait time before a load is ready to be washed may be sufficiently long that the solder joints may be superficially attacked, giving a matt result. This can be avoided by keeping the circuits to be washed in a tank with a dilute solution of a commercial chelating neutraliser based on ammonium carbonate until sufficient have accumulated to fill a basket. At the same time, it improves the cleanliness of the circuits at very little extra cost. On the other hand, it is probable that heavy metals may accumulate in the neutraliser bath which should be correctly destroyed. Chelating neutralisers based on EDTA salts should be avoided, as they may not conform to the Federal Ordinance relating to Environmentally Hazardous Substances (maximum concentration in the as-delivered neutraliser 0.5%)

#### IV. 2. 1. 1. 3 Rosin flux and saponifier

Rosin is not soluble in water. If treated with a suitable alkali, similarly to vegetable oils being treated with caustic soda in soap making, it forms a soap which can dissolve in water. This process, called saponification, has been used in the electronics industry for many years. The alkali used is based on an organic substance called monoethanolamine (MEA). It is sold in a concentrated form by most of the flux manufacturers. Cleanliness levels obtained, with good equipment, are usually better than those obtained with organic solvents, as carboxylic acid activators are also easily saponified, whereas their

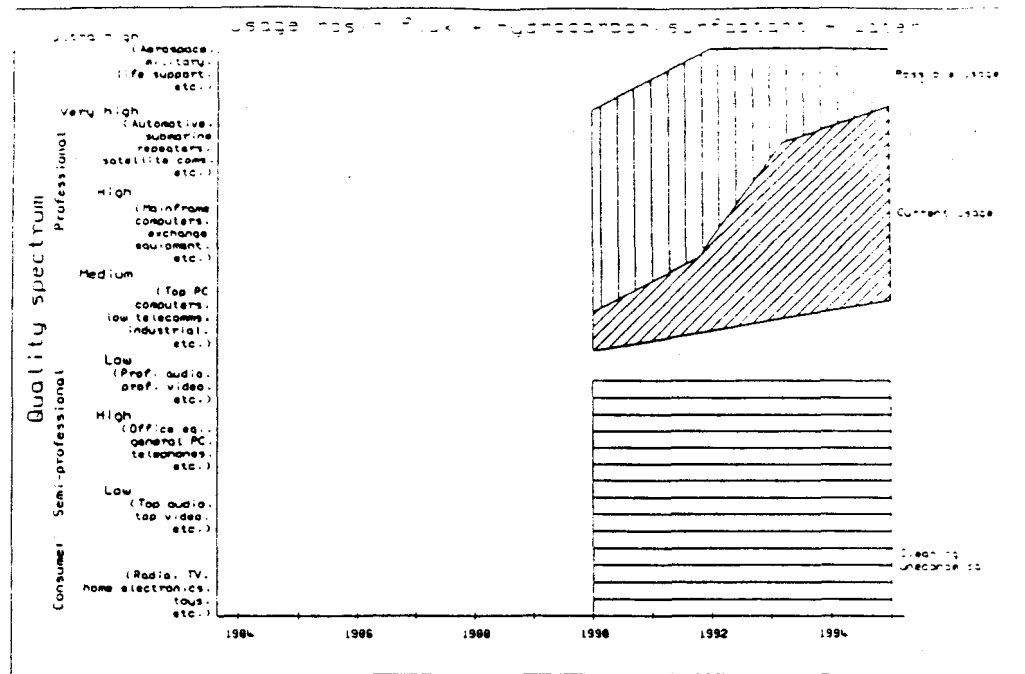


Fig. IV-5. Technical usage of hydrocarbon/surfactants

This graph is based on the following assumptions:

1. that competitive products will become commercially available in 1990
2. that these products become approved to diverse specifications by 1992
3. that production costs will prove to be too high for any but professional applications and will be initially underestimated
4. that no unforeseen hazards are discovered and no major accidents occur due to the use of hydrocarbon/surfactant cleaners

solubility in solvents is limited. The equipment that can be used is generally identical to that mentioned in the previous section. An important point to note is that saponification is not an instantaneous reaction and times of two minutes are typical with conventional circuits and longer for SM circuits, provided that the mechanical energy of the machine is high. The equipment must be dimensioned to take this into account.

In terms of pollution, the only major differences between the previous case and this one are the alkalinity (pH) and the biodegradability of the used saponifier solution. This problem can be divided into two categories, for batch machines and conveyors machines. Both types of batch machines dump about 5 litres of used wash solution per cycle. This solution has a typical pH of 10.5-11, which is outside the Federal limits (from 6-6.5 to 8.5-9.5, according to local conditions). Its biodegradability is more variable and this is only regulated by the cantonal authorities, except in the case of direct disposal in a water course. In reality, it is extremely unlikely that direct dumping of such small quantities of entirely biodegradable waste products will be the cause of any problems, and is not environmentally worse than the used wash water from a domestic dishwasher. Many cantonal authorities will grant a discretionary derogation for the use of such a small machine without water treatment, provided that application is made prior to its being put into service with a saponifier. If this is not the case, a small

neutralising installation can be used to correct the pH before dumping to drain. The larger installations where up to several hundred litres of saponifier solution are used and dumped will certainly not be the subject of derogations. As such solution is obligatorily circulated in the machine, heavy metal levels will also be a problem. If the factory has an industrial water treatment plant, this can usually handle such waste without difficulties. If not, the used saponifier should be put into drums and sent to a competent company for destruction.

This technique is fairly universal in its applicability and, provided suitable machines are used, is particularly useful for cleaning circuits which have been reflow soldered with a solder paste. It covers a wide range of applications (Figure IV-4).

Use of saponifiers with polyimide substrates and certain types of thick film circuits is not recommended, as the alkalinity may present compatibility problems. On the other hand, most commercial saponifiers are buffered in such a way that they will not attack light (amphoteric) metals or component markings. Dyed metal, such as cooling radiators for power semiconductors, especially if conversion coated rather than correctly anodised, may lose some of the colouring matter.

The cost of this process is slightly higher than that of the previous one, the only major differences being that of the purchase of the chemical and waste water treatment, if any.

The industrial hygiene aspects of saponifier cleaning must be examined. The concentrated and diluted products are strong irritants, so that suitable protective clothing, including gloves and goggles, is *de rigueur* when handling them. MEA fumes are highly toxic, but if the commercial products are used correctly, it is unlikely that concentrations would become dangerous. In any case, the smell is so unpleasant that it seems unlikely that high concentrations would pass unnoticed. Nevertheless, good ventilation of the cleaning area is required.

#### IV. 2. 1. 1. 4 Hydrocarbon/surfactant cleaning of rosin fluxes

This technique is relatively new. It was first announced in the USA about two years ago. Two products have appeared on the European market in experimental quantities. One of these is based on a terpene principally distilled from orange peel and the other is another type of hydrocarbon. It is too early to give definitive information on this type of process, but it appears to be technically very promising. There still remain a number of unanswered questions.

Figures published by both manufacturers suggest that the ionic contamination levels with this process can be up to an order of magnitude better than with straight CFC-113 blend cleaning. Even if we discount the fact that these figures are probably laboratory results obtained under the best conditions, there would seem little doubt that it is a valid cleaning process. Results obtained by users in the USA and Japan would seem to confirm this fact. It seems a process particularly indicated for SM cleaning. It will probably be too expensive for usage on mass production articles and it is expected that it will find its place in the upper third of the quality spectrum (Figure IV-5). Subsequent expansion will tend to be upwards.

What is sure is that this process is expensive. The solvent itself is expensive, even though it can be used for a longer time before it has to be discarded. Even more important is the fact that machinery cost is doubled for in-line machines and about 50% higher (estimated) for batch systems. The overall costs would approach the double of the elimination of water-soluble fluxes. To understand this, it must be realised that two distinct operations are necessary. The first is the solvent cleaning. This is then followed by a water rinse and dry.

The solvent cleaning machinery is divided into two categories. The conveyerised, in-line machines are usually provided as two, separate modules. The solvent module uses high pressure jets to dissolve the rosin flux residues. As this creates a fine mist which can be explosive under some conditions, the machines are usually nitrogen purged (requiring a large nitrogen supply system which may be quite expensive to run). Various safety devices are consequently necessary. As the solvent is a VOC pollutant, the nitrogen outlet has to be equipped with a water scrubber to prevent the mist from dissipating in the atmosphere. Batch machines, which are currently more experimental, use an agitated

soak technique for the solvent phase. This eliminates the problem of mist formation and it reduces the flammability difficulties to zero, as the open-cup flash points of these solvents are very high (70°–140°C) and the volatility very low. In both cases, the aqueous phase is done in machines similar to those previously described.

Other than the VOC pollution, which is easily handled, water pollution remains a thorny problem. In the USA, it would seem that the rinse waters are permissible pollutants. They are not so clearly defined in Europe. For batch machinery, the quantities involved would be so small that there should be no difficulty (see the previous section) and it is expected that cantonal authorities would raise no objections (note the case is not covered by the Federal Ordinance). For conveyerised equipment, two problems may arise. The first is that of a biodegradability of the rinse waters which would seem to be on the limit of what is currently acceptable, typically up to five times more severe than human faecal matter. The second is that not all surfactants that may be used are themselves fully biodegradable, although there is no reason to believe that the commercial products contain such detergents.

There are a number of unknown factors regarding the health and safety aspects. The products used are not common as concentrates for such industrial processes and relatively little is known about them. At least one component is known to be an allergen in remote cases and is an irritant. Fortunately, the smell of this substance is so bad that it would seem unlikely that dangerous quantities would accumulate in the operator environment. It is probable that we shall have definitive answers to these questions within a few months.

It would seem that this process is amongst the more promising of the new ones for those cases where good cleanliness is important and cost is of secondary importance.

#### IV. 2. 1. 1. 5 Hydrocarbon and derivative cleaning of rosin fluxes

This implies cleaning in volatile, flammable solvents. Theoretically, there is no reason why this should present any major difficulty that standard industrial processes do not already handle. Alcohol has, for example, been distilled for many years without major catastrophes happening. The real problem is that a printed circuit with its components is not the same thing as the walls of a still. It has many interstices which trap contaminants and solvents. At least three German manufacturers offer equipment for this purpose but it must be said that these must be considered as at least semi-experimental. For this reason, it would be unwise to install them without adequate fire precautions external to the machines. In Japan, for example, such machines have to be installed in separate buildings with a 20 metre fire break round them, at least for the moment. This extreme case is also partially due to the high earthquake risk.

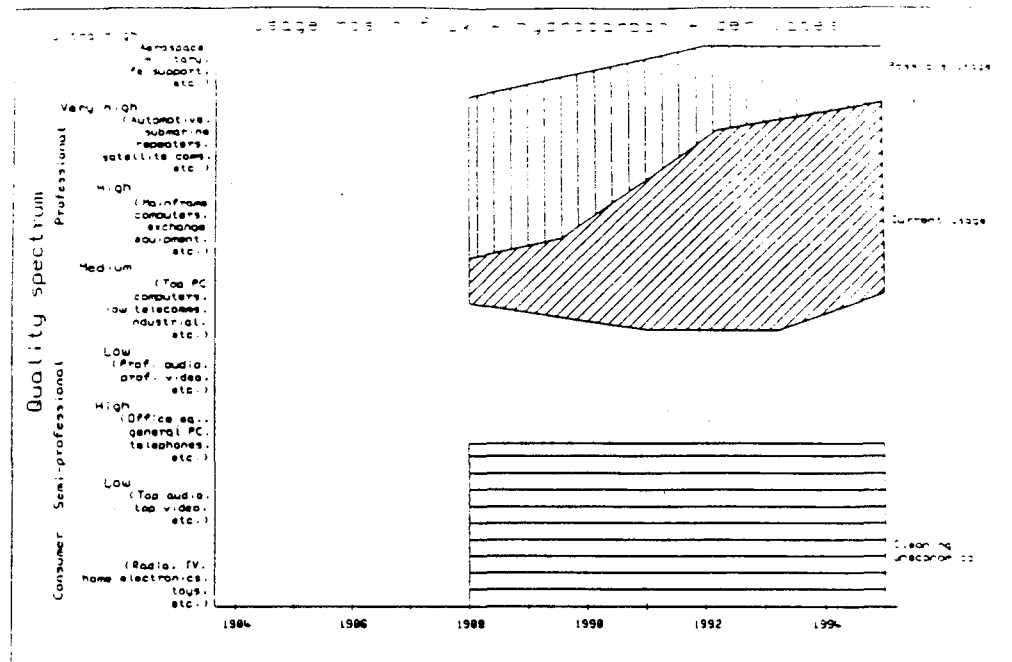


Fig. IV-6. Technical usage of alcohol cleaning

This graph is based on the following assumptions:

1. that alcohol cleaning is approved to diverse specifications by 1992
2. that no major accidents occur, due to the use of alcohols
3. that the costs will be initially underestimated.

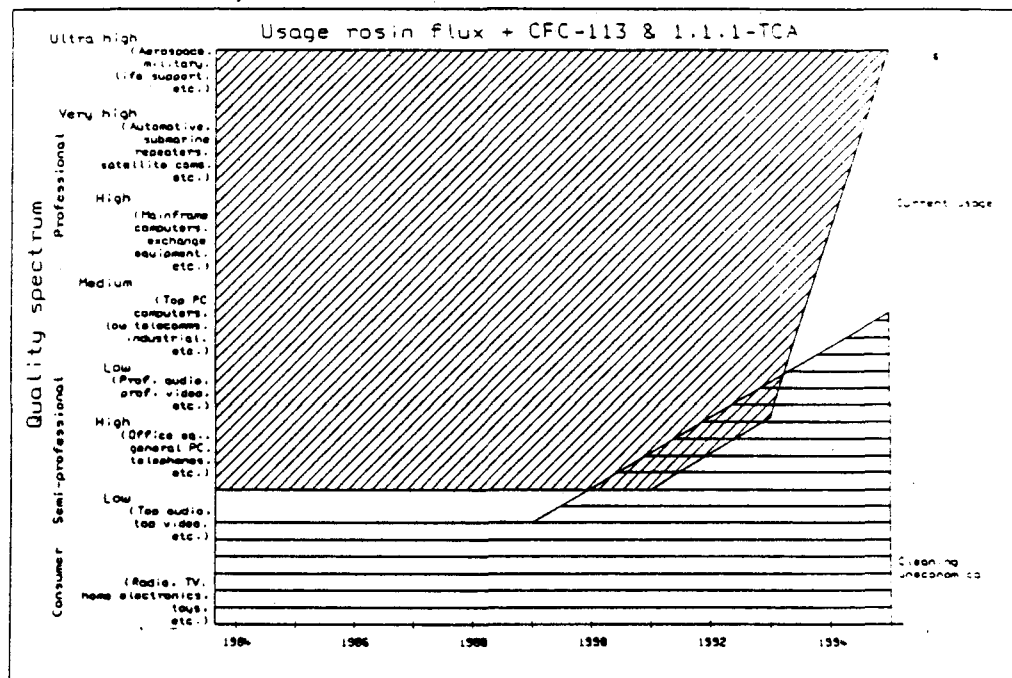


Fig. IV-7. Technical usage of ozone-depleting solvents

This is the reference diagram, based on the written standards and norms usual for industry up to 1986.

This graph is based on the following assumptions:

1. the price of CFC-113 will rise considerably from 1989 onwards
2. that either economic or legal considerations will enforce a *de facto* phase-out by 1995
3. that industry will not react fast enough after CFC-113 cleaning becomes economically non-competitive to prevent excessive cleaning costs



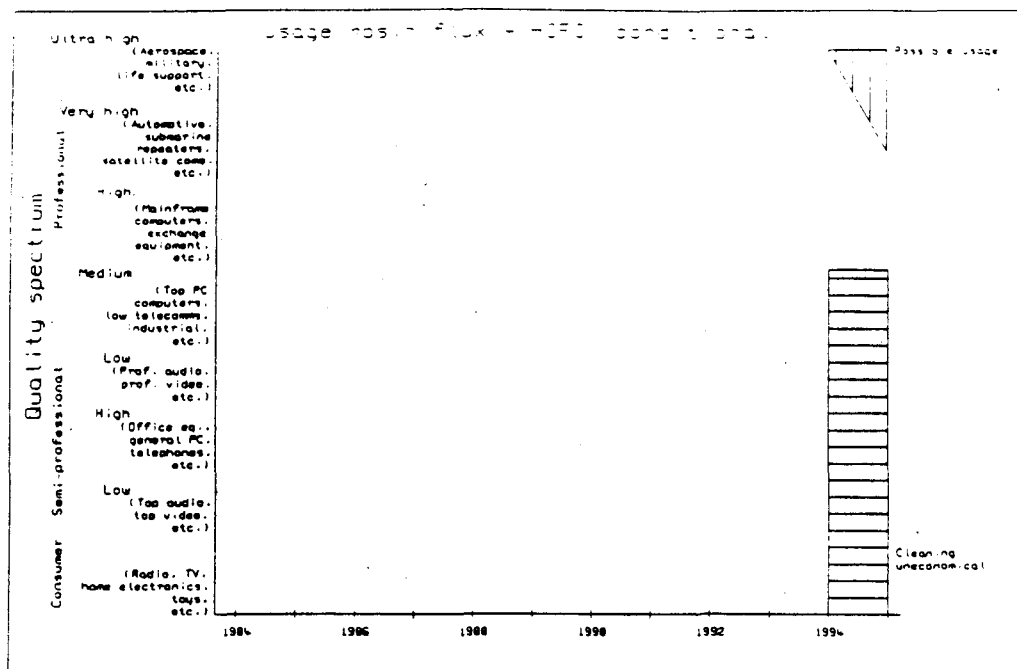


Fig. IV-8. Technical usage of HCFC solvents.

This graph is based on the following assumptions:

1. that suitable HCFC blends become commercially available by 1994
2. that their cost is likely to be 3-5 times that of CFC-113 (1989 price)
3. that they will be permitted legally (which is not certain)
4. that the toxicological aspects will render them as easy to use as CFC-113
5. that they will be permitted for use for military cleaning
6. that the ODP of the substances be less than 0.05, preferably less than 0.02

It must be realised that all these assumptions render the practical usage of this kind of solvent hypothetical, at least for the moment.

The most popular solvent is isopropanol which dissolves most components of freshly soldered rosin flux residues very well. Isopropanol is a VOC and may become subject to a special tax in the future. One of the machines uses a water azeotrope of propanol, 71.7% by weight of the alcohol. This raises the boiling point and reduces the flammability but the price to pay is very high: the solubility of the rosin is very much reduced because of hydrolysis. There seem to be three types of principle involved in these machines. The most advanced one is similar to the machines currently used for conveyorised cleaning using CFC-113, with pumped liquid phase and vapour phase cleaning and drying. The machines must be equipped with extensive security devices such as nitrogen purging, oxygen detectors, automatic water sprinklers, water scrubbers for the outgoing nitrogen, etc. The capital cost of such systems must obviously be very expensive, as such sophisticated safety precautions, including completely explosion-proof electrics, must be added to the price. Running costs for the solvent are not expensive if an external distillation unit is added to the equipment. On the other hand, the consumption of nitrogen will certainly add a considerable sum to the running costs. It would seem very unlikely that the total costs will be less than any other system but this is unconfirmed at the time of writing.

Because the process imposes important means with reasonable-to-high costs, its usage will mainly be confined to mass-production applications (Figure IV-6). In the case of mixed products, the attainable quality is sufficient for it to be used for high-reliability applications, as well.

Simpler machines are also likely to become available, but it is not yet certain that they will meet safety criteria. It should always be remembered that the flash point of isopropanol is 13°C and other alcohols in the same region. This means that any ignition source, including static discharges, will ignite alcohol at room temperature in the presence of air. An alcohol fire, as such, can be easily controlled if, by accident, such arises. What can not be controlled is the explosion that alcohol vapours or mists can provoke if ignited. Any machine that sprays alcohol on to a part is as effective as a carburettor at producing such a mist. *Caveat emptor.*

#### IV. 2. 1. 1. 6 Permitted halocarbon blends

As already discussed, none of the available halocarbon blends, not currently regulated by the Montreal Protocol, can be considered as a long-term solution at this time (Figure IV-7). They are based on blends of 1,1,1-trichloroethane and perchloroethylene with various alcohols or other derivatives and

stabilisers. On the whole, the cleaning quality obtained is probably not quite as good as with CFC-113 blends, but sufficient for many applications. Their high activity may cause damage to some components. This type of solvent blend is sometimes used as either an artisanal (see next section) cleaner or for cold cleaning in "kiss" machines (underbrushing). Those solvents based on 1,1,1-trichloroethane can also be used for vapour phase flux removal but the high temperature makes the solvent very aggressive towards many synthetic polymers. Wherever possible, it is recommended to avoid using these solvents as a replacement for CFC-113 and the more they are used for this, the more likely they will become subject to severe restrictions within the Montreal Protocol.

However, it is possible that some HCFC blends may be usable within a few years for special applications. The most promising ones, at the moment, would seem to be based on HCFC-225ca or HCFC-225cb, but it is unlikely that blends containing these substances will be available before the mid-1990s, assuming that the toxicity testing passes without problem (Figure IV-8). It is therefore utopian to defer a decision to change from CFC-113 type solvents because another similar one may become available in the indefinite future. In any case, all halocarbon solvents will, sooner or later, disappear from the market and all the new ones will be very expensive. If it is felt that no alternative exists for CFC-113 or any other halocarbon solvent for a specific application, ask for confirmation from an expert before thinking about applying for a derogation. It is very likely that an alternative exists for defluxing.

#### *IV. 2. 1. 2. Artisanal defluxing.*

Hand cleaning printed circuits is not easy under the best conditions. Fortunately, very few companies have used CFC-113 for this as the costs are so high because of the extreme volatility of the products in open trays. More popular are the chlorinated solvents blends, but the use of these also must stop within the short- to medium-term for reasons of either the environment or toxicity (or both). Isopropanol is an effective and cheap substitute for this type of cleaning, provided that it is executed, including the drying, in an efficient flameproof fume cupboard. The best method is probably saponification followed by water rinsing, but this, also, should be done in a fume cupboard but not necessarily flameproof. As the products used are hot and irritant, it is necessary to protect the operator from accidental contact with them by supplying adequate protective clothing.

#### *IV. 2. 2. Degreasing*

General degreasing can be replaced by aqueous degreasing, using one or more of the hundreds of detergents on the market. As each type of soil may require a fairly specific type, it is better to consult suppliers for advice before starting a frantic race to try to find the "best" one. See the section on detergents in Chapter II.

For degreasing with solvents other than CFC-113, the same general remarks apply as for defluxing, except that saponifiers are not applicable to removing mineral oils and greases. See the general discussion in Chapter II.

#### *IV. 2. 3. Precision cleaning*

This can be defined as cleaning to micrometre or angstrom cleanliness levels. This can be in ultra-precision mechanics, optical applications, etc. Precision cleaning, as opposed to degreasing, is always done in clean-room conditions. Traditionally, CFC-113 has been considered for many years as the ideal solvent for precision cleaning, although there has been a trend away from it in recent years for some applications. Unfortunately, there are hundreds of precision cleaning applications which would be too long to enumerate here. Each one has its particularities which renders the choice of CFC substitutes more difficult.

Also traditionally, precision cleaning has often been done with small bench-top ultrasonic tanks, presenting the worst conditions for CFC emissions. Any change must therefore involve not only the solvent, but also the method. It may transpire, for example, that some special applications may require the use of HCFCs as an alternative to CFC-113. These will be too expensive to simply let evaporate in a bench-top cleaner.

Many, probably the majority, of the applications may be replaced by some form of aqueous cleaning, using detergents. This may require systems with ultra-filtration on incoming 18 megohm-cm water with a special distribution network.

One example of the success of replacing CFC-113 by water is with hard disc drives. A large manufacturer has done this very successfully with even better results than obtained before. Inertial guidance and navigational systems for aircraft have also been successfully cleaned with aqueous systems, not only with better cleanliness but also faster results.

For particulate contamination, filtered, contaminant-free air has been found as effective as CFC-113 for semiconductor reticle masks, cathode ray tube shadow masks and electron guns. All these examples have been accomplished with cost savings.

Optical parts have also been successfully aqueously cleaned before vacuum coating or other operations. However, some glasses may be degraded by pure water or alkaline detergents. Tests are therefore essential. Drying of optical parts is often critical and CFC-113 has been the preferred method (see next section).

Many other applications have been converted from CFC-113 to some other method but there are a few others for which no replacement technology exists, as yet. For these, exceptional cases, it is hoped that one of the new HCFCs or SFP may offer the solution or solutions. In the meanwhile, CFC-113 will continue to be used provided that utmost measures are taken to minimise losses.

For fuller details of the applications mentioned in this section and other precision cleaning applications.

reference can be made to the Summary Report of the UNEP Solvents Technical Options Committee.

#### *IV. 2. 4. Drying by solvents*

CFC-113 has been used in two ways for precision drying. The first is by pumping pure CFC-113 upwards over the article to be dried. Any water will be displaced upwards and will flow over a weir into a separator. The second method uses a CFC-113/surfactant mixture which emulsifies the water into a micellar solution. In both cases, the drying is completed by passing the part through a conventional CFC-113 vapour phase degreasing process.

Hot air blasting has replaced these successfully in many applications, including the disc drive cleaning mentioned in the previous section. It is applicable also to drying some optical parts.

Another mechanical method which can be very effective without high energy requirements is by centrifuging. Small mechanical parts with an intricate shape, including blind holes, can usually be very successfully dried in suitable equipment. The cost of centrifugal drying is extremely small.

Evaporative drying is also useful but is costly and energy-consuming and may leave drying marks on ultra-precision parts.

There are two methods of chemical drying which are successfully applied. They are analogous to the two CFC-113 methods. The first is to use a downward current of certain aromatic hydrocarbons in a tank with a perforated false bottom. The water is washed off and carried downwards where it can collect under the false bottom and periodically drained via a tap. This is followed by a second, possibly a third, similar tank, from which the water-free part can be taken out and placed in a drying compartment which will collect the solvent vapours. This method is frequently used to prevent oxidation of base metals after a chemical cleaning operation, where a water-wet part on exposure to air will cause almost instantaneous reoxidation. It can also be used to lacquer chemically cleaned parts as a temporary protection barrier: it is sufficient to add a small percentage of compatible lacquer to the final solvent bath. The most popular solvent for this application is toluene, but only pure grades should be selected. Many commercial toluenes contain considerable quantities of other hydrocarbons which may be more hydrophilic, destroying the water displacement properties.

The other method is to use two or three successive baths of isopropanol. The water will dissolve readily in this alcohol. The problem is, as in the case of CFC-113/surfactant method, how to remove the water from the solution in order to continue using it. The answer is to pass the alcohol continuously through a narrow-range zeolite molecular sieve which will selectively adsorb the water. The sieve will require frequent regeneration and replacement.

Both these methods have the disadvantage that low-flash point flammable solvents are used and the appropriate safety measures must be taken.

#### *IV. 2. 5. Textile dry cleaning*

This is a difficult situation for which there is no ready-made answer. Most dry-cleaning is done today using perchloroethylene. Anyone entering a dry-cleaning shop must be aware, from the smell, that the operators are exposed to solvent vapours. Questions are being asked as to the toxicity of these vapours.

A few, modern, machines use 1,1,1-trichloroethane, which has a high ODP and is also under question for its toxicity.

Some garments, notably suedes, leathers and very delicate textiles, can only be cleaned in CFC-113, whose ODP is unacceptable, or a few mild hydrocarbon solvents.

The latter method uses a petroleum distillate known as Stoddard solvent. This is a white spirit which is reasonably effective and usable for most garment types. Its major disadvantage is its flammability.

It is possible that one or more of the new HCFC solvents may present some hope for special cases but the question must be asked whether the public will be willing to pay the price of cleaning with them, unless new dry-to-dry machines can be designed with quasi-zero losses. Another factor that must not be ignored is that many operators, especially in smaller establishments, try to increase the throughput by removing clothes from the machines before they are dry. New machine designs should have an interlock preventing such misuse. It must not be forgotten that these new solvents, if they become acceptable with a very low ODP and a low toxicity, may cost twenty times the price of perchloroethylene.

It is recommended that all garment manufacturers should be made aware of these changes that will be expected to take place over the next decade, so that they can adjust to the requirements of how their products may be cleaned.

As stated at the beginning of this section there is no ready-made answer: even less is there a miracle answer and both the cleaners and the public must be reconciled to a forced change in their habits and probably increased costs.

#### *IV. 2. 6. Particle removal*

Because of its high density, CFC-113 allows non-metallic particles to be floated off parts. Excellent results have been obtained with good cost reductions by simple high-velocity ultra-filtered air jets. See section IV.2.3.

#### *IV. 2. 7. Medical applications*

The most important medical application of CFC-113 is cleaning needles before sterilisation. Short, wide bore needles present no specific problems if they are one of the all-metal Luer lock or slip types; almost any cleaning method is usable. Plastic hub throw-away

types must use a cleaning method compatible with the plastic used. This rules out stronger organic solvents. The aspect ratio of some needles is most unfavourable. There is no difficulty in causing an aqueous cleaner to enter such needles. The capillary effect will do it automatically. The problem is how to rinse it out afterwards.

One suggestion is to robotise a system which takes each needle individually, after bulk cleaning of the exterior, and mounts it on one of a series of Luer lock receptacles through which a high pressure detergent solution is passed. This is replaced by high pressure, pure water in sufficient volume to ensure that no detergent remains in the bore. Finally, clean, hot air is blown through the bores to remove the water after which the robot removes the needles for the next process stage. This technique could not be applied to slip needles unless a retention jig holds them in place, as the pressures involved would shoot them off the adapters.

Other medical cleaning with CFC-113 is performed to many surgical implants, implements and instruments. In most cases, there is little reason for this choice other than simple convenience. However, where certain plastics are used, notably plasticised flexible pipes, there is a certain concern that inherently solvent-soluble plasticisers may leach into vital fluids. For this reason, CFC-113 flushing is used, this solvent being unlikely to degrade the polymers themselves. It has been found that a 50% by volume alcohol (ethanol)/water mixture will do the same work. A subsequent rinse with pure or 90% alcohol will aid drying by warm air. The resultant pipes will be sufficiently sterile for most applications if the outside is treated at the same time. Ethylene oxide sterilisation of plasticised polymers is usually undesirable.

Ethylene oxide is a popular sterilising compound. It is a gas at room temperature (boiling point variously given at 10.5° and 13.2°C) and forms a very explosive mixture with air. It is soluble in most solvents but, being highly reactive, it is difficult to conserve it. For this reason, it is sometimes used in mixture with an ultra-pure grade of CFC-113 which acts as an inert liquid vehicle. Water can also act as a vehicle, but it must be ultra-pure and neutral. Ethylene oxide will react with many acids and bases so that small excursions of pH are inadmissible. It is foreseen that perfluorocarbon and hydrofluorocarbon vehicles, which are generally inert to vital fluids, could replace CFC-113 for this application, these having zero ODP. For gaseous sterilisation, carbon dioxide is a good vehicle.

#### IV. 2. 8. *Vehicles for lubricants and adhesives*

CFC-113 is occasionally used as a vehicle for lubricants or as a corrosion inhibitor during cutting operations. One example is for the lubrication of ultra-miniature ball bearing assemblies used for instrumentation. The penetration of even a thin oil can not be ensured, so that the oil is dissolved in a pure-grade, inert solvent. CFC-113 is the usual choice. The ball race is sprayed with this mixture which penetrates to leave a microscopic oil film on all the surfaces after the solvent has evaporated. Many solvents could be used for this purpose. For space applications, low vapour pressure oils are essential and these are perfluorinated lubricants which are insoluble in all the usual non-fluorinated solvents. It is hoped that one of the HCFC or HFC products in development will be able to replace CFC-113 as a vehicle for this specific application.

As one example of a cutting aid, during drilling of blind rivet holes in aircraft manufacture, they are sprayed with CFC-113 to flush out possible corrosion-causing products and to cool the cutting tool. The rivet slug is inserted while the hole is still wet. It is probable that the CFC-113 may be able to be replaced by an HFC solvent or an HFC/HCFC blend, both of which will be even more non-reactive.

CFC-113 is occasionally used for the manufacture of speciality self-adhesive tapes, although it is too expensive for extensive use. 1,1,1-trichloroethane is more commonly used but this is also ozone-depleting and can only be used for applications where adequate ventilation and solvent recovery can be ensured. Water based systems have been developed for most tape types but suffer from the disadvantage of slower production rates. For ordinary adhesives, resins, lacquers and paints, it is rare for halocarbons to be an essential vehicle and there is a distinct tendency towards solvent-free or water-vehicled systems. This is a rapidly advancing area of technology and it is foreseen that very few applications will obligatorily require ozone-depleting vehicles by the mid-1990s. What is more is that far fewer will require VOC solvents, either.

Another vehicle application is for single page deacidification. Books which must be conserved for over, say, 100 years, may be mass treated using a suspension of suitable chemicals in liquid CFC-12. Single pages are more easily treated with such a mixture in CFC-113. As the major quality required with such a vehicle is complete inertness, it is easily envisaged that one of the perfluorocarbons would be ideal for this purpose.

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## Appendix A: Properties of halocarbons.

The following table gives the most up-to-date estimations of the boiling point, the ozone depleting potential, the global warming potential and the folded e lifetime of the principal halocarbons relating to cleaning and similar applications. Boiling point apart, these figures are calculated from theoretical principles using mathematical modelling. It should be noted that there are several algorithms used for such models and the results do not always agree. It is therefore possible that small differences may be observed between what

would seem to be the same information from different sources. In practical terms, these differences are negligible, as the premises used in making the models are not always very clearly defined.

If no figure is given in the following tables, it means that the information is not available. If a figure is given between round brackets (), it means that this figure is an estimation, between square brackets [], it means that this figure is little better than an inspired guess and is subject to confirmation.

Designation	Formula	Boiling point	ODP	GWP	t <sub>1/2</sub>
<b>1. CFCs</b>					
CFC-11	CFC1 <sub>3</sub>	+24	1.0	1.0	74
CFC-12	CF <sub>2</sub> Cl <sub>2</sub>	-30	1.0	3	111
CFC-112	CCl <sub>2</sub> F-CCl <sub>2</sub> F	+92	[0.7]		
CFC-112a	CCl <sub>3</sub> -CClF <sub>2</sub>				
CFC-113	CCl <sub>2</sub> F-CClF <sub>2</sub>	+48	0.8	1.3	100
CFC-113a	CCl <sub>3</sub> -CF <sub>3</sub>	+46	0.85		
<b>2. HCFCs</b>					
HCFC-21	CHCl <sub>2</sub> F	+9			
HCFC-22	CHClF <sub>2</sub>	-41	0.05	0.35	20
HCFC-122	CClF <sub>2</sub> -CHCl <sub>2</sub>	+72			
HCFC-123	CHCl <sub>2</sub> -CF <sub>3</sub>	+29	(0.02)	0.02	
HCFC-132b	CH <sub>2</sub> Cl-CClF <sub>2</sub>	+47			
HCFC-141b	CH <sub>3</sub> -CCl <sub>2</sub> F	+32	(0.1)	0.09	
HCFC-225ca	CF <sub>3</sub> -CF <sub>2</sub> -CHCl <sub>2</sub>	+51	[0.05]		
HCFC-225cb	CClF <sub>2</sub> -CF <sub>2</sub> -CHClF	+56	[0.05]		
HCFC-226	CHF <sub>2</sub> -CF <sub>2</sub> -CClF <sub>2</sub>	+21			
<b>3. Halons</b>					
1211	CF <sub>2</sub> BrCl	0	3.0		25
1301	CF <sub>3</sub> Br	-60	10.0		110
<b>4. Other halocarbons</b>					
1,1,1-trichloroethane	CCl <sub>3</sub> -CH <sub>3</sub>	+74	0.15	0.024	7
Carbon tetrachloride	CCl <sub>4</sub> *	+77	1.2	0.35	60
Chloroform	CHCl <sub>3</sub> **	+60			
Perchlorethylene	CCl <sub>2</sub> =CCl <sub>2</sub> **	+121	[<0.01]		
Trichlorethylene	CCl <sub>2</sub> =CHCl**	+87	[<0.01]		

\* Known carcinogen

\*\* Suspected carcinogen

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## **L. Useful lists of addresses**

### **L. 1. Government and official departments**

Federal Office for Environment, Forests and Landscape (BUWAL)  
Hallwylstrasse 4  
3003 Berne  
Telephone : 031-61 93 49

Federal Office for Public Health  
Toxic Products Division  
Bollwerk 27  
3001 Berne  
Telephone 031-61 96 40

Swiss National Accident Insurance Fund  
6002 Lucerne  
Telephone: 041-21 51 11

### **L. 2. Private sector organisations**

#### **L. 2. 1. Chemical Industry**

Schweizerische Gesellschaft für Chemische Industrie (SGCI)  
Nordstrasse 15  
8035 Zürich  
Telephone: 01-363 10 30

#### **L. 2. 2. Electronics industry:**

Groupement de l'Electronique de Suisse Occidentale (GESO)  
place de la Gare 10  
1001 Lausanne  
Telephone: 021-23 47 26

Schweizerisches Automatik Pool (SAP)  
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8022 Zürich  
Telephone 01-202 59 50

Verein Schweizerischer Maschinenindustrieller (VSM)  
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8032 Zürich  
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#### **L. 2. 3. Precision industry:**

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VSM (see above)



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# CFC ALLIANCE

## SPECIAL BULLETIN

2011 Eye Street, N.W., Fifth Floor, Washington, D.C. 20006

December, 1989

### THE NEW CFC TAX

The Omnibus Budget Reconciliation Act of 1989 imposes a new excise tax on certain ozone-depleting chemicals and on imports of products made with or containing such chemicals. The Treasury Department and the IRS have begun the process of implementing the new tax and expect to publish guidance for taxpayers on a variety of issues relating to the tax before the end of 1989.

The following is an explanation of the new tax. The explanation is based on the best information currently available. Until the IRS publishes guidance on the tax, however, a number of the issues discussed in this paper will remain uncertain. Before making business decisions that could be affected by the resolution of these issues, taxpayers should seek independent professional advice.

#### Taxable Chemicals

The bill defines eight chemicals as ozone-depleting chemicals and applies the new tax to them. The eight chemicals are those subject to production limitations under the Montreal Protocol and the implementing EPA regulations. The chemicals are the following:

CFC-11	(trichlorofluoromethane)
CFC-12	(dichlorodifluoromethane)
CFC-113	(trichlorotrifluoroethane)
CFC-114	(1, 2-dichloro-1, 1, 2, 2-tetrafluoroethane)
CFC-115	(chloropentafluoroethane)
Halon-1211	(bromochlorodifluoromethane)
Halon-1301	(bromotrifluoromethane)
Halon-2402	(dibromotetrafluoroethane)

Additions to this list of taxable chemicals can be made only by Congress. Therefore if other chemicals become subject to the Montreal Protocol or to other production limitations, those chemicals would not be subject to the tax unless Congress takes legislative action.

The bill excludes from the definition of ozone-depleting chemicals those chemicals produced outside the United States and not imported into the United States. Thus, ozone-depleting chemicals produced outside the United States by a U.S. taxpayer are not subject to the tax unless imported into the United States.

#### Taxable Events

The tax is imposed in three instances:

- Sale or use by manufacturer, producer, or importer. The principal taxable event is the sale of ozone-depleting chemicals after December 31, 1989, by the manufacturer, producer, or importer of the chemicals. The tax also will apply where the manufacturer, producer, or importer of ozone-depleting chemicals uses the chemicals after December 31, 1989, instead of selling them.
- Sale or use of imported products for which ozone-depleting chemicals are production material. In order to reach indirect imports of ozone-depleting chemicals, the tax applies to the sale or use by an importer, after December 31, 1989, of imported products for which any ozone-depleting chemical is used as material in the manufacture or production process.
- Ownership of floor stocks. The tax is imposed on stocks of ozone-depleting chemicals owned by any person (other than the manufacturer, producer or importer of the chemicals) on January 1, 1990 if the chemicals are held for sale or for use in further manufacture. The tax also is imposed on stocks of taxable chemicals held for the same purposes on January 1 of each year 1991 through 1994 if the tax rate for such chemicals increases on that date.

These three taxable events are explained in more detail below.

#### Persons Required To Remit the Tax to the IRS

- Regular tax on sale or use. The producer, manufacturer or importer of the chemicals is liable to the IRS for

the regular tax upon the sale or use of the chemicals by such person.

- **Imported products.** The importer of taxable imported products is liable to the IRS for the tax upon the sale or use of such products by the importer.
- **Floor stocks.** The owner of the chemicals on January 1 of each applicable year is liable to the IRS for the floor stocks tax.

#### Calculation of Amount of Tax

The amount of the tax is determined under the following formula:

$$\text{Tax} = \frac{\text{Base Tax}}{\text{Pounds of}} \times \frac{\text{Ozone-Depletion}}{\text{Amount X Factor X Chemicals}}$$

This formula applies in all instances and to all ozone-depleting chemicals except, as described in more detail below, halons and chemicals used in the manufacture of rigid foam insulation. Thus, the formula applies in the normal case of the sale or use of chemicals by the producer, in the case of the floor stocks tax, and in the case of imported products. In the latter case, the formula applies to the quantities of ozone-depleting chemicals used as material in the manufacture or production of the imported products.

#### Base Tax Amount

The bill designates a specific base tax amount for the years 1990-1994 and provides for an increase of 45 cents for each year beyond 1994. The base amounts through 1999 are as follows:

1990	\$ 1.37	1995	\$ 3.10
1991	1.37	1996	3.55
1992	1.67	1997	4.00
1993	2.65	1998	4.45
1994	2.65	1999	4.90

#### Ozone-Depletion Factors

Each ozone-depletion factor represents the comparative potential ozone-depletion resulting from the same weight of a given chemical. The factors are as follows:

CFC-11	1.0	Halon 1211	3.0
CFC-12	1.0	Halon 1301	10.0
CFC-113	0.8	Halon 2402	6.0
CFC-114	1.0		
CFC-115	0.6		

The ozone-depletion factors designated in the statute are those specified in the Montreal Protocol. Like the list of

chemicals subject to the tax, changes in the ozone-depletion factors can result only from Congressional action.

#### Application of the Tax on Sales by the Producer

- In the case of the regular tax on sales of ozone-depleting chemicals by the producer, the bill applies the tax to the quantity actually "sold." Thus, for example, under the plain meaning of the bill, tank truck heels and other similar quantities are not taxable until and unless they are sold.
- Although the bill is silent on the precise calculation of a producer's taxable sales volume, the normal procedure in the case of other federal excise taxes is to calculate the volume on a net basis -- that is, gross sales volume less returns and adjustments. An IRS official has indicated informally that this normal calculation should apply.
- In calculating the tax, fractions of pounds of chemicals are not rounded. The partial pounds are multiplied by the same ozone-depletion factor and base tax amount as whole pounds.
- The bill is silent on the issue of when a sale is deemed to occur for purposes of the tax. In the absence of specific rules, general tax rules probably would apply. Under the general rules, the IRS examines the substance, not the form, of a transaction to determine whether a sale has occurred. In such an examination, a sale generally is deemed to occur when the benefits and burdens of ownership are transferred, not merely when paper evidence of the sale is executed. This standard also would be relevant for determining ownership of taxable chemicals for purposes of the floor stocks tax.

#### Application of the Tax on Imported Products

- For imported products, the bill provides that the tax is equal to the amount of tax which would be imposed if the chemicals that were used as material in the manufacture or production of the products had been sold in the United States.
- To calculate the quantity of chemicals used as material in the manufacture or production of imported products, the Secretary of the Treasury is directed in the bill to choose one of three methods:

**A. Data Provided by Importer.** The Secretary can accept data the importer supplies showing the volume of chemicals used as material in the production process.

**B. Domestic Industry Norms.** If the importer fails to provide sufficient data, the Secretary can calculate the chemical amounts based on standards of use in the equivalent domestic industry.

C. **Five Percent of Appraised Value.** The bill also provides that, if necessary, the Secretary can bypass the foregoing procedures and impose a tax equal to five percent of the value of the imported product. This provision is intended to serve primarily as an incentive for importers to come forward with evidence as to the amount of ozone-depleting chemicals in their products.

- Treasury Department economists have begun work to compile a list of imported products for which ozone-depleting chemicals are used in the production process, and to determine the average quantity of the chemicals so used in each product.
- The Secretary of the Treasury also is authorized to prescribe regulations exempting products that use de minimis amounts of ozone-depleting chemicals as material in the production process. However, no such de minimis exception applies if the ozone-depleting chemicals are used for purposes of refrigeration or air conditioning, creating an aerosol or foam, or manufacturing electronic components.

#### **Application of the Floor Stocks Tax**

As stated previously, the floor stocks tax is imposed on January 1 of each year 1990 through 1994 on any ozone-depleting chemical owned by any person (other than the manufacturer, producer, or importer) on such date and held for sale or for use in further manufacture. The amount of the floor stocks tax is as follows:

**1990:** The amount of tax that would have been imposed if the chemical had been sold during 1990.

**1991-1994:** The excess of the tax that would have been imposed on the sale of the chemical by the manufacturer, producer or importer on January 1 of that year, over the tax, if any, previously imposed on the chemical.

The floor stocks tax is applicable to wholesalers, retailers, distributors, contractors, and any other type of business that holds stocks of ozone-depleting chemicals for sale or for use in further manufacture.

The bill contains no exemption from the floor stocks tax for small businesses or for businesses that hold de minimis quantities of chemicals. The IRS is considering the possibility of instituting exemptions administratively.

The tax applies only to stocks of chemicals held for sale or for use in further manufacture. However, the bill does not contain a definition of the term "use in further manufacture." The term probably is best read as denoting direct, proximate use in an actual manufacturing process. (If the bill had been intended to have a broader meaning, it probably would have been drafted to apply to stocks held "by" a manufacturer or simply "by" any business.) An IRS official has informally agreed with this conclusion; it is unclear, however, as to whether the IRS will publish any detailed guidance on this issue in the near future.

- Assuming the above interpretation of the term "use in further manufacture" is correct, then, as an example, stocks of chemicals held for use as a solvent in a manufacturing process probably would be taxable, as would stocks of chemicals held by a manufacturer of refrigeration equipment for use as a refrigerant in equipment made by the company. However, stocks of chemicals held for use other than a direct use in a manufacturing process -- for example, stocks of chemicals held for use in cooling systems for a factory -- probably would not be taxable. Stocks of chemicals held for use in routine factory maintenance also might not be taxable.
- The bill is drafted to apply the floor stocks tax only to ozone-depleting chemicals themselves and not to products that contain ozone-depleting chemicals (in contrast with the treatment of imports). Thus, generally speaking, the IRS probably does not have the power to apply the tax to such products. In administering the tax, however, the IRS probably does have the power to prevent taxpayers from abusing the purpose of the floor stocks tax through abnormal business practices.
- The bill is silent as to the tax treatment of chemical blends consisting partly of taxable chemicals and partly of non-taxable chemicals. The IRS also has not indicated any position on this issue.
- The IRS is expected to publish guidance on the payment procedures for the floor stocks tax by the end of the year. As in virtually all other federal taxes, it is expected that the responsibility for reporting and paying the tax will be the taxpayer's. In other words, the taxpayer's legal liability to pay the tax arises under the legislation and will not depend on identification or contact of the taxpayer by the IRS. According to an IRS official, the floor stocks tax probably will be payable on IRS form 720, which is the excise tax return. The IRS will revise the form to accommodate the floor stocks tax.
- The following are examples of the computation of the floor stocks tax:
  - A. A dealer holds 200 pounds of CFC-115 for sale on January 1, 1990. The floor stocks tax will equal \$164.40 ( $\$1.37 \times 0.6 \times 200$ ).
  - B. ABC Company holds 300 pounds of CFC-12 on January 1, 1993 for use in further manufacture. ABC Company purchased the chemical in June 1992. The floor stocks tax will equal \$294. That amount is the difference between the tax that would be imposed if the initial sale of the chemical had occurred on January 1, 1993, \$795 ( $\$2.65 \times 1.0 \times 300$ ) and the tax previously imposed in 1992, \$501 ( $\$1.67 \times 1.0 \times 300$ ).
  - C. A dealer holds 400 pounds of halon 1211 for sale on January 1, 1990. No floor stocks tax is imposed because, under the bill, halon 1211 is not treated as an ozone-depleting chemical until January 1, 1991.
  - D. A dealer holds 400 pounds of halon 1211 for sale on January 1, 1991. The floor stocks tax will equal \$100. That amount is the difference between the tax that would be imposed if the initial sale of the

halon had occurred on January 1, 1991, \$100 (25 cents/lb. x 400 lbs.) and the tax already imposed, \$0.

E. XYZ Company holds 500 pounds of halon 2402 on January 1, 1994. XYZ Company purchased the chemical in 1992. The floor stocks tax will equal \$7,825. That amount represents the difference between the tax that would be imposed if the initial sale of the chemical had occurred on January 1, 1994, \$7,950 ( $\$2.65 \times 6.0 \times 500$ ) and the tax previously imposed on the sale of the halon 2402 to XYZ Company in 1992, \$125 (25 cents/lb. x 500 lbs.) Note: No floor stocks tax was imposed in January 1, 1993 because the tax rate for halons, 25 cents/lb., remained the same.

### **Exemptions from the Tax**

The bill provides five full or partial exemptions from the tax, as follows:

- Chemicals produced from recycling.
- Chemicals used as feedstocks.
- Exports.
- Halons.
- Chemicals used in the manufacture of rigid foam insulation.

These exemptions apply in all instances where the tax applies (i.e., the regular tax on sale or use, the tax on imported products, and the floor stocks tax). The exemptions are explained below. Note that no exemption exists for sales of chemicals to a federal, state, or local governmental agency.

### **Recycling exemption**

- The bill fully and permanently exempts from the tax chemicals diverted or recovered in the United States as part of a recycling process. In effect, this exemption simply treats a recycling operation as not production or manufacture of ozone-depleting chemicals for purposes of the tax.
- Chemicals recovered by the original producer of the chemicals from loading operations, tank truck heels, and similar sources probably do not qualify for the recycling exemption (assuming such chemicals had not previously been taxed). Such chemicals probably would be treated as normal taxable chemicals when sold by the producer thereof.

### **Feedstock Exemption**

- The bill also fully and permanently exempts from the tax any ozone-depleting chemical used and entirely consumed in the manufacture or production of any other chemical.
- The bill implements the feedstock exemption by permitting sales of chemicals for feedstock use to be made tax-free. The exemption applies both on direct sales from

the producer to the exempt user and on sales to a wholesaler or distributor who intends to resell to the exempt user.

- The exemption for of ozone-depleting chemicals for feedstock use applies only if the parties to the transactions meet registration requirements to be prescribed by the Secretary of the Treasury. See the separate discussion of the registration requirements below.
- If tax is actually paid on chemicals used as a feedstock, the user is permitted to obtain a refund of the tax from the IRS.

### **Export Exemption**

- The bill provides producers of ozone-depleting chemicals with a partial exemption for exports. The exemption consists of a base portion and an additional portion.
- The base portion of the export exemption is the percentage of the producer's yearly production equal to the percentage of production the producer exported in 1986.
- The percentage calculation of the base portion is made using ozone-depletion factor adjusted pounds, as follows:  
$$\text{Percentage Allowed} = \frac{1986 \text{ Ozone-depletion factor adjusted pounds exported}}{1986 \text{ Ozone-depletion factor adjusted pounds produced}}$$

- Ozone-depletion factor adjusted pounds (ODFAPs) are calculated by multiplying the number of pounds of each chemical (pounds exported if calculating the numerator, pounds produced if calculating the denominator) by the chemical's ozone-depletion factor. The ODFAPs for each of the eight chemicals are then added together to determine the total ozone-depletion factor adjusted pounds.
- The bill provides that the determination of the level of exports of each producer for 1986 is to be determined based on data published by the EPA.
- The second part of the export exemption relates to production increases destined for export. Under the Montreal Protocol and implementing rules, the EPA is authorized to grant additional production allowances to U.S. producers for the explicit purpose of export. Those exports are exempt from the tax.
- The bill indicates in a cross reference that producers of ozone-depleting chemicals have the discretion to transfer part of their export exemptions to third parties.
- Ozone-depleting chemicals used as a material in the manufacture of products that are exported are not exempt from tax under the bill.

### **Halon Exemption**

- Halons receive favorable treatment through 1993. After 1993, they are treated the same as all other ozone-depleting chemicals. The treatment for 1990-1993 is as follows:

1990: All sales and uses of halons are exempt from tax. The term "ozone-depleting chemical" does not include halon-1211, halon-1301 or halon-2402 for the year 1990.

1991-93: Taxed at a rate of 25 cents per pound, without adjustment for ozone-depletion factor. (Note: the bill actually expresses this preferential rate in terms of varying percentages of each year's regular tax rate, rather than as a 25-cent-per-pound rate.)

### **Rigid Foam Insulation Exemption**

- Chemicals used or sold for use in the manufacture of rigid foam insulation receive preferential treatment through 1993.
- Proceedingly, this preferential treatment is structured in precisely the same manner as the feedstock exemption, so that producers are permitted to sell chemicals at the preferential rate for use in making rigid foam insulation. Such sales can be made both to direct users and to wholesalers and distributors who intend to resell to rigid foam makers. As in the feedstock exemption, the IRS will impose registration requirements that must be followed in order for sales to be permissible at the preferential rate. (See the discussion below.) In cases where sales are not made at the preferential rate, purchasers of chemicals who use the chemicals in the making of rigid foam insulation are permitted to obtain a refund of the excess tax paid.
- The preferential treatment for chemicals used in the manufacture of rigid foam insulation is as follows:

1990: Complete exemption.

1991-93: Taxed at a rate of 25 cents per pound, without adjustment for ozone-depletion factor. (Note, as in the case of the halon exemption, the bill actually expresses this preferential rate in terms of varying percentages of each year's regular tax rate, rather than as a 25-cent-per-pound rate).

The bill does not define the term "rigid foam insulation." According to an IRS official, the IRS is aware of several issues that have arisen in interpreting the term, but has not yet resolved the issues.

### **Registration Requirement for Feedstock and Rigid Foam Exemptions**

The IRS is expected to provide guidance by the end of the year as to the registration requirement for the feedstock and rigid foam exemptions.

According to an IRS official, it is likely that, at least for the short-term, the IRS will prescribe a system of exemption certificates in lieu of a comprehensive system for actually registering producers and purchasers with the IRS.

- An exemption certificate would be, essentially, a declaration by the purchaser of chemicals that such chemicals

will be put to a tax-preferred use. The IRS would prescribe the form and content of the certificate and would require that the certificate be signed under penalty of perjury. The purchaser would prepare and sign the certificate and deliver it to the producer.

- Once received by the producer in proper form, the certificate would entitle the producer to sell chemicals to the purchaser at the preferential tax rate applicable to the use declared in the certificate. The producer would not need to exercise judgment as to whether the purchaser was legally entitled to the preferential rate and would not be subject to an IRS challenge for having relied upon the certificate in failing to collect the full tax from the purchaser.
- The purchaser would be fully subject to IRS audit to determine the validity of its claim for a preferential tax rate, and IRS penalties would apply in the case of improper claims.

### **Payment Schedules**

- The initial payment for taxes on the sale or use of ozone-depleting chemicals and imported products is due April 1, 1990.
- The IRS will issue guidance mandating a payment schedule beyond April 1, 1990. The likely period will be semi-monthly with the taxes required to be deposited within nine days after the end of each semi-monthly period.
- The floor stocks tax is due April 1 of each year.

### **IRS Enforcement**

- The normal IRS tools for enforcing other taxes apply to the new CFC tax. For example, the IRS will have the authority to impose penalties ranging from five percent of underpayments for negligence, to 75 percent of underpayments for civil fraud, and to fines or imprisonment for criminal fraud.
- The IRS probably will pay particular attention to policing the exemptions from the tax. In other words, the IRS will seek to ensure that chemicals purchased tax-free for an exempt purpose are so used.

*This document was prepared by James C. Gould, a partner in the Washington, D.C. law firm of Vinson & Elkins.*



OMNIBUS BUDGET RECONCILIATION ACT  
OF 1989

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CONFERENCE REPORT

TO ACCOMPANY

H.R. 3299



NOVEMBER 21, 1989.—Ordered to be printed

**"Subchapter D—Ozone-Depleting Chemicals, Etc.**

"Sec. 4681. Imposition of tax.  
"Sec. 4682. Definitions and special rules.

**"SEC. 4681. IMPOSITION OF TAX.**

"(a) **GENERAL RULE.**—There is hereby imposed a tax on—

"(1) any ozone-depleting chemical sold or used by the manufacturer, producer, or importer thereof, and

"(2) any imported taxable product sold or used by the importer thereof.

"(b) **AMOUNT OF TAX.**—

"(1) **OZONE-DEPLETING CHEMICALS.**—

"(A) **IN GENERAL.**—The amount of the tax imposed by subsection (a) on each pound of ozone-depleting chemical shall be an amount equal to—

"(i) the base tax amount, multiplied by

"(ii) the ozone-depletion factor for such chemical.

"(B) **BASE TAX AMOUNT FOR YEARS BEFORE 1995.**—The base tax amount for purposes of subparagraph (A) with respect to any sale or use during a calendar year before 1995 is the amount determined under the following table for such calendar year:

"Calendar year:	Base tax amount
1990 or 1991.....	\$1.37
1992.....	1.67
1993 or 1994.....	2.65.

"(C) **BASE TAX AMOUNT FOR YEARS AFTER 1994.**—The base tax amount for purposes of subparagraph (A) with respect to any sale or use during a calendar year after 1994 shall be the base tax amount for 1994 increased by 45 cents for each year after 1994.

"(2) **IMPORTED TAXABLE PRODUCT.**—

"(A) **IN GENERAL.**—The amount of the tax imposed by subsection (a) on any imported taxable product shall be the amount of tax which would have been imposed by subsection (a) on the ozone-depleting chemicals used as materials in the manufacture or production of such product if such ozone-depleting chemicals had been sold in the United States on the date of the sale of such imported taxable product.

"(B) **CERTAIN RULES TO APPLY.**—Rules similar to the rules of paragraphs (2) and (3) of section 4671(b) shall apply.

**"SEC. 4682. DEFINITIONS AND SPECIAL RULES.**

"(a) **OZONE-DEPLETING CHEMICAL.**—For purposes of this subchapter—

"(1) **IN GENERAL.**—The term 'ozone-depleting chemical' means any substance—

"(A) which, at the time of the sale or use by the manufacturer, producer, or importer, is listed as an ozone-depleting chemical in the table contained in paragraph (2), and

"(B) which is manufactured or produced in the United States or entered into the United States for consumption, use, or warehousing.

"(2) **OZONE-DEPLETING CHEMICALS.**—

"Common name:	Chemical nomenclature:
CFC-11.....	trichlorofluoromethane
CFC-12.....	dichlorodifluoromethane
CFC-113.....	trichlorotrifluoroethane
CFC-114.....	1,2-dichloro-1,1,2,2-tetra-fluoroethane.
CFC-115.....	chloropentafluoroethane
Halon-1211.....	bromochlorodifluoromethane.
Halon-1301.....	bromotrifluoromethane

"Common name:

Halon-2402

Chemical nomenclature:

dibromotetrafluoroethane.

"(b) **OZONE-DEPLETION FACTOR.**—For purposes of this subchapter, the term 'ozone-depletion factor' means, with respect to an ozone-depleting chemical, the factor assigned to such chemical under the following table:

Ozone-depleting chemical:	Ozone-depletion factor:
CFC-11	1.0
CFC-12	1.0
CFC-113	0.8
CFC-114	1.0
CFC-115	0.6
Halon-1211	3.0
Halon-1301	10.0
Halon-2402	6.0

"(c) **IMPORTED TAXABLE PRODUCT.**—For purposes of this subchapter—

"(1) **IN GENERAL.**—The term 'imported taxable product' means any product (other than an ozone-depleting chemical) entered into the United States for consumption, use, or warehousing if any ozone-depleting chemical was used as material in the manufacture or production of such product.

"(2) **DE MINIMIS EXCEPTION.**—The term 'imported taxable product' shall not include any product specified in regulations prescribed by the Secretary as using a de minimis amount of ozone-depleting chemicals as materials in the manufacture or production thereof. The preceding sentence shall not apply to any product in which any ozone-depleting chemical is used for purposes of refrigeration or air conditioning, creating an aerosol or foam, or manufacturing electronic components.

"(d) **EXCEPTIONS.**—

"(1) **RECYCLING.**—No tax shall be imposed by section 4681 on any ozone-depleting chemical which is diverted or recovered in the United States as part of a recycling process (and not as part of the original manufacturing or production process).

"(2) **USE IN FURTHER MANUFACTURE.**—

"(A) **IN GENERAL.**—No tax shall be imposed by section 4681—

"(i) on the use of any ozone-depleting chemical in the manufacture or production of any other chemical if the ozone-depleting chemical is entirely consumed in such use.

"(ii) on the sale by the manufacturer, producer, or importer of any ozone-depleting chemical—

"(I) for a use by the purchaser which meets the requirements of clause (i), or

"(II) for resale by the purchaser to a second purchaser for a use by the second purchaser which meets the requirements of clause (i).

Clause (ii) shall apply only if the manufacturer, producer, and importer, and the 1st and 2d purchasers (if any), meet such registration requirements as may be prescribed by the Secretary.

"(B) **CREDIT OR REFUND.**—Under regulations prescribed by the Secretary, if—

"(i) a tax under this subchapter was paid with respect to any ozone-depleting chemical, and

"(ii) such chemical was used (and entirely consumed) by any person in the manufacture or production of any other chemical,

then an amount equal to the tax so paid shall be allowed as a credit or refund (without interest) to such person in the same manner as if it were an overpayment of tax imposed by section 4681.

**"(3) EXPORTS.—**

**"(A) IN GENERAL.—**Except as provided in subparagraph (B), rules similar to the rules of section 4662(e) (other than section 4662(e)(2)(A)(ii)(II)) shall apply for purposes of this subchapter.

**"(B) LIMIT ON BENEFIT.—**

**"(i) IN GENERAL.—**The aggregate tax benefit allowable under subparagraph (A) with respect to ozone-depleting chemicals manufactured or produced by any person during a calendar year shall not exceed the sum of—

**"(I) the amount equal to the 1986 export percentage of the aggregate tax imposed by this subchapter with respect to ozone-depleting chemicals manufactured or produced by such person during such calendar year (other than chemicals with respect to which subclause (II) applies), and**

**"(II) the aggregate tax imposed by this subchapter with respect to any additional production allowance granted to such person with respect to ozone-depleting chemicals manufactured or produced by such person during such calendar year by the Environmental Protection Agency under 40 CFR Part 82 (as in effect on September 14, 1989).**

**"(ii) 1986 EXPORT PERCENTAGE.—**A person's 1986 export percentage is the percentage equal to the ozone-depletion factor adjusted pounds of ozone-depleting chemicals manufactured or produced by such person during 1986 which were exported during 1986, divided by the ozone-depletion factor adjusted pounds of all ozone-depleting chemicals manufactured or produced by such person during 1986. The percentage determined under the preceding sentence shall be based on data published by the Environmental Protection Agency.

**"(e) OTHER DEFINITIONS.—**For purposes of this subchapter—

**"(1) IMPORTER.—**The term 'importer' means the person entering the article for consumption, use, or warehousing.

**"(2) UNITED STATES.—**The term 'United States' has the meaning given such term by section 4612(a)(4).

**"(f) SPECIAL RULES.—**

**"(1) FRACTIONAL PARTS OF A POUND.—**In the case of a fraction of a pound, the tax imposed by this subchapter shall be the same fraction of the amount of such tax imposed on a whole pound.

**"(2) DISPOSITION OF REVENUES FROM PUERTO RICO AND THE VIRGIN ISLANDS.—**The provisions of subsections (a)(3) and (b)(3) of section 7652 shall not apply to any tax imposed by this subchapter.

**"(g) PHASE-IN OF TAX ON CERTAIN SUBSTANCES.—**

**"(1) TREATMENT FOR 1990.—**

**"(A) HALONS.—**The term 'ozone-depleting chemical' shall not include halon-1211, halon-1301, or halon-2402 with respect to any sale or use during 1990.

**"(B) CHEMICALS USED IN RIGID FOAM INSULATION.—**No tax shall be imposed by section 4681—

**"(i) on the use during 1990 of any substance in the manufacture of rigid foam insulation,**

"(iii) on the sale during 1990 by the manufacturer, producer, or importer of any substance—

"(I) for use by the purchaser in the manufacture of rigid foam insulation, or

"(II) for resale by the purchaser to a second purchaser for such use by the second purchaser, or

"(iii) on the sale or use during 1990 by the importer of any rigid foam insulation.

Clause (ii) shall apply only if the manufacturer, producer, and importer, and the 1st and 2d purchasers (if any) meet such registration requirements as may be prescribed by the Secretary.

"(2) TREATMENT FOR 1991, 1992, AND 1993.—

"(A) HALONS.—The tax imposed by section 4681 during 1991, 1992, or 1993 by reason of the treatment of halon-1211, halon-1301, and halon-2402 as ozone-depleting chemicals shall be the applicable percentage (determined under the following table) of the amount of such tax which would (but for this subparagraph) be imposed.

In the case of:	The applicable percentage is:		
	For sales or use during 1991	For sales or use during 1992	For sales or use during 1993
Halon-1211.....	6.0	5.0	3.3
Halon-1301.....	1.8	1.5	1.0
Halon-2402.....	3.0	2.5	1.6

"(B) CHEMICALS USED IN RIGID FOAM INSULATION.—In the case of a sale or use during 1991, 1992, or 1993 on which no tax would have been imposed by reason of paragraph (1)(B) had such sale or use occurred during 1990, the tax imposed by section 4681 shall be the applicable percentage (determined in accordance with the following table) of the amount of such tax which would (but for this subparagraph) be imposed.

In the case of sales or use during:	The applicable percentage is:
1991.....	18
1992.....	15
1993.....	10

"(3) OVERPAYMENTS WITH RESPECT TO CHEMICALS USED IN RIGID FOAM INSULATION.—If any substance on which tax was paid under this subchapter is used during 1990, 1991, 1992, or 1993 by any person in the manufacture of rigid foam insulation, credit or refund (without interest) shall be allowed to such person an amount equal to the excess of—

"(A) the tax paid under this subchapter on such substance, over

"(B) the tax (if any) which would be imposed by section 4681 if such substance were used for such use by the manufacturer, producer, or importer thereof on the date of its use by such person.

"Amounts payable under the preceding sentence with respect to uses during the taxable year shall be treated as described in section 34(a) for such year unless claim therefor has been timely filed under this paragraph.

"(h) IMPOSITION OF FLOOR STOCKS TAXES.—

"(1) JANUARY 1, 1990, TAX.—On any ozone-depleting chemical which on January 1, 1990, is held by any person (other than the manufacturer, producer, or importer thereof) for sale or for use in further manufacture, there is hereby imposed a floor stocks tax in an amount equal to the tax which would be imposed by section 4681 on such chemical if the sale of such chemical by the manufacturer, producer, or importer thereof had occurred during 1990.

**"(2) OTHER TAX-INCREASE DATES.—**

**"(A) IN GENERAL.—**If, on any tax-increase date, any ozone-depleting chemical is held by any person (other than the manufacturer, producer, or importer thereof) for sale or for use in further manufacture, there is hereby imposed a floor stocks tax.

**"(B) AMOUNT OF TAX.—**The amount of the tax imposed by subparagraph (A) shall be the excess (if any) of—

**"(i) the tax which would be imposed under section 4681 on such substance if the sale of such chemical by the manufacturer, producer, or importer thereof had occurred on the tax-increase date, over**

**"(ii) the prior tax (if any) imposed by this subchapter on such substance.**

**"(C) TAX-INCREASE DATE.—**For purposes of this paragraph, the term 'tax-increase date' means January 1 of 1991, 1992, 1993, and 1994.

**"(3) DUE DATE.—**The taxes imposed by this subsection on January 1 of any calendar year shall be paid on or before April 1 of such year.

**"(4) APPLICATION OF OTHER LAWS.—**All other provisions of law, including penalties, applicable with respect to the taxes imposed by section 4681 shall apply to the floor stocks taxes imposed by this subsection."

**(b) CLERICAL AMENDMENT.—**The table of subchapters for chapter 38 is amended by adding at the end thereof the following new item:

**"SUBCHAPTER D. Ozone-depleting chemicals, etc."**

**(c) EFFECTIVE DATE.—**

**(1) IN GENERAL.—**The amendments made by this section shall take effect on January 1, 1990.

**(2) NO DEPOSITS REQUIRED BEFORE APRIL 1, 1990.—**No deposit of any tax imposed by subchapter D of chapter 38 of the Internal Revenue Code of 1986, as added by this section, shall be required to be made before April 1, 1990.

**(3) NOTIFICATION OF CHANGES IN INTERNATIONAL AGREEMENTS.—**The Secretary of the Treasury or his delegate shall notify the Committee on Ways and Means of the House of Representatives and the Committee on Finance of the Senate of changes in the Montreal Protocol and of other international agreements to which the United States is a signatory relating to ozone-depleting chemicals.

\* \* \*

*Conference report language follows*

#### *4. Excise Tax/Fee on Ozone-Depleting Chemicals*

##### *Present law*

The use or manufacture of chemicals which deplete the earth's ozone layer is not subject to specific Federal taxes or fees.

##### *House bill*

###### *In general*

The House bill assesses an excise tax on the sale or use by a producer, manufacturer, or importer of certain ozone-depleting chemicals. The amount of tax is determined by multiplying a base tax amount by an "ozone-depleting factor."

###### *Chemicals subject to tax*

The specific chemicals subject to tax are CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon-1201, Halon-1301, and Halon-2402.

###### *Base tax amount*

For calendar years 1990 and 1991, the base tax amount is \$1.10 per pound of ozone-depleting chemical; for 1992 the base tax amount is \$1.60 per pound; for 1993 and beyond, the base tax amount is \$3.10 per pound. The base tax amount is indexed for inflation occurring after 1989.

###### *Ozone-depleting factors*

The ozone-depleting factors for the chemicals subject to tax are those specified in the Montreal protocol.

###### *Exemptions and reduced rates of tax*

The House bill provides exemptions for feedstock chemicals, recycled chemicals, and chemicals exported subject to Environmental Protection Agency regulations.

The House bill also exempts from tax in 1990 CFCs used in the production of rigid foam insulation and all halons.

The House bill provides for a reduced rate of tax in 1991 through 1993 for CFCs used in the production of rigid foam insulation and all halons.

###### *Imports*

The House bill applies the tax to any ozone-depleting chemical which is imported into the United States and to any product or substance imported into the United States in which a taxable ozone-depleting chemical was used in the manufacture or production.

###### *Effective date*

The House bill is effective for ozone-depleting chemicals sold or used after December 31, 1989. In addition, a floor stocks tax is imposed on ozone-depleting chemicals held by a person other than the manufacturer or importer on January 1, 1990. A floor stocks tax is also imposed on each subsequent change in the tax rate for any taxable chemical. The initial deposits of taxes due need not be made until April 1, 1990.

##### *Senate amendment*

###### *In general*

The Senate amendment contains two provisions pertaining to the taxation of ozone-depleting chemicals: one reported by the Committee on Finance and the other reported by the Committee on the Environment and Public Works.

The Finance Committee provision is generally the same as the House bill.

The Environment and Public Works Committee provision imposes a fee on the production, importation or distribution of ozone-depleting chemicals. The fee does not depend upon the ozone-depleting factor of the chemical. The fee is generally related to profits earned on the production of such chemicals.

#### *Chemicals subject to tax*

The Finance Committee provision is identical to the House bill.

The Environment and Public Works Committee provision is the same as the House bill. In addition, the Environment and Public Works provision permits the Administrator of the Environmental Protection Agency to add chemicals to the list of chemicals subject to the fee.

#### *Base tax amount*

The Finance Committee provision imposes a base tax amount which is similar to the House bill. For calendar year 1990, the base tax amount is \$1.07 per pound of ozone-depleting chemical; for 1991, the base tax amount is \$1.12 per pound; for 1993, the base tax amount is \$1.67 per pound; for 1994 and beyond, the base tax amount is \$3.15. The base tax amount is not indexed for inflation.

The Environment and Public Works Committee provision imposes a fee. The fee is the greater of 60 cents per pound of taxed chemical or an amount equal to the profit earned on the sale of the chemical to the extent such profits exceed the profits earned on the sale of such chemical in 1987. The Administrator of the EPA determines the excess profit amount by comparing total revenues generated from the sale of taxed chemicals to an allowance for revenues generated from like sales in 1987. An offset for Federal and State income tax liability is permitted. Distributors of taxed chemicals are granted an additional exemption of 60 cents per pound from the excess profits tax.

#### *Ozone-depleting factors*

The Finance Committee provision is identical to the House bill.

The Environmental and Public Works Committee provision does not provide for an ozone-depleting factor.

#### *Exemptions and reduced rates of tax*

The Finance Committee provision is identical to the House bill.

The Environment and Public Works Committee provision is the same as the House bill with respect to exports and feedstock chemicals.

#### *Imports*

The Finance Committee provision is identical to the House bill.

The Environment and Public Works Committee provision imposes the fee on importation of taxed chemicals, but not on derivative products.

#### *Trust fund*

The Finance Committee provision does not establish a trust fund.

The Environment and Public Works Committee provision establishes within the Treasury an "Ozone Layer and Climate Protection Trust Fund." Fees collected are to be deposited in the trust fund. The proceeds of the fund are to be invested in interest-bearing obligations of the United States. Trust fund expenditure purposes include implementation of the Montreal protocol, research and development activities of the EPA, and to carry out the abatement and control activities of the EPA.

#### *Effective date*

The Finance Committee provision is identical to the House bill.

The Environmental and Public Works Committee provision is effective July 1, 1989, for chlorofluorocarbons, and is effective January 1, 1992, for halons. The Administrator of the EPA may, by regulation, change the effective dates.





"WASHINGTON REPORT"

FEBRUARY 1990

## UNEP Formulates CFC Options

The U.S. Environmental Protection Agency (EPA), in a briefing held in Washington for the Agency's Stratospheric Ozone Protection Advisory Committee, reviewed the proposed amendments to the Montreal Protocol considered recently at the United Nations Environment Program (UNEP) meeting in Geneva.

The purpose of the UNEP meeting was to discuss various options developed by participating nations for additional restrictions on fully halogenated chlorofluorocarbons (CFCs) and other ozone-depleting chemicals. Participants attempted to refine and consolidate, where possible, existing choices for review. A final round of negotiations will be held in London before approval by signatory nations in June.

Currently, the UNEP Montreal Protocol, which took effect in July and with which the United States is in full compliance places reductions on CFCs 11, 12, 113, 114 and 115 according to the following time table:

July 1989 - Cutback to 1986 production levels  
July 1993 - Reduction to 80 percent of 1986 production  
July 1998 - Reduction to 50 percent of 1986 production.

Halons 1211, 1301 and 2402 are to be frozen at 1986 production levels in 1992.

The Montreal Protocol also addresses other non-technical items including special provisions related to international trade, production allotments and special situations of the developing nations.

## Additional CFC restrictions

Eileen Claussen, EPA's director of atmospheric programs, reported that a broad consensus exists among the Geneva participants for a complete phaseout of fully halogenated CFCs by the year 2000. Claussen emphasized President Bush's earlier statement that the U.S. position for a phaseout would depend on the availability of environmentally acceptable alternatives based on the continuing reassessment of technology.

Various proposals were put forth by representatives of the attending nations in Geneva related to additional interim restrictions on the currently targeted CFCs with an understanding of a phaseout in the year 2000.



The UNEP parties which attended the earlier meeting in Nairobi and Canada proposed:

1994 or 1995: Reduction to 50 percent of 1986 production  
1998: Reduction to 15 percent of 1986 production.

The European Community proposed:

1991 or 1992: Reduction to 50 percent of 1986 production  
1995 or 1996: Reduction to 15 percent of 1986 production.

EPA reported that the Nordic nations with Austria, Switzerland, Australia and New Zealand proposed:

1993: Reduction to 50 percent of 1986 production  
1996: Reduction to 15 percent of 1986 production.

Japan did not support any interim reductions.

EPA indicated that the U.S. position on any interim adjustments on the reduction schedule in effect will be made in Spring 1990 as more technology assessment information becomes available.

#### Possible HCFC restrictions

Although HCFCs have relatively low ozone depletion factors, world concern over controlling additional chlorine buildup in the upper atmosphere has drawn attention to even the smaller contributors to the issue. HCFC 22 has a depletion factor of 0.05 (as compared to a depletion factor for CFC 11 or 12 of 1.0), and the new potential alternative for CFC 11 is HCFC 152a which has an estimated depletion factor of 0.02. Three proposals were placed on the table at the Geneva meeting.

As reported by EPA, the United States proposed a phaseout in new equipment by the year 2020 or up to 2040 and in existing equipment by the year 2020 or up to 2060. The Nordic nations proposed a phaseout by the year 2010 or 2020 except in essential uses (which they defined as foams, refrigeration and medical applications); it was unclear whether "refrigeration" included air conditioning. The European Community proposed the reporting of data on HCFC production (outside of any Protocol provisions).

As possible restrictions on HCFCs are addressed in future UNEP negotiations, potential protocol actions may be tied to the specific ozone depletion factor of the particular HCFCs in question. For example, restrictions may be applied only to HCFCs whose depletion factors are greater than 0.02.

## Halons

Also of interest to the ASHRAE community are halons, which have very large depletion factors (up to 10.0). Several proposals for additional restrictions on the targeted halons were presented. The U.S. position at this time on halons is a phaseout by the year 2000 provided safe substitutes are available (the phaseout may be possible by 1995 or 1996); the U.S. supports no interim steps.

Canada proposed a complete phaseout (essential uses exempted) in the year 2000 with no interim reductions. The European Community proposal was comprised of a 50 percent reduction from 1986 production levels in 1995 or 1996 with a phaseout in the year 2005. Japan proposed a 50 percent cutback in the period of 1995 to 1997 with a phase out as soon as feasible except for exemptions. The U.S.S.R. proposed a 10 to 50 percent reduction by the year 2000 with exemptions for essential uses (to be established by each nation); EPA indicated that in order to be acceptable, exemptions would have to be coupled to a particular list of applications.

## Other chemicals

It is probable that other chemicals will be added to the Montreal Protocol. Proposals (similar to those proposed for CFCs) were put forward to include carbon tetrachloride and methyl chloroform. The United States, along with the Soviet Union and Japan, proposed a freeze on carbon tetrachloride (with feed stocks exempted) tied with a phaseout schedule identical to that adopted for CFCs. The U.S. position on methyl chloroform was a 25 to 100 percent cutback in production by the year 2000. The base year for these chemicals will have to be determined.

## U.S. Negotiating Strategy

Adjustments to the restrictions of targeted chemicals listed in the Montreal Protocol requires a two-thirds approval of signatory nations (representing at least two-thirds of the parties' production) and would be binding on all parties to the Protocol. The addition of new targeted chemicals (carbon tetrachloride, methyl chloroform and/or HCFCs) requires an amendment process with a simple two thirds vote of parties in attendance and voting.

The U.S. strategy is to package all provisions for newly added chemicals into a single amendment. When adopted by the international body, an amendment (which can address the addition of new chemicals or any other topic) is subject to ratification by the individual countries. By putting all provisions related to new chemicals into a single comprehensive amendment, the international body may be able to avoid numerous small individual amendments - each of which could be applicable to different nations. Claussen indicated that "It will be a very tough negotiation process to achieve a packaged amendment."

### Series of Meetings Scheduled

The final decisions will take place when the full diplomatic conference held June 20-29. However, there will be numerous meetings in the interim to "slim-down" the number of proposals to an acceptable number from which a compromise hopefully can be attained in June.

The UNEP process involves factors other than the technical considerations. In working with nations with a wide spectrum of economies and levels of industrialization, many considerations must be hammered out particularly as related to developing nations. How will new technology be made available to developing nations? Should additional trade considerations be implemented? Should funds be provided to assist developing nations?

### EPA Lead Agency

The EPA serves as the lead agency on formulating the United States negotiating position. To support the meetings at the international level the Agency will continue with its assessments and analysis. The Advisory Committee is an integral part of the process.

The EPA Advisory Committee was established in the Fall 1989 to provide the Agency with "informed advice on policy and technical issues that relate to domestic and international aspects on the Montreal Protocol on Substances that Deplete the Ozone Layer." The makeup of the 25-member advisory body is drawn from business and industry, educational and research institutions, government bodies, non government and environmental groups and international organizations.

# THE DESTRUCTION OF HALONS IN THE NORDIC COUNTRIES

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## SUMMARY

On behalf of the Nordic Council of Ministers' steering committee for the halon project, Environmental Consultants at Studsvik has studied the conditions for halon destruction in the Nordic countries. This report investigates collection of halons and the methods for the destruction of the halon bank which can be put into operation within the next five years. The halon bank is estimated at 3 000 tonnes. More than 80 % of the halon bank consists of H 1301, i.e bromotrifluoromethane.

If the governments decide that halons must be actively collected, this can be achieved without any technical difficulties. For this to succeed, it must be possible to reach the end-users of halogenated fire extinguishers with information stating clearly that the fire-extinguishers must be replaced by sending all stored halon to a specific collection point. Collected halons can be stored pending destruction. The cost of transporting and storing halons is insignificant compared with the cost of destruction.

If the governments decide to initiate halon destruction in the Nordic countries within the next five years, this would clearly indicate the desire to set an example and a precedent. The choice of the method of destruction would be based on what is least hazardous to the environment. Therefore, the cost of the destruction technique would not be the deciding factor.

This report describes four techniques which can be put into operation within a few years. In Denmark and Finland, halons can be incinerated together with hazardous waste. It is probably not possible to adopt a similar incineration technique in Sweden since the amount of halogens which may be supplied to the incinerator is restricted.

It is our conclusion that the destruction of halons by incineration together with combustible hazardous waste should be avoided. Destruction techniques where aromatic compounds occur should similarly be avoided. With such techniques, the formation of persistent toxic organic compounds would not be minimized. It is possible to compensate for this by adopting more stringent requirements for flue gas cleaning and the deposition of residual products.

There are two techniques which enable the destruction of halons to be carried out without the formation of aromatics such as dioxins arising from chlorine and bromine in the process. These methods are incineration using fuel not containing aromatics or destruction in a plasma reactor. In both cases, the flue gases from the reactor are quenched in a venturi cooler and the halogenated hydrocarbons are absorbed in a multi-stage scrubber. The flue gases are then heated and finally cleaned by a fabric filter. If the plant is sited together with the hazardous waste incineration plant, considerable advantages can be gained. The cost of halon destruction is estimated at between SEK 25 and SEK 44 per tonne.

If the capacity of the plant is adapted to the destruction of both halons and CFCs, the destruction costs can be substantially reduced without any major disadvantages.



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## 1 Introduction

### 1.1 Background

Brominated fluorocarbons (halons) and chlorofluorocarbons (CFCs) are the collective terms for a number of different substances which contain chlorine, fluorine and bromine. The basic substance is a hydrocarbon in which the hydrogen atoms have been replaced. If halons and CFCs are released into the atmosphere, they will partially decompose due to ultra-violet radiation. The part of the substance that is transported to the stratosphere is a significant contributing factor to the depletion of the ozone layer.

An international agreement was reached under the auspices of the United Nations in 1987, known as the Montreal Protocol, concerning the successive reduction of the usage of halons and CFCs. According to the agreement, the production and consumption of halons shall be restricted to the 1986 level.

In the mid-eighties, the world production of CFCs amounted to about 1 million tonnes per year. The production of halons is estimated at approximately 20 thousand tonnes per year. Recent research has shown that despite the fact that the amount of halons is insignificant, halons are a significant contributor to the depletion of the ozone layer. Table 1 shows the estimated lifetime of the most common halons and CFC compounds in the atmosphere and their ozone depleting potential.

Table 1

Ozone depleting potential of halons and CFCs

Name	Designation	Chemical formula	Lifetime in atmosphere year	Ozone depleting potential
Trichlorofluoromethane	CFC 11	$\text{CCl}_3\text{F}$	58	1
Dichlorodifluoromethane	CFC 12	$\text{CCl}_2\text{F}_2$	96	0.9
Trichlorotrifluoroethane	CFC 113	$\text{C}_2\text{Cl}_3\text{F}_3$	103	0.9
Dichlorotetrafluoroethane	CFC 114	$\text{C}_2\text{Cl}_2\text{F}_4$	247	0.8
Pentachlorofluoroethane	CFC 115	$\text{C}_2\text{Cl}_5\text{F}$	548	0.4
Bromochlorodifluoromethane	H 1211	$\text{CF}_2\text{ClBr}$	18	4
Bromotrifluoromethane	H 1301	$\text{CF}_3\text{Br}$	72	10
Dibromotetrafluoromethane	H 2402	$\text{CF}_2\text{BrCF}_2\text{Br}$	23	7
Carbon tetrachloride	$\text{CCl}_4$	$\text{CCl}_4$	51	1.2

In the comparison provided in the table, the amounts are the same for each substance. The ozone depleting potential of CFC 11 is used as a basis. The negative effect of the halons on the ozone layer is 4 to 10 times greater than that of the CFCs.

The halons are mainly used as fire extinguishants. Their fire fighting properties are exceptional. One major advantage is that human beings can usually be present in areas where they are being used.

The quantity of banked halon is at present many times greater than the annual consumption. There are very important reasons why this bank should not be released to the atmosphere.

Halon can be replaced as a fire extinguishant in most fire fighting equipment. The main area of technical difficulty is dealing with areas where personnel must be present when the fire extinguishant has been released. An example of such areas is control rooms in nuclear power plants, aeroplanes and air traffic control centers.

## 1.2 The project

In June 1989, Environmental Consultants at Studsvik was given the task of evaluating the possibilities of halon destruction in the Nordic countries by the steering committee for the halon project of the Nordic Council of Ministers. The report was to be presented no later than on November 15, 1989.

The objective of the study is to identify the technical and economic conditions necessary for the environmentally safe destruction of halons.

The report provides information on three main areas:

- techniques for halon destruction.
- evaluation of suitable siting for a destruction plant.
- general outline of the collection and storage of halons.

## 2 Halons

### 2.1 General

One of the oldest halon fire extinguishants is carbon tetrachloride,  $\text{CCl}_4$ . If combustion of  $\text{CCl}_4$  is incomplete, the very toxic phosgene ( $\text{COCl}_2$ ) is formed. For this reason, carbon tetrachloride is no longer used as a fire extinguishant.

A large number of halons has been developed for use as fire extinguishants. Table 2 shows the most common.

Table 2  
Halon

Name	Halon number	Chemical formula	Car-bon	Fluor-ine	Chlor-ine	Brom-ine
Bromotrifluoromethane	1301	$\text{CF}_3\text{Br}$	1	3	0	1
Bromochlorodifluoromethane	1211	$\text{CF}_2\text{ClBr}$	1	2	1	1
Dibromodifluoromethane	1202	$\text{CF}_2\text{Br}_2$	1	2	0	2
Dibromotetrafluoromethane	2402	$\text{CF}_2\text{BrCF}_2\text{Br}$	2	4	0	2
Methyl bromide	1001	$\text{CH}_3\text{Br}$	1	0	0	1
Chlorobromomethane	1011	$\text{CH}_2\text{ClBr}$	1	0	1	1
Dibromotrifluoromethane	2302	$\text{C}_2\text{HF}_3\text{Br}_2$	2	3	0	2

Today, halon 1301 and 1211 are mainly used. The halons 1011, 1202 and 2402 are also used to a lesser extent.

### 2.2 The halon bank in the Nordic countries

Halon is not produced in the Nordic countries. The halon bank has developed through the importation of halons from other countries. No exact data is available, but an estimate of the

volume of the halon bank in the Nordic countries, carried out by BTI (Brandtekniska ingenjörbyrån) is presented in Table 3, ref (1).

**Table 3**

Total banked halon in the Nordic countries (tonnes)

	Halon 1301	Halon 1211	Halon 2402
Denmark	600 - 1000	80 - 100	10
Finland	350	330	-
Norway	600 - 1000	60 - 100	3 - 5
Sweden	930 - 1430	70	-
<b>Total</b>	<b>2400 - 3780</b>	<b>540 - 600</b>	<b>13 - 15</b>

The halon bank includes both hand-held fire extinguishers and permanent installations.

### 2.3 Physical properties

The physical properties of halons used are shown in Table 4.

**Table 4**

Physical properties

	Halon 3101	Halon 1211	Halon 2402
Chemical composition	$\text{CF}_3\text{Br}$	$\text{CF}_2\text{ClBr}$	$\text{CF}_2\text{BrCF}_2\text{Br}$
Molecular weight	149	165	260
Boiling point (1 atm) °C	-58	-4	+48
Density 20°C, fluid kg/dm <sup>3</sup>	1.6	1.8	2.2
Vapour press. at 20°C bar	14	2.5	0.35
Vapour press. at 70°C bar	42	9.0	2.0
Critical temperature °C	67	154	215
Critical pressure bar	41	42	35

The table shows that halon 1211 has a higher boiling point than 1301. Therefore it does not vaporize as rapidly and is more suitable for use in hand-held fire extinguishers where an extinguishant with a good stream range is desirable.



### 3 Handling before destruction

#### 3.1 Management of the halonbank

Halons are imported to the Nordic countries in large tanks. These tanks are designed to withstand a pressure of 42 bars, which is halon 1301's vapour pressure at 70°C.

The halons are taken from the tank and pressure vessels of a suitable size are filled. The pressure vessel must meet the stringent pressure vessel standards as regards material, manufacturing and control.

For permanent installations, the discharge time of the extinguishant should not exceed 10 seconds. In order to guarantee this, the vessels are usually pressurized up to 25 or 42 bars. The pressure is selected depending on the time required to empty the vessel. The propellant gas is nitrogen, N<sub>2</sub>. Nitrogen is also used as the propellant in hand-held fire extinguishers, where the pressure is usually 14 bars.

Halons are also stored in pressure vessels by the users of the fire extinguishers. Halon containers with a weight of a few kilograms up to a maximum of 250 kg are kept at permanent installations. The halon content of hand-held extinguishers varies from about 1 to 10 kg.

The volume of the halon bank has not been exactly determined. It is even more difficult to obtain precise information on the number of halon containers in existence. In order to arrive at some estimate, it can be mentioned that 4 730 hand-held fire extinguishers were sold in Finland in 1986. The amount of halon 1211 contained in these extinguishers was about 21 tonnes. Thus, each extinguisher contained on average 4 to 5 kg of halons. In Finland, halon 1211 is only used in hand-held extinguishers. The bank of 1211 is estimated at 330

tonnes. The number of hand-held fire extinguishers is thus estimated at between 60 000 and 75 000.

When some of the major distributors of halons were contacted, it was found that they should be able to reach more than 90 % of the end-users of halon through their customer registers. Halon containers are required to undergo hydrostatic testing every fifth or tenth year. The testing is largely carried out by the distributors. The hydrostatic testing requirement provides a natural opportunity for contact between the suppliers and end-users.

During hydrostatic testing, the halon containers are emptied. There are established procedures for this. The extent of the losses which occur in connection with the emptying of the containers has so far been determined by the cost of halons, not taking into account environmental considerations.

### 3.2 Collection and storage

If the governments decide that halons shall be actively collected and stored, this can be achieved without technical difficulty.

For this to succeed, it must be possible to reach the end-users of halogenated fire extinguishers with information stating clearly that the fire-extinguishers must be replaced, which entails sending all stored halon to a specific collection point. The users must be sufficiently motivated to avoid discharging the halons, otherwise there is a risk that too many individual users will consider that discharging the small quantities of halons that they have is insignificant.

The premises of halon distributors can function as collection points. The distributors must naturally be bound by contract to provide this facility, and a fee for receiving and storing the halons must be determined.

The storage of halon containers requires storage space, but in general, no other major difficulties are associated with this task.

The only consequence of storing the halon bank for a long period of time, is the cost of the buildings used for storage, since it is anticipated that most of the containers will not be put to alternative use. In any case, because of the pressure vessel classification of the containers, they cannot be used for CO<sub>2</sub> fire extinguishants.

The schedule for the collection of halogenated fire extinguishants is mainly determined by the possibility of obtaining a replacement for halons which conforms with the safety requirements for fire extinguishing agents. This is also the determining factor for estimating the volume of storage space which must be set aside in each country or region.

We estimate the annual cost for facilities for the storage of halons to be SEK 150/m<sup>2</sup>. With certain arrangements, it should be possible to store halons in such storage facilities at an annual cost of SEK 400/tonne.

A general estimate of the cost of transporting the collected halons to the destruction facility cannot be made. However, it is clear that the transportation and storage costs for halons are negligible compared to the cost of halon destruction.

#### 4 Principles of halon destruction

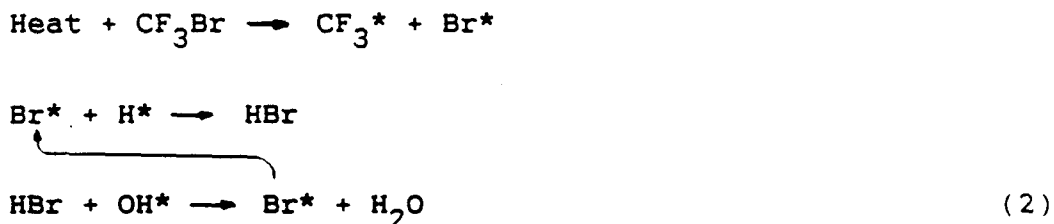
##### 4.1 Halons as fire extinguishants

The fire suppression capability of halons is mainly due to the fact that halogen radicals are released at a relatively low temperature, 400 - 500°C. Expressed in simple terms, bromine steals the OH radical which is important for combustion. Water is formed and bromine is again released as a radical. The chain reaction continues and interferes with combustion. If enough halons are used at the initial stages, the fire will be extinguished. On the other hand, if a moderate amount of halons is used on a blaze, this will only result in the production of corrosive smoke.

The process is described in the following model. \* is used to indicate the radicals. Combustion occurs as follows:



Halons interfere with the reaction as follows:



With halogen in the combustion gas (2) water ( $\text{H}_2\text{O}$ ) is formed by the hydroxyl radical. Without halogen, the hydroxyl radical yields  $\text{H}_2\text{O} + \text{heat}$  and combustion continues.

##### 4.2 Destruction of halons

Halon molecules can be decomposed by chemical processes or by thermal processes, in principle, combustion. During combustion, reaction (1) must be dominant. Enough energy must be supplied

at the same time that an excess of hydrogen and oxygen is maintained.

A summary of the binding energies of the halons in use today is provided in Table 5. A comparison with methane, dichloromethane and carbon tetrachloride is made. The term binding energy refers to the amount of energy needed to decompose the molecule into atoms.

The required energy can be supplied in very different ways.

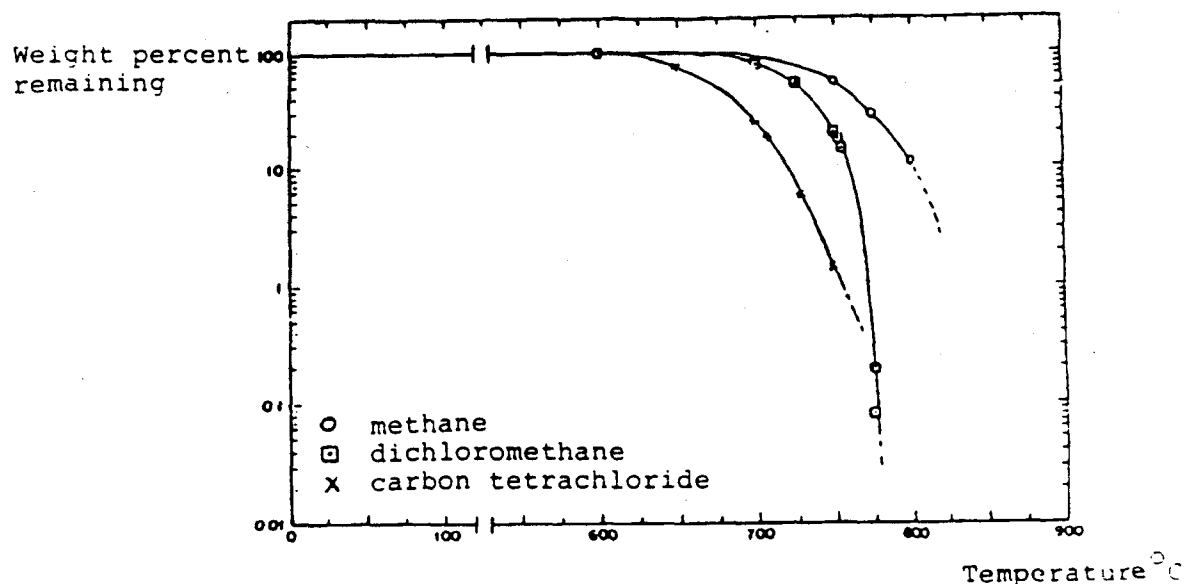
Table 5

Binding energies for substituted methane molecules

Halon	Compared substance	Binding energy kJ/mol
1301 CF <sub>3</sub> Br	$\begin{array}{c} \text{Br} \\   \\ \text{F} - \text{C} - \text{F} \\   \\ \text{F} \end{array}$	1739
	Methane (CH <sub>4</sub> )	
	$\begin{array}{c} \text{H} \\   \\ \text{H} - \text{C} - \text{H} \\   \\ \text{H} \end{array}$	1655
1211 CF <sub>2</sub> ClBr	$\begin{array}{c} \text{Br} \\   \\ \text{F} - \text{C} - \text{F} \\   \\ \text{Cl} \end{array}$	1593
	Dichloromethane (CH <sub>2</sub> Cl <sub>2</sub> )	
	$\begin{array}{c} \text{H} \\   \\ \text{Cl} - \text{C} - \text{Cl} \\   \\ \text{H} \end{array}$	1505
	Carbon tetrachloride (CCl <sub>4</sub> )	
	$\begin{array}{c} \text{Cl} \\   \\ \text{Cl} - \text{C} - \text{Cl} \\   \\ \text{Cl} \end{array}$	1354

### 4.3 Combustion

During combustion, halons can react with hot gas with enough excess hydrogen to decompose the halon molecules and to form halogenated hydrogen and  $\text{CO}_2$ . The combustion process is always controlled by the three t's, namely: temperature, time and turbulence. If halons are permitted to remain in hot gas for a long time and if the mixing is good, the temperature necessary for decomposition is not particularly high. Figure 1 shows the decomposition of methane, carbon tetrachloride and dichloromethane as a function of temperature. The residence time is 2 seconds.



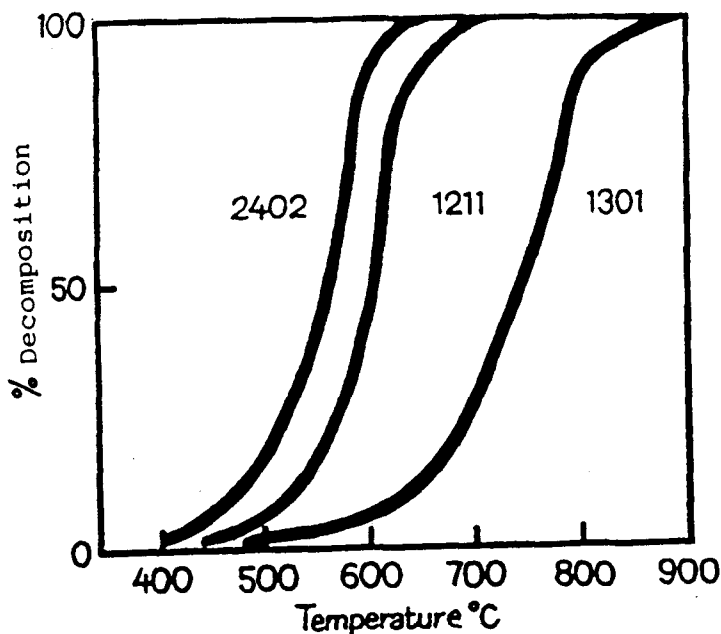
**Figure 1**

Decomposition of methane, carbon tetrachloride and dichloromethane as a function of temperature

The data in Figure 1 were obtained from laboratory experiments, Ref 2, and therefore cannot be applied to combustion in actual plants.

Laboratory experiments also carried out with halons confirm the data shown in Figure 1. The halons were passed through a

quartz tube filled with quartz balls. The residence time in the reactor was two seconds. The destruction is shown in Figure 2.



**Figure 2**

Thermal decomposition of halons

There is a sound basis for maintaining that halon destruction by combustion in an excess of hydrogen is a technically feasible method.

#### 4.3.1 Catalytic destruction

The temperature during combustion may be reduced by using suitable catalysts. Catalysts used in laboratory experiments include platinum/titanium oxide and palladium/active carbon. These experiments have shown that the fluorohydrocarbons studied can decompose in a methane or steam atmosphere at approximately 400 - 500°C. The temperature can probably be further reduced as a result of testing other suitable catalysts.

#### 4.4 Molten iron

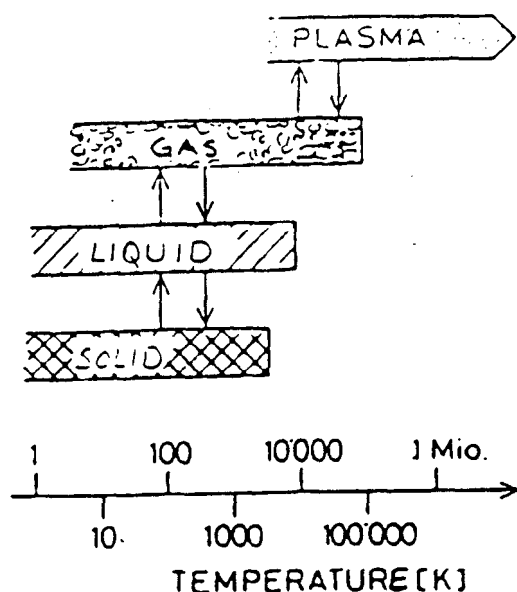
The energy needed to decompose the molecules can be supplied by molten metal. The molten metal is a conductor of heat, and fluorine and bromine which are released can be directly bound as salts. Molten metal containing sodium and iron has been tested for this purpose.

MEFOS in Luleå, Sweden has a pressurized coal gasifier which has also been test operated for chemical waste destruction. Experiments with halon destruction in molten iron have also been carried out in a smaller test furnace. The experiments show that bromine and fluorine are released from the molten iron in the form of dust-bound iron salts.

#### 4.5 Plasma decomposition

The energy for the destruction of halons can also be supplied by electricity, e.g in a plasma reactor. The amount of energy supplied is so great that the molecules turn into plasma. This plasma is formed in a continuous flow of an inert gas such as argon or nitrogen, at atmospheric pressure. Plasma is the physical state where the electrons of the molecules are free from the nucleus. The physical states of matter are illustrated in Figure 3.

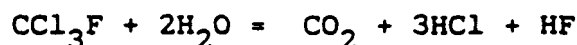




**Figure 3**

The physical states of matter

Laboratory experiments have been carried out by the National Research Institute for Pollution and Resources (NRIPR), Ref 3, on the destruction of chlorofluorohydrocarbons in a plasma reactor. These experiments show that a mixture of  $\text{CCl}_3\text{F}$  and water in an argon atmosphere is almost fully converted to  $\text{CO}_2$ ,  $\text{HCl}$  and  $\text{HF}$  according to the formula:



#### 4.6 Reduction

Halogenated hydrocarbons can be converted into hydrocarbon (carbon) and sodium salts through reduction with sodium naphthalenide. The reaction occurs when halogenated hydrocarbons are mixed with sodium naphthalenide in tetrahydrofuran.

In the interests of safety, it is recommended that the pulverization of sodium and the mixing of sodium with naphthalene to produce sodium naphthalenide should be done on

an industrial scale. skala. Sodium naphthalenide must also be handled very carefully to prevent contact with air or moisture. The cost of the chemicals is also substantial. This method has been used for the small scale destruction of PCB.

#### 4.7        Supercritical water

Chemical reactions can occur very rapidly and completely in supercritical water. Supercritical conditions are achieved by raising the pressure and temperature so that the liquid assumes properties which resemble gas and liquid at the same time. The critical point of water is 374°C and 218 bar. The pressure and temperature must therefore exceed these levels. Halon destruction can probably be achieved by using this technique. However, several years' work is necessary before the technique can be evaluated and compared with the destruction techniques which can currently be carried out on a commercial basis.

## 5 Techniques

Several of the methods of destruction described in section 4 require several years of development work with an investment of several millions before they can become technically feasible plant designs. At present, it is only possible to evaluate thermal destruction from a technical, economic and environmental standpoint. If halon destruction is to be initiated within a five-year period at a plant located in one of the Nordic countries, one of the following alternatives must be chosen:

- utilization of existing incineration plants for hazardous waste.
- utilization of the coal gasification facility in Luleå.
- construction of a purpose-built incineration plant for halogenated hydrocarbons.
- construction a plasma plant modified for halogenated hydrocarbons.

If it is decided to use the incineration plants for mixed hazardous wastes, no separate investment will be required. Several countries have planned to considerably expand the destruction capacity of such plants. Our assessment of the consequences of this course of action is provided in section 6.

The other techniques would require an in-depth study of technical, economic and environmental considerations before a decision on investment can be made. In principle, the techniques are comparable, since they can be evaluated on the basis of how they fulfil the need for destruction of the halon bank in the Nordic countries alone. This comparison is

provided in section 7. However, we assume that, in practice, plant capacity will not only be suited to fulfil the need for halon destruction, but also that of CFCs and other halogenated hydrocarbons which can be gasified.

## 6 Existing plants

There are currently three plants in the Nordic countries which receive and incinerate hazardous waste originating from industry and the public. The destruction of combustible waste is carried out in the same way. Most of the waste is fed into a rotary kiln where it is incinerated. Final oxidization of the combustion gases is carried out in a secondary combustion chamber (after burner). Heat is transferred from the flue gases in a steam boiler and the flue gases are cleaned by a method which results in a dry residual product.

The plants are located in Nyborg in Denmark, Rihimäki in Finland and Kumla in Sverige. In Norway, there is as yet no facility for this purpose. There are detailed plans to locate a plant in Mo in Rana, and in Denmark a third furnace was recently taken into operation. Consequently, there is some capacity which has not yet been utilized. Finland and Sweden need additional capacity as soon as possible to avoid storing the hazardous waste which is collected in these countries. Finland has decided to invest in a new furnace in Rihimäki. In Sweden, no decision has been taken as regards the siting or financing of a new processing facility.

The combined halon bank in the Nordic countries would occupy a small share of the plants' nominal capacity. In spite of this, the high concentrations of halogens in halons mean that a significant part of the destruction capacity is affected. Since the existing plants are all equipped with steam boilers, the corrosion conditions can also result in a limited capacity for the halon flow.

In Sweden, the granting of a licence for the incineration of hazardous waste has involved certain conditions which, in practice, mean that halons cannot be destroyed in a Swedish facility. This is due to the bromine content of halons. Only waste which allows an instantaneous halogen load during

combustion of less than 100 g/s may be supplied to the furnaces in Sweden. The halogen load is defined as  $(Cl + 10 \times Br)$  g/s. This condition has been enforced in order to limit the production of chlorine and bromine substituted aromatics.

The incineration of halons in furnaces where mixed organic waste is destroyed at the same time, will, in our opinion, lead to the substantial formation of bromine aromatics, such as bromodioxines, bromophenols and bromobenzenes. At present, no plant is regulated as regards acceptable emission levels of these pollutants. We have assumed that the granting of a licence to destroy halons in the existing plants would involve requirements on limiting emissions which would be more stringent than the current levels. This is mainly due to the fact that the bromine load would increase considerably compared to when the licences were previously granted.

It is not possible for us to estimate the cost of performing halon destruction in the existing plants. However, if no additional requirements on emissions control are made, it is evident that it will be less expensive to conduct halon destruction in the existing plants than in new, separate plants.

## 7 New plants

It is possible to put into operation three different types of plants for halon destruction in the Nordic countries within a period of five years. It is uncertain when this can be done, largely due to uncertainty as regards how soon the decision on siting can be made.

However, if it is decided that the molten iron technique should be used, the siting issue should be resolved. This technique is not feasible without the substantial investment represented by the existing coal gasifier in Luleå, Sweden.

As regards the other techniques we assume that they will be located on the same site as an existing plant for handling hazardous waste. Such a plant has the necessary infrastructure which would limit the need for investment. Halon destruction involves a limited period of time and limited quantities of waste

We have also opted for siting halon destruction facilities together with already existing plants to enable a comparison of all three kinds of plants in our cost estimate.

### 7.1 Capacity

The capacity of the plant is based on the assumption that 3 000 tonnes of halon will be destroyed within a period of five years. The plant will be operated periodically or will be capable of a day shift operation of 220 days a year. The destruction capacity obtained on the basis of these assumptions is 340 kg/h of halon.

The material to be destroyed is a mixture of halons and nitrogen. The average composition of the halons is estimated as shown in Table 6.

**Table 6**

Elemental composition of 3 000 tonnes of halon

	weight %
Carbon	8
Fluorine	36
Chlorine	3
Bromine	53

**7.2 Environmental requirements**

The environmental impact of the plant will be an important factor in the choice of the destruction technique, as will economic and technical considerations. Regardless of the design of the plant, the surroundings are affected by transportation of materials personnel. This can affect siting but not the choice of the process used.

In the design basis, the halon emissions from the plant are assumed to be less than 1% of the quantity of incoming halons. In order to reach this level, considerable effort must be put into devising a system of handling halon containers that prevents leakage during emptying. Stringent safety arrangements are required. The total halon emission is probably not affected by the destruction efficiency of the processes, which should be higher than 99.99% for all the cases.

In the design basis, it was assumed that all the techniques would fulfil the requirements on emissions to the air, as presented in Table 7.



Table 7

## Emission factors

---

Dust	g/tonne halon	20
Hydrogen chloride	g/tonne halon	20
Hydrogen fluoride	g/tonne halon	20
Hydrogen bromide	g/tonne halon	20
Total hydrocarbons	g/tonne halon	200
TCDD-equivalents	µg/tonne halon	1

---

Emissions to water are to a high degree affected by the choice of technique, as well as by the amount and kind of residual products which arise.

A reasonable, general requirement is that the technique chosen results in the generation of a quantity of residual products which is as small as possible, and a quantity of substances hazardous to health and environment which is as small as possible.

### 7.3 Incineration

Halons themselves do not contribute to the energy which is needed for their destruction. Therefore, fuel is required. The necessary excess hydrogen should also be provided along with the fuel to guarantee the formation of HBr, HF and HCl. The excess oxygen is controlled by the combustion air.

The carbon content of the halon mixture is low, only 8 %. If a fuel without carbon is selected, i.e. hydrogen gas, the risk of the formation of aromatic hydrocarbons is minimized. However, hydrogen gas is expensive and is not a standard fuel. A standard fuel, rich in hydrogen which is readily obtainable is propane (LP gas).

In order to ensure maximum safety to the environment, the amount of excess hydrogen ( $H/(F+Cl+Br)$ ) which is supplied during incineration in practice, must be  $\geq 10$ . This is probably a conservative estimate. In practice, the necessary amount of excess hydrogen necessary in practice, may be lower. Since this factor has a tangible effect on the fuel consumption, it should be investigated experimentally, after a decision to adopt incineration as a technique for destruction has been made. We do not have the resources available in this study to investigate the issue more closely.

Fuel consumption and air requirements for the destruction of 340 kg/h halon with a large excess of hydrogen is shown in Table 8.

Table 8

Incineration of halons with hydrogen gas or propane

		Hydro- gen gas	Propane
Fuel rating	MW	3	6
Excess hydrogen ( $H/(F+Cl+Br)$ )	mol/mol	10	10
Halons	kg/h	340	340
Hydrogen gas	kg/h	90	-
Propane	kg/h	-	475
Air requirement	Nm <sup>3</sup> /h	2435	5900

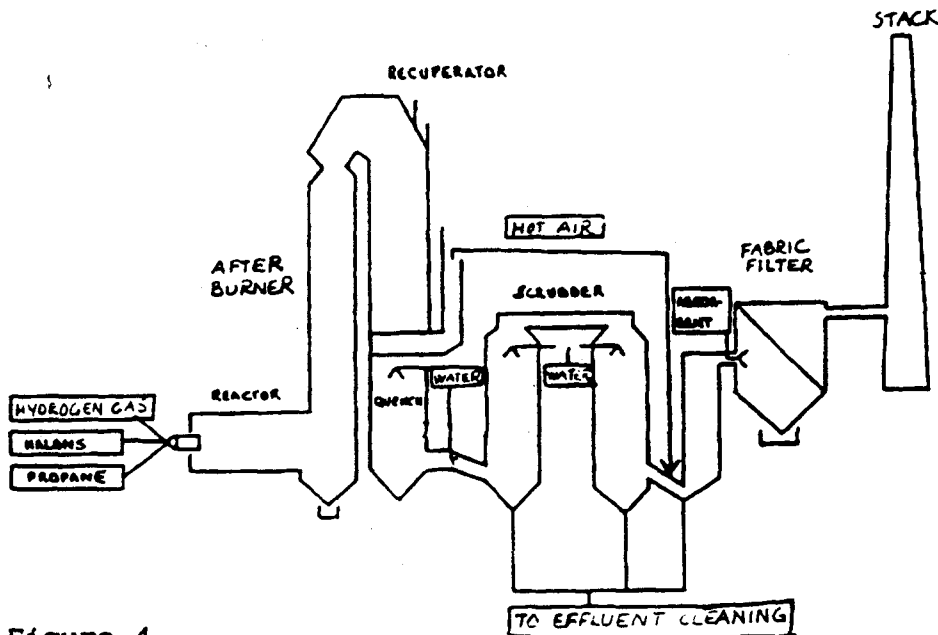
With propane as a fuel, the thermal output of the plant is doubled to maintain the excess of hydrogen. However, the fuel rating of 6 MW means that the plant design is easily manageable.

### 7.3.1 Design

The plant design remains the same, regardless of the fuel used. The reactor required is relatively small. The facility is equipped with a propane station for the fuel supply. The same applies for incineration using hydrogen. Propane can be used as a cheaper form of fuel for startup, standby and similar operating conditions. With a hydrogen gas consumption of 90 kg/h it may be necessary to erect a separate factory for the production of hydrogen gas if this fuel is used.

It is possible to avoid the relatively substantial costs that this would involve if the siting is selected in connection with a chemical industry producing a surplus of hydrogen gas.

A schematic diagram of the plant is provided in Figure 4.



**Figure 4**  
Incineration plant

The fuel is burnt in the reactor, where the decomposition of the halons is initiated. The halons remain in the secondary combustion chamber (afterburner), for the necessary residence

time and the mixture which is required for complete combustion is achieved.

The necessary residence time in the reactor and the secondary combustion chamber is estimated at four seconds. The reactor and the secondary combustion chamber are both made of brick.

Once the gases have left the secondary combustion chamber, they are cooled in a radiant-type cooler. The hot air obtained is used in the plant for superheating the flue gases before final cleaning. The flue gases from the recuperator are quenched in a venturi cooler before the acidic gases are removed by water in a multi-stage scrubber. The moisture can be condensed and removed in the scrubber to limit the flue gas flow rate. A multi-stage scrubber system for the removal of the hydrogen halides from incineration is required, since the quantities to be removed are considerable. The acid effluent from the cleaning process is neutralized and filtered before being taken to the recipient.

The flue gases from the scrubber are mixed with hot air to attain suitable conditions in the fabric filter used for the final stage of the flue gas cleaning.

The composition of the flue gases from incineration is shown in Table 9 when hydrogen and propane are used as fuels.

Table 9

Flue gas composition before scrubber

Flue gas Vol %, dry gas	Hydrogen	Propane
N <sub>2</sub>	85.9	81.6
CO <sub>2</sub>	1.8	11.0
O <sub>2</sub>	5.3	4.5
HCl	0.2	0.1
HF	5.0	2.1
HBr	<u>1.8</u>	<u>0.7</u>
	100.0	100.0
Flue gas flow, nm <sup>3</sup> /h dry gas	2900	7200
H <sub>2</sub> O vol %	24	11
Flue gas flow, nm <sup>3</sup> /h	3800	8030

**7.3.2 Construction work**

It is assumed that the plant for the process described on the previous page will be located on the same site as a similar plant. The financial investment can thereby be limited, since an infrastructure, in the form of buildings, personnel, workshops and control systems will already exist and can be used.

In our cost estimate, we have assumed that the flue gases can be led to a flue gas cleaning facility in an existing plant, thereby making separate stacks unnecessary. We also assume that the effluent can be cleaned together with effluent from the already existing plant.

We have not considered unfavorable site conditions and other factors which affect cost when assessing the scope of the construction work.

The items in the cost estimate are shown in Table 10.

Table 10  
Scope of the construction work

---

Halon handling plant
Construction of plant and connection to existing systems for electricity and water and sewage
Liquid petroleum system
Hydrogen system (only for hydrogen-based technique)
Reactor
Secondary combustion chamber (afterburner)
Radiant-type cooler
Quench
Scrubber
Connection to existing water cleaning system
Connection to existing flue gas cleaning system
Power system
Control and monitoring system
Measurement instrumentation

---

#### 7.4 Molten iron

Pressurized Coal Iron Gasification (P-CIG) is a process for the gasification of coal which is injected into a slag covered iron bath along with oxygen. The temperature of the melt is approximately 1 450°C. The main functions of the melt in the process are to:

- to transfer heat to the coal particles
- to act as a buffer to the coal to ensure an even gas composition
- to take up and transfer the sulphur in the coal to the slag

A schematic diagram of the gasifier is provided in Figure 5.

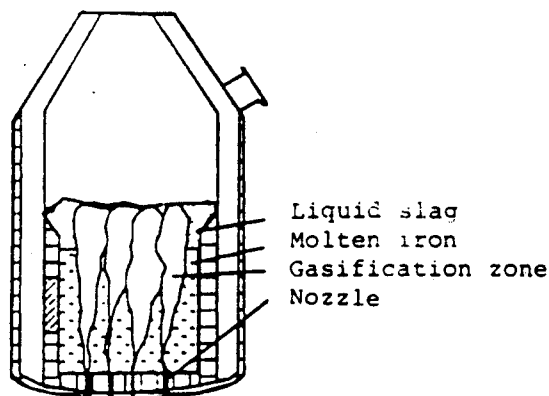


Figure 5

#### Vertical steel converter type gasifier

The gasifier has a lining made of brick. The molten iron can either be supplied from an external smelting furnace or be obtained from melting scrap iron directly in the gasifier by gas or oil-firing.

For several years, the Swedish National Board for Technical Development (STU) has supported the development of the P-CIG process. At present there is a pilot plant as well as a demonstration plant for the technique at the metallurgical research station in Luleå, MEFOS. The pilot plant has the capacity for to handle 50 tonnes of coal/day while the larger demonstration plant has a capacity for 250 tonnes of coal/day. The pilot plants would have sufficient capacity for halon destruction.

#### 7.4.1 Tests performed

When heated, the halogens in halons form salts easily due to their high electron negativity. In order to check this, STU granted funds to Interproject Service AB, Bettna, to conduct a test campaign on the destruction of halon in an iron bath.

Experiments on the destruction of halon 1301 were carried out during the summer of 1989 in a laboratory furnace at MEFOS. The furnace had a capacity for 150 kg of molten iron and was heated by induction. The halon was injected by a lance into the molten iron.

Six series of tests were carried out in all, one of which was a reference test. The measurements carried out in connection with the tests show that bromine and fluorine are released from the molten iron in the form of dust. A characteristic dust formation occurs when the halon is injected into the molten iron. In addition to bromine and fluorine, the dust contains large quantities of iron, which indicates that the halogens have formed iron salts. A certain amount of PAH, Br-benzenes and Br-phenols are also released with the dust.

#### 7.4.2 P-CIG for halon destruction

The thermal capacity of the pilot plant for coal gasification corresponds to 15 MW. Its capacity is thereby greater than that of the plant using a combustion technique. Figure 4 is a schematic diagram of the pilot plant.

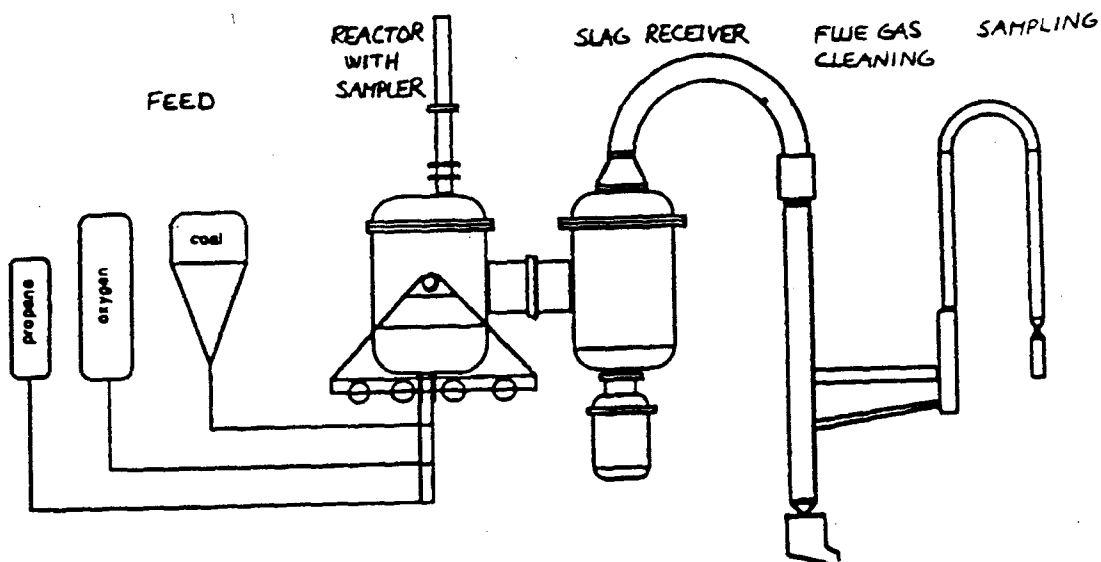


Figure 6

Schematic diagram of P-CIG



The substance to be gasified is injected together with oxygen through nozzles at the bottom of the reactor. Gasification is carried out in the molten iron through the partial combustion of coal which forms carbon monoxide. Hydrogen and iron halides are formed at the same time. The feed material, e.g. halons, has a short residence time in the molten iron - less than one second. Halon decomposes due to the good heat transfer conditions and the high temperature in the molten iron.

With the present plant design, the gas and dust from the reactor pass through a slag separator in the gas line prior to cooling and dust removal in a wet scrubber. The temperature of the gas on entering the scrubber is approximately 1 200°C and the total residence time of the gas and dust in the system before reaching the scrubber is approximately 2 - 5 seconds.

Table 11 shows the calculated flow rates for the destruction of halon 1301 using the P-CIG process.

Table 11

Flow rates for the destruction of halon 1301

<u>Incoming</u>		
Halon 1301 (total)	kg/h	1 000
of which		
C		81
Br		537
F		383
Required O <sub>2</sub>	nm <sup>3</sup> /h	78
Required Fe	kg/h	563
<u>Outgoing</u>		
FeBr <sub>2</sub>	kg/h	726
FeF <sub>3</sub>	" -	759
Flue gases	nm <sup>3</sup> /h	407

As a first step, the interested parties propose that a test campaign be carried out in the pilot plant to verify the calculations and results obtained from previous experiments. The test operations will comprise two test campaigns each involving operation of the plant for a week, destroying 10 to 20 tonnes of halons. The aim is to take comprehensive measurements during the test period. If the test operations indicate that the technical and environmental requirements have been fulfilled, the next step will be to modify the plant to carry out halon destruction on a commercial basis.

#### 7.4.3 Pilot plant modification

Interprojekt Service AB has expressed its willingness to continue the development work with MEFOS and other interested parties and modify the plant for halon destruction.

A cost estimate has been performed for the development work and for certain specified plant modification work. The estimate covers the replacement of the brickwork and the addition of a ceramic liner to the reactor. The estimate also includes the acquisition of additional instrumentation and measurement systems as well as changes in the system for handling the substances to be gasified. A new wet scrubber system for the removal of dust has been budgeted for. However, this does not include a fabric filter and sludge treatment has not been specified in detail.

In the cost estimate we have taken into account certain investments which are already known, including equipment for handling halons, so that the emissions requirements can be met.

The destruction of halon is estimated to be completed within five years. It is planned that the plant will be operated periodically, with three operating periods per year. During each operating period, 200 tonnes of halons will be destroyed

in 20 operating days. It is anticipated that the plant will be operated in two shifts for ten hours a day.

## 7.5 Plasma technology

The development of plasma technology for the destruction of hazardous waste is being carried out in many different companies and organizations. In Norway, Kvärner Engineering and SINTEF are involved in joint work on plasma technology. These companies are planning to put a prototype plant into operation during autumn 1989. The plant will have an output of 100 kW and will be used for research and development work. It can also be used for tests on the destruction of certain substances, for example, halons. In Sweden, SKF Plasma Technologies AB is working with plasma technology for the destruction of substances, including hazardous waste.

During the past year, at least two proposals have been put forward for commercial plants using plasma technology for the destruction of hazardous waste. Two small-scale plants have been proposed by companies which are prepared to enter into negotiations for a contract to construct these plants. One of the systems is supplied by Nutrail Corporation, Mass, USA. The system is called the SSP process. MGC Moser Glaser in Basel, Switzerland markets a plasma technique, known as the MGC process, which is similar in principle. We will describe the MGC process since we have obtained details on this particular technique.

### 7.5.1 Design

The MGC process for the destruction of solid and liquid wastes is shown in the schematic diagram in Figure 7.

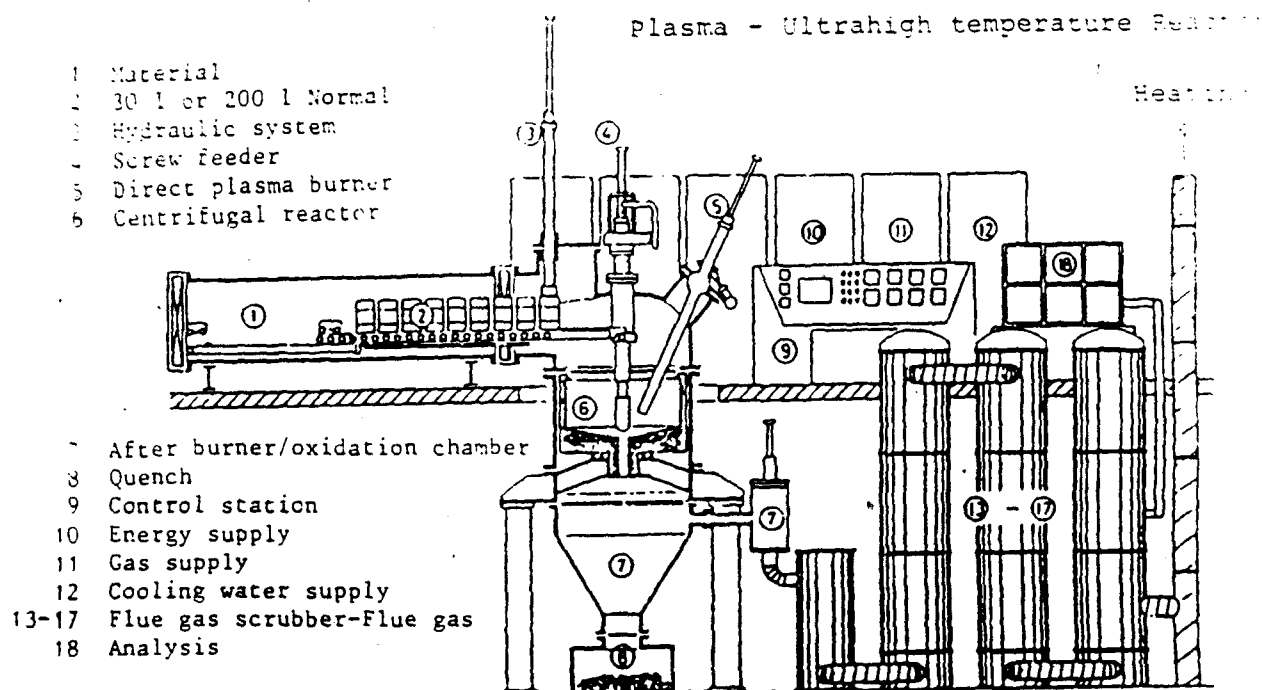


Figure 7

The MGC process

For halon destruction, the plant does not have to be equipped with equipment for handling drums. However, this does not seem to have a significant effect on the total cost of the plant.

The plasma is generated by a direct burner, which allows a long residence time for halons in the plasma. The reactor consists of a centrifuge where the slag is collected. When substances which do not form slag are destroyed, such as halons, a matrix of silica (sand, glass etc) must be provided, since the slag is the anode in the process.

Unlike combustion, the substances in this reactor are heated without the addition of external oxygen. Argon or helium are used as inert gases in the reactor. Any hydrogen necessary during the destruction process, is supplied to the reactor as

methane or water. Tests have been carried out using methane in the reactor in the aim of increasing the lifetime of the Cu electrode. Tests with halon destruction must be carried out to investigate whether the anticipated reactions occur and can be checked.

When the plasma leaves the reactor, it is cooled and the gases are oxidized with oxygen gas ( $O_2$ ) in a reaction chamber. The temperature in the chamber can be held at  $2000^\circ\text{C}$ . By using oxygen directly, the volume of the flue gas is less than that from ordinary combustion. However, it should be necessary to supply air to cool the flue gases before they reach the scrubber system. The flue gas cleaning system handles the same flue gas components as those arising from combustion. Therefore, the requirements for and the design of the flue gas cleaning system are the same regardless of the type of reactor used.

At present, we do not have the necessary information on construction and design for a cost estimate.

MGC Mosel Glaser has stated that a plant with a capacity for handling 7 000 tonnes/year of mixed hazardous waste would cost MSEK 100. We have assumed that this waste would consist of 50% organic material. With this design the plant would be overdimensioned. We have therefore scaled down the costs to a level that we consider applicable to a plant with a capacity of 600 tonnes/year.

## 8. Economic evaluation

The decision to invest in a particular plant cannot be based entirely on the cost estimate. However, it can be used to distinguish between the capital required and the funding required due to other factors affecting the cost of the destruction process.

### 8.1 Investment costs

When estimating the cost of the incineration and the plasma techniques, it has been assumed that the plants will be located on the same site as an existing plant in the Nordic countries. The cost of determining the final site has not been taken into account in the investment costs. With the P-CIG alternative, it is assumed that the equipment at MEFOS in Luleå will be used.

The costs are based on the price levels for autumn 1989. Interest and other financing costs arising during the construction period have not been taken into account since this requires a knowledge of the form of financing to be adopted.

Information obtained in consultation with plant and component vendors was used as a basis for the cost estimate. For the P-CIG technique, estimates were obtained from Interproject Service AB. MGC Mosel Glaser submitted certain estimates for the costing of the plasma process. In addition to this, we used our experience from other projects of a similar nature as a basis for the cost estimates.

The scope of the construction work was presented in section 7. The investment costs, divided into main categories, are presented in Table 12.

Table 12

Investment costs, MSEK.

Technique	Combustion			
	Hydro- gen gas	Propane	P-CIG	Plasma
Development	3	3	6	1
Licence acc. to ML, PBL*	2	2	2	2
Plant	43	45	14	30
Uncertainty 10%	5	5	2	3
Investment	53	55	24	36

\* Corresponding legislation in other Nordic countries

**8.2 Capital costs**

The capital costs for all the techniques are estimated on the basis of an assumed amortization period of 5 years. The capital costs are calculated for the total investment in each case, including the development and licencing costs. With an assumed interest rate of 15%, the fixed annual instalment factor is  $a = 0.3$ .

The capital costs for the different techniques are shown in Table 13.

Table 13

## Capital costs

Technique	Combustion			
	Hydro- gen gas	Propane	P-CIG	Plasma
Investment, MSEK	53	55	24	36
Capital cost, MSEK	15.8	16.4	7.2	10.8

## 8.3 Operating costs

This heading includes costs for personnel, fuel, handling of residual products, maintenance and repair etc.

The personnel requirement for both the combustion and plasma techniques is estimated to correspond to four man years. The cost for one man year is estimated at SEK 230 000.

The P-CIG plant is operated periodically. Interproject estimates that the cost for personnel including preparatory, plant operation and post operation work amounts to MSEK 3.4/year.

The operating and maintenance costs for the combustion and plasma techniques have been estimated at a flat rate corresponding to 3 % of the investment. In addition to these running costs, the combustion technique results in an annual cost of MSEK 0.6 for the replacement of the brickwork in the combustion chamber. The plasma technique involves a similar amount for the replacement of the electrode. The fuel costs (propane, hydrogen gas) and electricity have been calculated according to the current price levels in Sweden.

Interprojekt has estimated the annual operating and maintenance costs for the P-CIG process, at MSEK 8.8 MSEK.



The cost of the necessary replacement of the brickwork in the reactor etc is also included.

The operating costs for the different techniques are summarized in Table 14.

Table 14

Total operating costs, MSEK

Hydrogen gas	Propane	P-CIG	Plasma
9.5	5.0	12.8	4.1

The operating costs for propane incineration and plasma are relatively low because of the proposed use of these techniques in conjunction with the destruction of other kinds of hazardous waste. The same applies to hydrogen, but the fuel costs are higher. The operating costs from the P-CIG process are high due to the periodic operation of the plant with contracted personnel and resources.

#### 8.4 Summary

Table 15 is a summary of the costs of the different techniques. The table also includes the unit cost of halon destruction.

Table 15

## Summary of costs

Technique	Combustion			
	Hydro- gen gas	Propane	P-CIG	Plasma
Investment, MSEK	53	55	24	36
Annual destruction, tonnes	600	600	600	600
Costs:				
capital, MSEK	15.8	16.4	7.2	10.8
operation, MSEK	9.5	5.0	12.8	4.1
Annual cost, MSEK	26.5	21.4	20.0	14.9
Destruction cost, SEK/kg	44	36	33	25

In the summary, the highest cost is obtained from the use of the combustion techniques. This may be due to the fact that we are more familiar with the consequences of this technique. The other processes do not exist in the form of plants operating on a commercial basis.

## 9 Environmental impact

The economic considerations should not be the only deciding factor in the choice of technique and siting. The environmental impact of the plant can affect the final decision to a large extent.

Regardless of the technique used, the environment will be affected through the transportation of the substances. Similarly, the halon emissions are estimated to be 1 % of the amount supplied to the facility.

Halon destruction entails a considerable specific energy consumption in connection with collection, storage and final destruction. This is largely the case, regardless of the technique used. However, it can be noted that halon destruction in already existing plants is carried out without the need for extra energy in any measurable quantity. The destruction of halon only results in a reduction of the capacity to handle other products containing halogen. Because of the capacity for the destruction of hazardous waste which will be available in the Nordic countries during the nineties this effect may be negligible. The halon bank is very small when compared with the quantities of chemical waste products.

The decision to destroy halons is based on the substantial ozone depleting potential of halons. In the light of this, the energy consumption involved in the use of the different techniques is hardly of interest. The different techniques use very different energy carriers.

The destruction of halons using the P-CIG process, involves a high consumption of energy from coal or electricity since for each tonne of halon destroyed at least half a tonne of molten iron is used. The total energy consumption resulting from the use of the other techniques is lower and does not vary greatly from technique to technique.

We are limiting this description of the environmental impact to a comparison of the new techniques and the factors which are not dependent on siting conditions, but which are different for each technique.

The destruction of halons in the existing plants is not taken into account, since the effect of the additional halons cannot be specifically measured. For this to be done, the substance which is destroyed along with the halons in the furnaces must be defined. Neither the flue gas emissions, residual products nor any other environmental factor, such as noise, need be measurably affected. At the same time, it is obvious that if halon destruction is performed by increasing the halogen load in the combustion process, more chlorine and bromine aromatics will be produced in the plant.

#### 9.1 Emissions to the air

When dimensioning the plant for the different techniques, we have taken into account general requirements concerning emissions to the air. However, the processes involve different flue gas flow rates. For this reason, the total emissions will be somewhat different.

However, all the techniques are well within the limits of the emission requirements which can be anticipated in connection with the licencing. Table 17 is a summary of the anticipated annual emission.

Table 17

## Emissions to the air

Technique		Combustion			
		Hydro- gen gas	Propane	P-CIG	Plasma
Flue gas flow,	m <sup>3</sup> /h*	2900	7200	400	2900
Halon flow,	kg/h	340	340	1000	340
Annual halon destruction,	tonne	600	600	600	600
Emission:					
hydrogen chloride,	kg/yr	5	12	0.2	5
hydrogen fluoride,	kg/yr	5	12	0.2	5
hydrogen bromide,	kg/yr	5	12	0.2	5
Total hydrocarbons		50	120	?	50
TCDD equiv. acc. to Eadon mg/yr		0.5	1.2	?	0.5

\* m<sup>3</sup> dry gas with 4 % O<sub>2</sub>

This assessment of the quantities of substances emitted are based on calculated equilibrium quantities and detection limits when determining emissions from the plants.

Question marks are used in the table for the P-CIG technique for the same reason that the conclusion was drawn that the emissions of corresponding pollutants cannot be specified for halon destruction in existing plants. It is not possible to determine how any halogens released during the destruction process substitute gasified organic substances originating from the coal used in the process.

There are good reasons for assuming that the other techniques result in very small emissions of organic pollutants, especially of the aromatic type, since no aromatic rings are supplied with the fuel.

It should only be possible for these pollutants to occur as impurities in the halons or to be formed in the process.

## 9.2 Emissions to water

With a destruction capacity of 340 kg/h of halons with the composition shown in Table 6, an effluent is obtained from combustion and plasma, containing halogens, as shown in Table 18.

Table 18

Halogen content in effluent

Effluent flow rate	20 m <sup>3</sup> /h
F	6 g/l
Cl	0.5 g/l
Br	9 g/l
Total halogens	15.5 g/l

This acidic effluent can be neutralized with sodium hydroxide and sent to a recipient as dissolved salts. If it is neutralized with lime, most of the fluoride is obtained as sludge. Chloride and bromide are sent to the recipient as dissolved salts. The choice of method is probably wholly dependent upon the siting of the facility.

An effluent is obtained from the P-CIG process with a high dust content, mainly of iron. It is possible that the quantity of effluent sent to the recipient can be lower from this process, while the amount of sludge handled is greater.

The environmental protection analysis should result in the implementation of safety systems enable detailed analyses to be done before the effluent is released.

### 9.3 Residual products

Solid residual products in the form of sludge from effluent cleaning mainly occur with the P-CIG process. The production of sludge amounts to 6 t/h or 600 t/yr. The quoted amounts of sludge mainly consist of iron dust. The sludge will contain most of the halogens as iron salts. These salts can form hydrogen bromide and hydrogen fluoride if moisture is present. More or less the same quantity of sludge arises from combustion if the fluoride is trapped with lime.

The sludge will probably be handled as hazardous waste and be deposited at a controlled depository which is dry and leaktight.

## 10 Conclusions

In the Nordic countries, there is a bank of about 3 000 tonnes of halons. This is a small share of the global amount which depletes the ozone layer in the stratosphere. If the Nordic countries find reasons for coming to a decision regarding halon destruction before any international agreement is reached on how this is to be done, this will be a clear indication of the desire to set a precedent for the rest of the world. Therefore, it is logical to conclude that the choice of a method of destruction will not be based on the cost of the technique but on what is least hazardous to the environment.

The destruction of halons should therefore be performed so that the conditions for the formation of persistent toxic organic compounds is minimized. The halogen substituted aromatic compounds are greatly enriched in the environment and can lead to unforeseen problems in the future.

The destruction of halons by incineration together with hazardous waste should therefore be avoided, as well as processes involving the occurrence of large amounts of aromatic compounds which can be substituted by halogens. In each case, it is necessary that the requirements on flue gas cleaning and deposition of the residual products be adjusted in plants which are to be used for halon destruction.

There are two techniques which are preferable for the destruction of halons in the Nordic countries. One is incineration in a separate furnace and the other is destruction in a plasma reactor. In both cases, the mixture of the flue gases will be more or less the same regardless of how the energy for the destruction process is supplied.

A decision as regards which of the two processes is optimal from a technical and economic standpoint should be deferred



until the point of investment. At the present, the description of the environmental impact of the plasma facility is not acceptable since there is no operating experience for such plants. However, this situation may improve within a year. If the decision is to be made at present, combustion according to the process description given in section 7 is preferable. At present, it is the only alternative which can be defined in operational, economic and environmental terms.

Combustion using hydrogen as fuel provides maximum safety. However, use of this fuel involves a higher risk of operational interruptions than propane.

If it is decided to destroy halons separately in the plant for environmental reasons, hydrogen should also be used as fuel. If it is decided that halon should be incinerated together with CFCs and other halogenated hydrocarbons, propane is adequate as fuel. This applies in any event, if CFCs mixed with oil are to be destroyed in the plant.

## References

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          National Research Institute for Pollution and Resources.

MINISTRY OF ENVIRONMENT AND FORESTS

CFCs IN INDIA

Avani Vaish  
Director, Ministry of Environment and Forestry

Phase I Work Plan

<u>Week Ending</u>	<u>Tasks</u>
January 5	<ol style="list-style-type: none"><li>1. Agreement on workplan between MOEF<sup>1</sup> and SBB/TR/C&amp;W<sup>2</sup>.</li><li>2. SBB briefs C&amp;W on uses and manufacture of CFCs in India.</li><li>3. C&amp;W prepares initial listing of technical options relevant to India.</li><li>4. SBB finalizes C&amp;W technical visit program.</li><li>5. Agreement on structure and content of Phase I/Interim Report by SBB/TR/C&amp;W.</li><li>6. TR prepares definition of "transition costs."</li></ol>
January 12	<ol style="list-style-type: none"><li>1. C&amp;W program of technical visits starts.</li><li>2. TR investigates:<ul style="list-style-type: none"><li>-- market structures</li><li>-- economic background</li><li>-- industry development</li></ul></li><li>3. C&amp;W expands/develops their statement of technical options.</li><li>4. SBB completes data collection and analysis.</li></ol>

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<sup>1</sup>MOEF is the Ministry of Environment and Forestry

<sup>2</sup>SBB, TR, and C&W are private consulting firms.

<u>Week Ending</u>	<u>Tasks</u>
January 19	<ol style="list-style-type: none"><li>1. C&amp;W completes program of technical visits.</li><li>2. SBB commences drafting Interim Report - Part A.</li><li>3. TR investigates industry structures.</li><li>4. C&amp;W completes statement of technical options and technical risks.</li><li>5. TR drafts Interim Report - Introduction.</li><li>6. Tr develops demand projections, with SBB support.</li><li>7. TR prepares sectoral analysis for reduced use of CFCs.</li></ol>
January 26	<ol style="list-style-type: none"><li>1. SBB completes drafting of Interim Report - Part A.</li><li>2. C&amp;W makes technical presentation to MOEF and technical experts on "the options for India."</li><li>3. C&amp;W commence drafting Interim Report - Part B.</li><li>4. TR prepares CFC production reduction analysis (and feedstocks).</li><li>5. TR prepares "scenarios for ????????"</li><li>6. TR commences drafting Interim Report - Part C.</li><li>7. SBB presents "CFC use in India" to MOEF.</li></ol>
February 2	<ol style="list-style-type: none"><li>1. SBB draft of Interim Report - Part A to MOEF for review (and to TR and C&amp;W).</li><li>2. TR presents "Targets and Scenarios" to MOEF.</li><li>3. C&amp;W completes drafting of Interim Report - Part B.</li><li>4. Tr prepares cost implications of main scenarios.</li><li>5. TR continues drafting Interim Report - Part C.</li></ol>

<u>Week Ending</u>	<u>Tasks</u>
February 9	<ol style="list-style-type: none"><li>1. TR completes drafting Interim Report - Part C.</li><li>2. Tr drafts "Executive Summary."</li><li>3. Production and internal review of draft report.</li><li>4. Draft report to MOEF for review.</li></ol>
February 16	<ol style="list-style-type: none"><li>1. MOEF reviews draft report.</li><li>2. Consultants meet MOEF to discuss comments/reactions/suggested revisions.</li><li>3. Interim Report revised to take account of MOEF comments.</li><li>4. Interim Report - Final submitted to MOEF.</li></ol>

# Protonique News

The Clean Printed Circuit

Volume 1, No. 2    Editor: Protonique S.A. P.O. Box 78 CH-1032 Romanel    Telephone 021-38 23 34    January 1990

## Editorial

When we sent out the first number of *Protonique News*, we were a little apprehensive as to how it would be received. It may be qualified as a semi-success. Those that we sent out directly to known customers (about 500) were accompanied by a reply card. Where our agents sent out copies (about 1,000) to their customers, we asked they did the same. We received back 47, just under the traditional 10% for such a mailing. Of the ones we received, three had favourable comments and no-one made any unfavourable ones. All of them had the square requesting a continuation of reception ticked. In a few cases, we received photocopies of the card, as the News was circulated amongst several persons. About half the cards received back requested literature on one or more of our products. One of them has even resulted in an important order.

On the whole, we find this good, but what are we to think of the 90% who did not send back the card? Does this mean that these persons do not wish to receive it, or does it mean the card got lost? Worse still for us, who have gone to such pains to produce a short newsletter which we have tried to make as interesting as possible, does it mean that it was relegated to the waste-paper-basket without even having been read or that it arrived on the desk of the wrong individual? A plea! *If you receive this and you think it concerns a colleague, pass it on to him, please.*

To try and get more feedback, we are including this time a card in all the copies (the circulation list is currently about 1600, including those sent through agents). Please ensure we get back as many as possible and especially if you do not wish to continue receiving *Protonique News*. Also, to help companies who are not sure who is the right individual, we have drawn up a blank circulation list to help you pass it round. If you have a colleague who would like his own copy, there is space for his name on the accompanying card.

To end this self-imposed "bouquets and brickbats" department, we have received exactly one letter on this subject which we have translated from French and reproduced here. It makes us quite proud. The person who wrote it has requested that we do not publish his name, address or Company and we respect this wish. ☐

## Brian Ellis Honoured by U.N.

The General Director of Protonique S.A., Brian Ellis, has been honoured to receive a Citation of Excellence from the United Nations Environment Programme "in recognition of an outstanding contribution to the protection of the Earth's Ozone Layer". ☐

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## Ozone Layer Protection

### Latest News

As most of you are probably aware, the Solvents Technical Options Committee reported to the United Nations Environment Programme last Summer. In view of the Helsinki Declaration, at which the Parties to the Montreal Protocol agreed that more severe measures were necessary, a meeting was held in Nairobi starting last August at which the various Committee reports were accepted. The Parties to the Protocol are now studying the various possibilities of revision, which will take place in June 1990.

What can we expect from this first revision? It is impossible to forecast the decisions but, as far as solvents are concerned, the situation is clear. The following, under reserve, indicates the general lines of thought behind any revision:

✓the calendar may be modified. Instead of a 50% reduction of CFCs by 1998, we can expect at least a 90% reduction (possibly 100%) by 2000 and a 100% by 2005. It is not known yet whether or how these reductions will be scaled.

✓other CFCs may be included. CFC-112 may be brought into the Protocol.

✓carbon tetrachloride may be included. This is amongst the worst ozone depleters (other than halons which some class it with) and it may be a surprise to know that about 70,000 tonnes are still emitted each year, despite its known carcinogenicity. A complete phase-out of this substance as a solvent within the Protocol as soon as possible is probable.

✓1,1,1-trichloroethane may be included. This substance, also known as methyl chloroform, is a moderate ozone depleter but it is used in such vast quantities that the total effect is nearly as great as that of CFC-113. Due to a relatively short lifetime, if it is phased out

rapidly, it would produce the most rapid reduction in stratospheric chlorine levels possible, within a few decades. Unfortunately, a phase-out would be more difficult than with the CFC solvents. It seems likely that this substance may become severely restricted, but a complete phase-out is unlikely.

✓some new solvents may be included. Concern is expressed that some of the

*continued on next page...*

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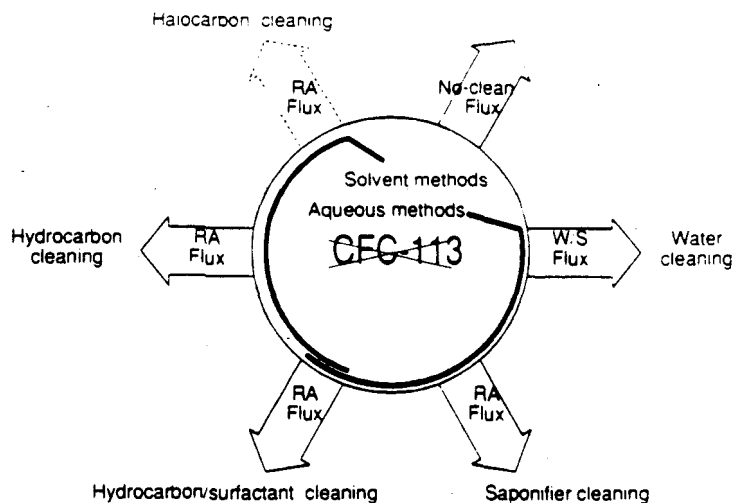
proposed substitute solvents, mostly HCFCs (hydrochlorofluorocarbons), have ozone depletion potentials (ODP) which are still too high to prevent continued damage to the ozone layer, especially if they are massively adopted. It has been proposed to introduce ceiling values of ODP and substitution rate.

Proposed ceiling levels for the ODP have been between 0.02 and 0.08 and for the substitution rate between 20% and 50%. What does this mean? If, for example, the Parties to the Protocol adopt values of 0.05 and 35% respectively and a nation had a total annual consumption in 1986 of, say 1,000,000 tonnes of all types of CFCs, for all applications, it will be permitted to use 35%, i.e. 350,000 tonnes, of substitutes whose ODP does not exceed 0.05. It seems unlikely that much usage of HCFC solvents can be envisaged and such substances will have to be reserved for very special applications where it can be proved there is no other viable alternative.

In practice, it is foreseen that CFC-113 solvents will be phased out more rapidly than is thought. In the industrialised world, a snowball effect may occur. A number of large consumers will make strong efforts to reduce their consumption as much as possible. This has started, with a few names among many that can be quoted: AT&T, Boeing, IBM, Northern Telecom, Seagate, Seiko-Epson, Siemens and at least a hundred others. Various nations are introducing or proposing legislation more severe than is required by the Protocol, notably Sweden with a phase-out by 1991 and many who propose 85-100% phase-downs by 1995. Taking these cases alone, global demand will drop between 1990 and 1995 by more than 50%, even if everybody else maintains status quo. The price will increase by nearly 100% on the 1989 prices, under such a scenario. This price increase will cause others to stop using CFC-113 on economic grounds, causing the price to rise still further. Self-regulation will create an almost complete *de facto* phase-out of CFC-113 by as early as 1994-5.

This is a warning to electronics companies who are adopting a "wait and see" policy. They may be taken by surprise. If they have not already started to examine the five substitute methods (plus the sixth one shown dotted in the figure), then they may be forced to make a hasty and possibly bad decision. Start now, if you have not already done so.

We, at Protonique, are obviously engaged in this matter as we can offer equipment for three of the five viable substitute methods. This has not stopped us



Schematic of available substitutes for CFC-113

from establishing an impartial data base and we are consultants for several organisations. The largest mandate we have received to now has been from the Swiss Government to write a booklet entitled "Replacement of CFC-113 in Industry" in English, French and German. This is over 50 A4 pages of closely typeset material. It will be available in early 1990. Although written with the Swiss context in mind, it is a useful guide for individuals and companies in other countries. As over half the Swiss consumption of CFC-113 is in electronics, emphasis has been placed in this sector with an equal accent on methods where we have no commercial axe to grind as those where we have. At this time, it has not been decided by the Swiss Authorities how this booklet will be distributed outside of Switzerland, but if anyone is interested in obtaining a copy, return us the post card with the appropriate box marked ☐ and we shall inform you of the details within a few weeks.

Countries "under development" present one of the thorniest problems regarding the Montreal Protocol. Some provisions are included for exceptions for developing countries and this has proved to be a stumbling block. At the Helsinki Conference, some developing countries pointed out that they needed aid for technological transfer if they had to reduce their CFC needs. Without going into the details this was admitted in principle. This idea was

pursued at the Nairobi Conference, the first revision of the Protocol, in June. We have to take the needs of these nations into account, but how? The US Environmental Protection Agency are holding a workshop in Washington in January to study such technological transfer. Representatives from sponsor countries, technology experts and, at all, top representatives from so-called developing countries such as Brazil, Egypt, India, Kenya, Malaysia, Mexico, China, Singapore and Venezuela, are to study how to do such studies for each country, establish methods of organisation, operation and cooperation and examine the economical aspects. This will probably be one of the big steps forward since the Montreal Protocol came into force, especially as the USA states that at least two developing countries are planning to construct CFC-producing plants. It must be brought home to these countries that, even under the existing Protocol, they are courting economic disaster as the Parties (which form their major markets) will not import products where ozone-depleting substances have entered into any manufacturing process. This could include such products as frozen foodstuffs, optical goods, automotive components and vehicles, anything containing plastic foams, and as cleaned electronics assemblies. The onus of proof that regulated substances have not been used must lie with producers. ☺

### Thought for the Day:

*Many have said that if the summer of 1989 is anything to judge by, Long the Greenhouse Effect! But if the summer of 1989 is just a small-scale fore of things to come...? ☺*

## Letter to the Editor

Dear Sir,

I am probably one of the first users of a Contaminometer. My employers bought one eleven years ago with a Myron Conductivity Meter. At that time, all the instruments were manual and were difficult to use, as was yours. In 1984, we decided to replace it by a CM-2D with a Hewlett-Packard computer. This has given, and still gives, good service, with only one major problem in nearly six years: we had to replace the cell and amplifier after three years. Other repairs have been small: replacement of the flexible hoses twice, replacement of the resins twice and a standard software exchange. Last year, it was decided to purchase a contamination tester for another department and the choice fell on the latest CM-4 turnkey system. This was slightly dearer than X (Ed.: the name of a competitive instrument was put in here), but the greater flexibility and the fact that it was a European instrument swung the choice in your direction. I was personally a little sceptical regarding some of your claims. We received this instrument in late 1988 with three software up-dates since. Not only can I say that your claims were met, but that this instrument is fantastic, especially for SMD circuits. In addition to this, the instruction manual is exemplary: it is clear, well presented and, above all, well indexed, so that even someone of French mother-tongue can follow it.

I am not in the habit of writing complimentary letters and I would not have written this one but that I received *Protonique News* on my desk this morning. This is the most informative and interesting technical news sheet that I have seen for a long time. But please allow me to criticise it: on the back page you have put in half a page of publicity: this is half a page less of information! I enclose the card asking that I be kept on your mail list.

Yours faithfully,

*Name and address supplied*

Editor's note: thank you for the compliments—we are all blushing collectively after reading this! We have perhaps neglected communications in the past. Our old instruction books, for example, have not been perfect. Over the past two years or so, we have made conscious efforts to improve them and we think we have made advances in the right direction. You are the first to have put your comments on the new manual in writing, but several customers have said that it is much better than the old ones. Please be assured that we also know of our other weaknesses and we shall be making conscious efforts to improve them, as well. ☺

## New Year's Thoughts

As it is planned that this copy of *Protonique News* be sent out in January, it is perhaps not too late to take stock of what has happened in 1989 and to foresee what is likely to happen in 1990.

This past year has, for us, been a difficult one for mainly internal reasons. Qualified personnel is almost impossible to find in Switzerland which has what is probably now the lowest unemployment rate in the world. The official figures, averaged over the country, quote about 0.4%. Of course, these do not take into account that there are situations currently vacant of over 5% of the total workforce, nearer 10% in and near the major towns. In the Lausanne agglomeration, where we are, there is a total population of nearly quarter of a million. The number actually officially unemployed is just over one hundred, in about thirty communes. An unofficial estimation places the number of temporary and permanent jobs vacant in the region at over 10,000. One of the local newspapers has an average of five to six full pages per day of advertisements for situations vacant plus a weekly supplement of up to 48 pages! We were lucky to find a much-needed secretary who started in December, but we are still badly understaffed on both the technical and commercial sides.

All this has contributed to slowing down our development, not helped by the extra charge of environmental studies.

On the more cheerful, positive side, 1989 was an excellent year for us with a very marked improvement in interest in all our product range. Our turnover has beaten all records. This is certainly because we have kept to the forefront of contamination and cleaning technology. We should like to thank you, our customers, for this state of affairs by the confidence you have expressed in us through your orders.

Looking forward to 1990, we can confidently state that this year will not be without interest. We shall be introducing some new products, two of them very shortly. We shall lift a corner of the veil of secrecy from the first one and we are already in a position to talk about it, although the product will not be launched for a little while yet. It is the APL-5HS unit. This is a module which will fit into a standard APL-5 line for use with the new hydrocarbon-surfactant solvents, such as terpene mixtures and similar ones. Laboratory tests have been very positive and a full scale preproduction test is now planned. The price? It may be necessary to count up to 50% more than a standard APL-5L line and running costs will neces-

sarily be higher. The actual cost of cleaning circuits using this method, including all running, amortisation and product costs, is estimated at about twice that of CFC-113 or ordinary water and saponifier/water methods, but only two-thirds that of alcohol cleaning, for throughputs of up to 10 m<sup>2</sup>/h of ordinary circuits or 5 m<sup>2</sup>/h for SMD circuits. Tick the post card if you want more details. ☺

The other products in the pipeline are not yet ready for announcement.

Finally, assuming it is not too late, may we offer you our best wishes for 1990? We stopped sending out Greetings Cards and presents some eight years ago. We send the money thus saved to aid distressed children, especially in famine areas. This does not mean that we do not offer our interlocutors our best wishes, so:

*May 1990 bring every one of our  
readers all the best in Health,  
Prosperity and Happiness.*

## Telex

### Important announcement

Please note that as from the end of March 1990, we shall no longer have a telex machine. Please cancel our telex number from your records.

This decision has been made because of the sharp decline in telex communications. Over the last two years, we have received 29 messages, of which 16 were publicity, and we have sent out 11. This averages out at one real message received or sent per month. As we pay the PTT a rental for the line and machine of over SFr 115.00 (\$75) per month and as virtually all our correspondents now have fax (quicker and cheaper), we feel that our decision is entirely justified for such a small volume of traffic.

For those who wish to make sure that their records are up-to-date, please note that we can be reached through:

Telephone: +41 21-38 23 34

Fax: +41 21-38 24 11



## The Ballad of the Zone of Ozone

A light-hearted look at a serious subject

To clean a printed circuit, oh  
How life is so unfair,  
It used to be so easy, till  
We found the ozone layer!

But over the Antarctic land,  
A hole did find its way,  
Away up in the stratosphere  
To end the Winter day.

The men of knowledge looked so hard  
To find the very cause.  
Molina, Rowland and some more  
Suggested Nature's laws.

The laws were thought to be a cinch:  
A can of aerosol,  
Refrigerator, plastic foam  
And nothing more, at all.

And then amongst the CFCs  
One thought of one-one-three,  
But that is what is used to clean,  
And we're no longer free!

In nineteen-eighty-seven year,  
The men of nations met  
In Montreal: they said "no more",  
And this to our regret.

Then some like Wally Rubin said,  
"It does not matter much,  
"Because I have a better flux  
"Ex-thirty-two or such."

This kind of flux is not to clean,  
For all is safe and sure,  
Contamination is not there  
And high is SIR.

But MIL and DEF did not agree.  
Too simple was this view,  
"You have to clean, no matter what",  
With solvents, far too few.

So Michael Hayes in Florida  
Distilled some orange peel,  
And EC-seven was the way,  
Or so some people feel.

Bill Kenyon, speaking for Du Pont,  
An answer did release.  
He felt the future must rely  
On his HCFCs.

And Colin Lea in NPL  
On his white charger rode.  
In "Circuit World" he wrote a lot  
Of papers à la mode.

In EPA, Steve Andersen  
For UNEP started work.  
His committee did further go  
And stopped us with a jerk.

They said that things like one-one-one  
Trichloroethane were  
Not the answer any more,  
To clean the upper air.

The Germans said that alcohol,  
It was the only way.  
But this is how they make the schnapps  
They drink up ev'ry day.

So, what is left to save the day?  
Well, water does just that.  
To clean both rosin and OA.  
It seems to be just pat.

And what about the ozone layer?  
Let's not forget it's there.  
If we act sharp and hit the gas,  
We might just clean the air.

But it will take some hundred years.  
Before the stratosphere  
Begins to get its ozone back.  
And this will cost us dear.

Now let us draw a moral from  
This poem, full of wit:  
That future cleaning does not land  
Us truly in the mud".

BNE

\*(If they can find a better one,  
are asked to improve on the last  
but no prizes are offered for  
one.)

## The Montreal Protocol? No problem!

Clean your conventional and SM assemblies with water, the  
only non-polluting solvent

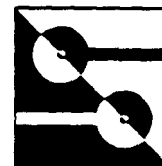


### Brief Specifications:

Typical practical throughput (SMD)	3-6 m <sup>2</sup> /h
Typical practical throughput (conventional)	5-20 m <sup>2</sup> /h
Typical Contaminometer™ CM-4 readings:	
under SM devices	<0.8 µg/cm <sup>2</sup> eq. NaCl
general surface contamination	<0.4 µg/cm <sup>2</sup> eq. NaCl
Typical Insulohmeter™ IRMA-1 readings	
under SM devices 1 hr after cleaning	>10 <sup>16</sup> Ω/□
idem, at 40°C, 95% RH	>10 <sup>15</sup> Ω/□
Typical DI water consumption	4-8 l/m <sup>2</sup>
Typical electricity consumption	800 Wh/m <sup>2</sup>
Typical saponifier injection (optional)	100-500 cm <sup>3</sup> /m <sup>2</sup>
Typical rinse water/isopropanol injection (optional)	200-400 cm <sup>3</sup> /m <sup>2</sup>

The above are indicative under average conditions, without obligation

The new Protonique  
APL-5SMD line is in the  
tradition which has made  
our aqueous cleaners  
and dryers known  
throughout the world as  
the best!



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