



Conservation And Recycling Practices For CFC-113 And Methyl Chloroform



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CONSERVATION AND RECYCLING PRACTICES FOR CFC-113 AND METHYL CHLOROFORM

by

ICOLP Technical Committee*

John Thome (Chairman)

Ray Allen

Jonathon Andell

Kenneth Beach

David Hey

Stewart Holm

Jim Landers

Dara O'Rourke

Robert Ramsey

Bill Richardson

Farzan Riza

Richard Szymanowski

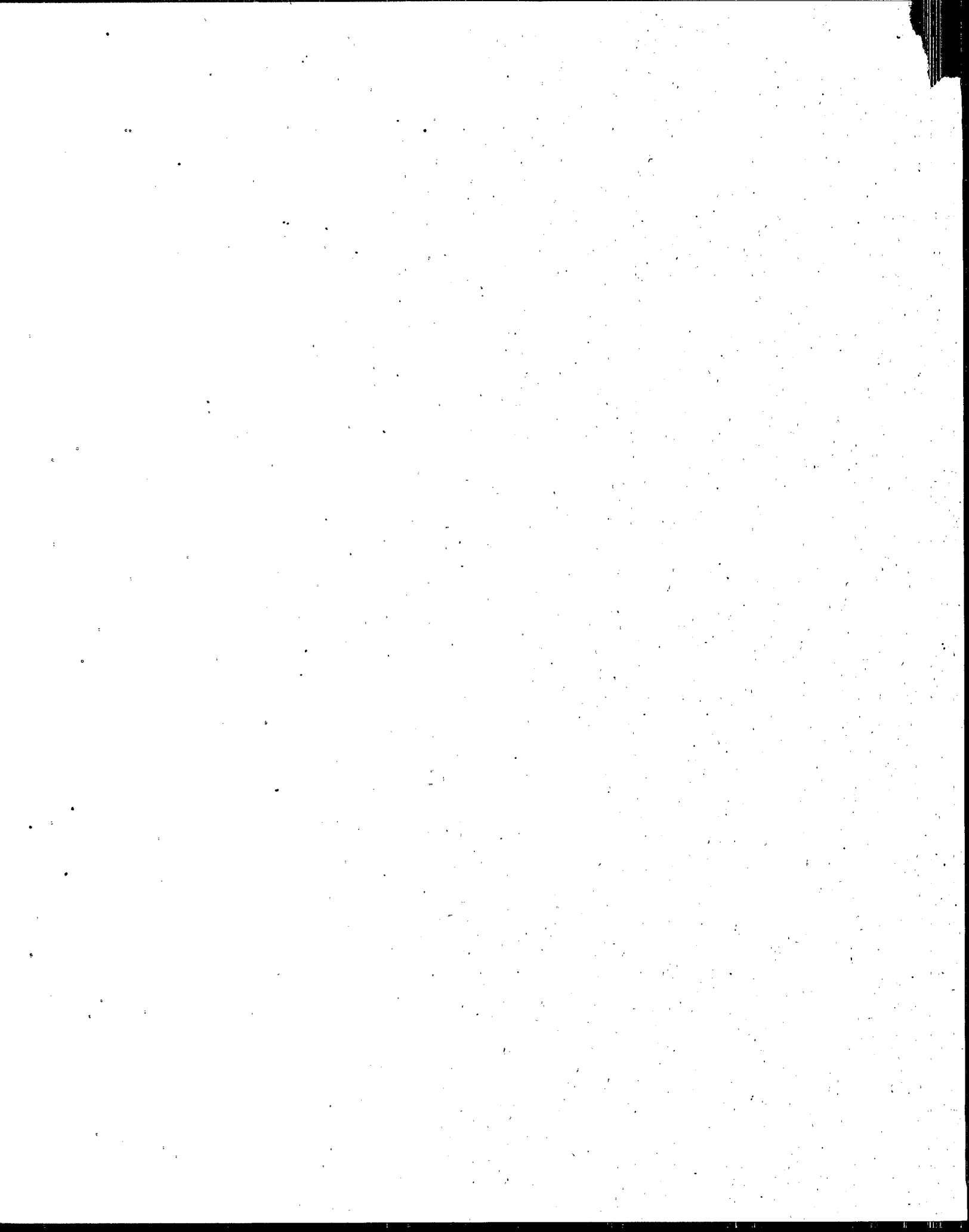
Peter Thorstensen

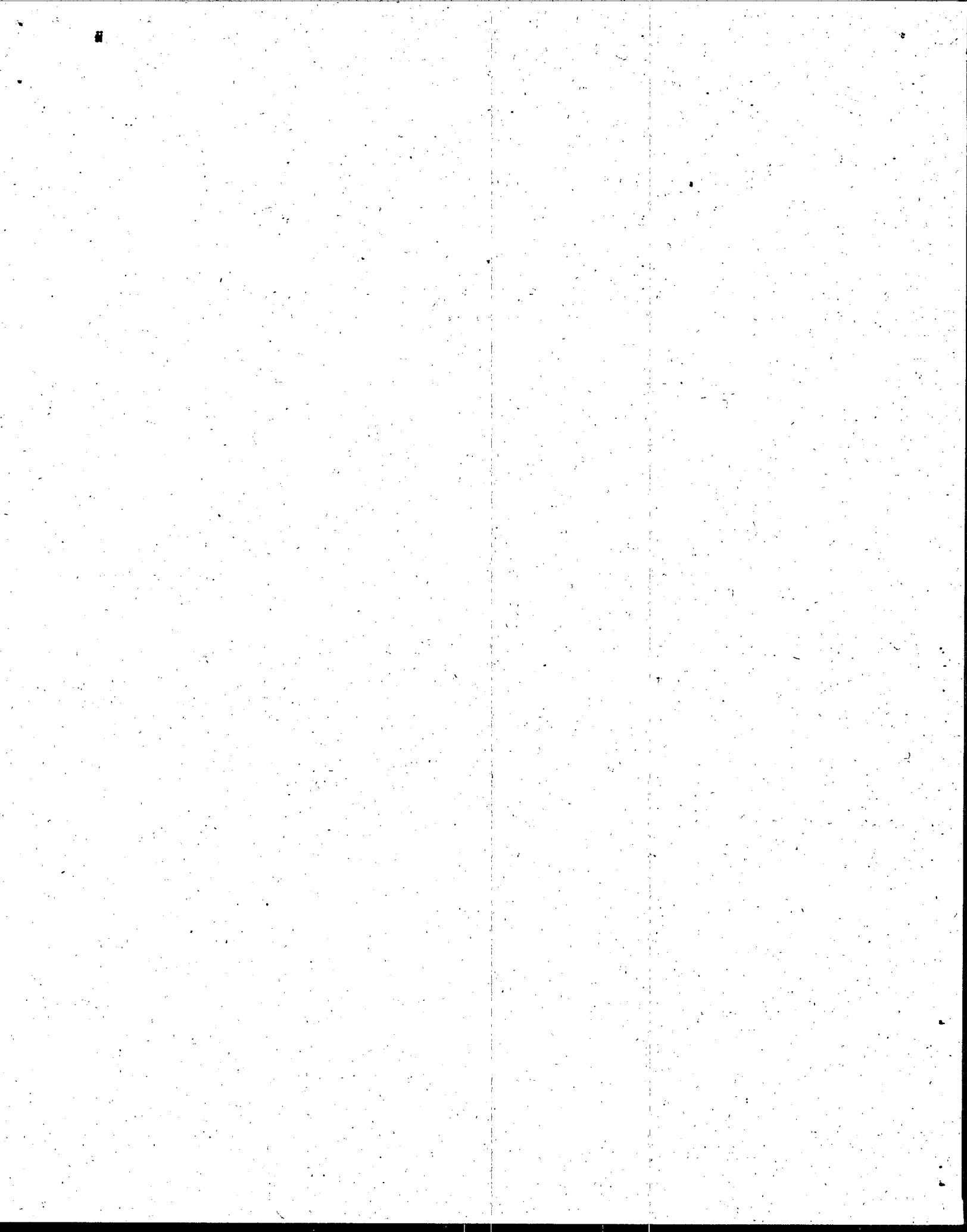
Stephen O. Andersen

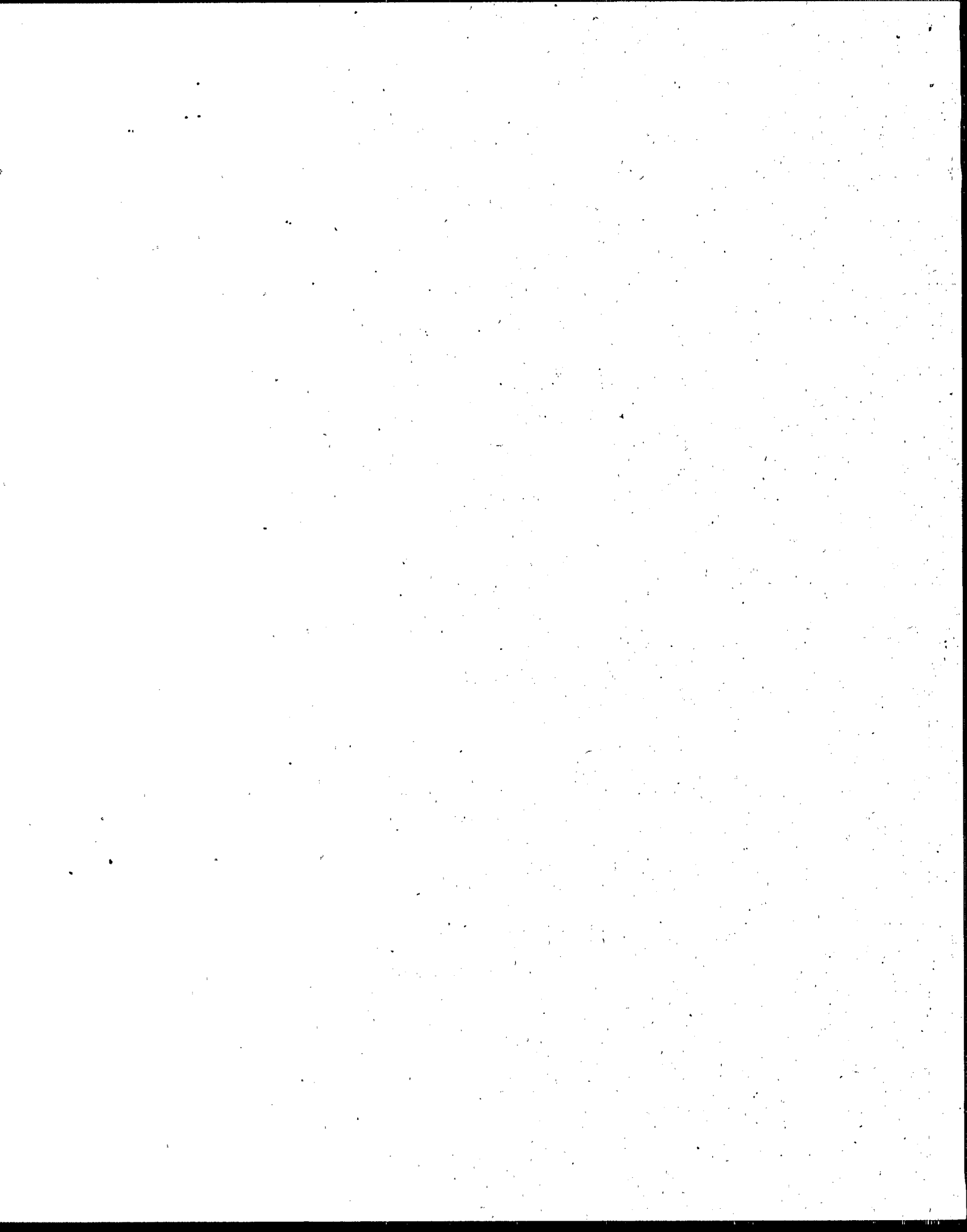
U.S. Environmental Protection Agency

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John Thome, Ray Allen, Jonathon Andell, and Jim Landers are employed by Motorola; Kenneth Beach is employed by Honeywell; David Hey is employed by ICI (UK); Stewart Holm is employed by the Halogenated Solvents Industry Alliance; Dara O'Rourke and Farzan Riza are employed by ICF Incorporated; Bill Richardson is employed by Digital Equipment Corporation; Robert Ramsey is employed by DuPont de Nemours & Co.; Richard Szymanowski is employed by Northern Telecom; and Peter Thorstensen is employed by Manchester Corporation. We would like to thank the many individuals and companies that provided insight and information that helped produce this manual. This manual was funded by the U.S. EPA and ICOLP.







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FOREWORD

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, and subsequent 1990 amendments and adjustments, restricts the production and consumption of ozone-depleting chemicals. Two such chemicals, chlorofluorocarbon 1,1,2-trichloro-1,2,2-trifluoroethane (commonly referred to as CFC-113) and 1,1,1-trichloroethane (commonly referred to as methyl chloroform or MCF), will be completely phased out in developed countries by years 2000 and 2005 respectively, and ten years later in developing countries.

Exhibit 1 lists the countries that are Parties to the Montreal Protocol as of April 1991. In addition, many companies worldwide have corporate policies to expedite the phaseout of ozone depleting chemicals. Exhibit 2 presents the corporate policies on CFC-113 reduction for some of these companies.

In addition to providing regulatory schedules for the phaseout of ozone-depleting chemicals, the Montreal Protocol established a fund that will finance the incremental costs of phasing out ozone-depleting substances by developing countries that are Party to the Protocol.

U.S. Clean Air Act Amendments

The U.S. Clean Air Act (CAA) was amended in 1990, and contains several provisions pertaining to stratospheric ozone protection. Section 602 of the CAA presents a list of ozone-depleting substances that are restricted under the CAA. These ozone-depleting substances are defined as Class I and Class II substances. Class I substances include all fully halogenated chlorofluorocarbons (CFCs) including CFC-113, three halons, MCF, and carbon tetrachloride. Class II substances are defined to include 33 hydrochlorofluorocarbons (HCFCs). The sections of the CAA that are of importance to users of this manual are discussed below.

Exhibit 1

MONTREAL PROTOCOL PARTICIPANTS

Argentina	Malawi
Australia	Malaysia
Austria	Maldives
Bahrain	Malta
Bangladesh	Mexico
Belgium	Netherlands
Brazil	New Zealand
Bulgaria	Nigeria
Burkina Faso	Norway
Cameroon	Panama
Canada	Poland
Chile	Portugal
Czechoslovakia	Singapore
Denmark	South Africa
Ecuador	Spain
Egypt	Sri Lanka
European Community	Sweden
Finland	Switzerland
Fiji	Syrian Arab Rep.
France	Thailand
Germany	The Gambia
Ghana	Trinidad and Tobago
Greece	Tunisia
Guatemala	Uganda
Hungary	USSR (includes Byelorussia and Ukraine)
Iceland	United Arab Emirates
Iran	United Kingdom
Ireland	United States
Italy	Uruguay
Japan	Venezuela
Jordan	Yugoslavia
Kenya	Zambia
Libya	
Liechtenstein	
Luxembourg	

Non-Ratifying Signatories: Congo, Indonesia, Israel, Morocco, Philippines, Senegal, Togo

Date: April, 1991

*Exhibit 2***CORPORATE POLICIES ON CFC-113 REDUCTION SCHEDULE**

<u>Company</u>	<u>Reduction Schedule CFC-113</u>
American Electronics Association Member Companies, U.S.	Phaseout 2000
AT&T, U.S.	Phaseout 1994
Canon, Japan	Phaseout 1994
Digital Equipment Corporation, U.S.	Phaseout 1995
Hitachi Corporation, Japan	Phaseout 1993
Honeywell, U.S.	Phaseout 1997
IBM, U.S.	Phaseout 1993
Intel Corporation, U.S.	Phaseout 1992
Matsushita, Japan	Phaseout 1995
Motorola, Inc., U.S.	Phaseout 1992
Nissan Motor Corp., Japan	Phaseout 1993
Northern Telecom, Canada	Phaseout 1991
Seiko-Epson, Japan	Phaseout 1993
Sharp Corporation, Japan	Phaseout 1995
Texas Instruments, U.S.	Phaseout 1994
Toshiba Corporation, Japan	Phaseout 1995
Volvo, Sweden	Phaseout 1994

Section 604 and Section 605: Phaseout of Production and Consumption of Class I and Class II Substances.

These provisions of the CAA present phaseout schedules for Class I & Class II substances. The phaseout dates for ozone-depleting substances listed in the CAA are more stringent than the Montreal Protocol. Exhibit 3 presents the phaseout schedule for CFC-113 and MCF. Other substances with ozone-depleting potential are also regulated under the Montreal Protocol and the CAA. While they are not used in solvent cleaning applications, these substances are used in other applications. Section 605 of the CAA presents provisions for the phaseout of HCFCs. The CAA freezes the production of HCFCs in 2015 and phases them out by 2030. Since these restrictions focus on production limitations, to the extent that these chemicals can be recovered, recycled, and reused, they may continue in commerce past the applicable phase-out dates.

Section 608: National Emissions Reduction Program

This section calls for EPA to promulgate regulations by July 1992 requiring emissions from all refrigeration sectors (except mobile air conditioners that are covered in Section 609) to be reduced to their "lowest achievable levels." Regulations affecting emissions from all other uses of Class I and Class II substances including solvent cleaning are to take effect by November 1995. This section also prohibits any person from knowingly venting any of the controlled substances, including HCFCs, during servicing of refrigeration or air conditioning equipment (except cars) beginning July 1, 1992, and requires the safe disposal of these compounds by that date.

Section 610: Nonessential Products Containing Chlorofluorocarbons

This provision directs EPA to promulgate regulations that prohibit the sale or distribution of certain "nonessential" products that release Class I & Class II substances during manufacture, use, storage, or disposal. In the CAA, Congress defined several products as nonessential including CFC-

containing cleaning fluids for noncommercial electronic and photographic equipment, and CFC-propelled plastic party streamers and noise horns. In addition, Congress established guidelines to identify additional products that are nonessential. Regulations banning nonessential products that release Class I substances must be promulgated by November 15, 1991 and become effective November 15, 1992. In addition, the CAA bans the sale and distribution of certain products releasing Class II substances, including aerosols and pressurized dispensers and noninsulating foam, by January 1, 1994. Exemptions can be granted from the ban on aerosols and pressurized dispensers due to flammability and worker safety concerns.

Section 611: Labeling

This section of the CAA directs EPA to promulgate regulations by May 15, 1992 requiring labeling of products that contain or were manufactured with Class I or Class II substances and containers containing these substances. The label will read "Warning: Contains or manufactured with [insert name of substance], a substance which harms public health and environment by destroying ozone in the upper atmosphere".

The CAA defines three types of products that must be labeled and specifies the time frame by which these products must be labeled. The three products and time frame are as follows:

- Effective May 15, 1993, containers in which a Class I or Class II substance is stored or transported, and products containing Class I substances must be labeled;
- Effective May 15, 1993, products manufactured with Class I substances must be labeled. However, products manufactured with Class I substances can be temporarily exempted from the labeling requirements of this section if EPA determines that there are no substitute products or manufacturing processes that (a) do not rely on the use of the Class I substance, (b) reduce the overall risk to human health and the

Exhibit 3

**PHASEOUT DATES FOR CFC-113 AND METHYL CHLOROFORM
UNDER THE U.S. CLEAN AIR ACT
AND THE MONTREAL PROTOCOL**

CFC PHASEOUT

Clean Air Act

Reduce from 1986
levels by:

1991 - 15%
1992 - 20%
1993 - 25%
1994 - 35%
1995 - 50%
1996 - 60%
1997 - 85%
1998 - 85%
1999 - 85%
2000 - 100%

Montreal Protocol

Freeze at 1986 production and consumption levels by July
1989

20% reduction from 1986 levels by January 1993
50% reduction from 1986 levels by January 1995
85% reduction from 1986 levels by January 1997
100% reduction from 1986 levels by January 2000

Also call for future assessment to determine if an earlier
complete phaseout by January 1997 is achievable

METHYL CHLOROFORM PHASEOUT

Clean Air Act

Freeze at 1989 levels
by 1991
Freeze at 1989 levels
continues in 1992
Reduce from 1989
levels by:

1993 - 10%
1994 - 15%
1995 - 30%
1996 - 50%
1997 - 50%
1998 - 50%
1999 - 50%
2000 - 80%
2001 - 80%
2002 - 2004*
2005 - 100%

Montreal Protocol

Freeze at 1989 production and consumption levels by
January 1993

30% reduction from 1989 levels by January 1995
70% reduction from 1989 levels by January 2000
100% reduction from 1989 levels by January 2005

* New authority would be given to EPA to authorize, to the extent consistent with the Protocol, the production of methyl chloroform in an amount not to exceed 10% of baseline per year in 2002, 2003, and 2004 for use in essential applications for which no safe substitutes are available.

environment, and (c) are currently or potentially available. If EPA temporarily exempts products manufactured with Class I substances from the labeling requirement based on the lack of substitutes, the products must be labeled by January 1, 2015; and

- No later than January 1, 2015, products containing or manufactured with a Class II substance must be labeled. EPA may require such products to be labeled as early as May 15, 1993 if it determines, after notice and opportunity for public comment, that there are substitute products or manufacturing process available.

The CAA allows for petitions to be submitted to EPA to apply the requirements of Section 611 to products containing Class II substances or a product manufactured with Class I or II substances which are not otherwise subject to the requirements. This petition process will operate between May 15, 1993 and January 1, 2015. For products manufactured with Class I substances, a successful petition would result in the labeling of a product previously determined by EPA to be exempt. For products containing or manufactured with Class II substances, the petition process could lead to labeling of a product that had been left unlabeled by default.

Section 612: Safe Alternatives Policy

Section 612 establishes a framework for evaluating the environmental impact of current and future potential alternatives. Such regulation ensures that the substitutes for ozone-depleting substances will not create environmental problems themselves. The key provisions of Section 612 require EPA to:

- Issue rules by November 15, 1992 which make it unlawful to replace any Class I and Class II substances with a substitute that may present adverse effects to human health and the environment where EPA has identified an available or potentially available alternative that reduces the overall risk to human health and the environment.
- Publish a list of prohibited substitutes, organized by use sector, and a list of the corresponding alternatives;

- Accept petitions to add or delete a substance previously listed as a prohibited substitute or an acceptable alternative;
- Require any company which produces a chemical substitute for a Class I substance to notify EPA 90 days before any new or existing chemical is introduced into commerce as a significant new use of that chemical. In addition, EPA must be provided with the unpublished health and safety studies/data on the substitute.

To implement Section 612 EPA will (1) conduct environmental risk characterizations for substitutes in each end use and (2) establish the Significant New Alternatives Program (SNAP) to evaluate the future introduction of substitutes for Class I substances. EPA has also initiated discussions with NIOSH, OSHA, and other governmental and nongovernmental associations to develop a consensus process for establishing occupational exposure limits for the most significant substitute chemicals.

The environmental risk characterizations for the substitutes will involve a comprehensive analysis based on the following criteria: ozone-depleting potential, flammability, toxicity, exposure effects, energy efficiency, degradation impacts, air, water and solid waste/hazardous waste pollution effects, and global-warming potential. Economic factors will also be considered. EPA will organize these assessments by use sector (i.e. solvents, refrigeration, etc). The risk characterizations will result in risk-management strategies for each sector and substitute. EPA will then categorize a substance as unacceptable, acceptable with limitations on use or quantity, acceptable without comment, or delayed pending further study. Petitions will be allowed to change a substance's status with the burden of proof on the petitioner.

The SNAP program, effective November 15, 1992, will review future substitutes not covered in the initial risk characterization process. SNAP will evaluate a substitute based on the criteria established for the risk characterization and will classify it similarly.

Excise Tax

Congress has also placed an excise tax on ozone-depleting chemicals manufactured or imported for use in the United States. This tax provides a further incentive to use alternatives and substitutes to CFC-113 and MCF. The tax amounts are based on each solvent's ozone depleting potential.

Calendar Year	Tax Amount Per Pound	
	CFC-113	MCF
1991	\$1.096	\$0.137
1992	\$1.336	\$0.167
1993	\$2.120	\$0.265
1994	\$2.120	\$0.265
1995	\$2.480	\$0.310

The tax will increase by \$0.310 per pound for CFC-113 and \$0.045 per pound for MCF each year after 1995.

Other International Phaseout Schedules

European Community Directive

Under the Single European Act of 1987, the twelve members of the European Community (EC) are now subject to various environmental directives. The members of the EC are Belgium, Denmark, Germany, France, Greece, Great Britain, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Council Regulation number 594/91 of March 4, 1991 provides regulatory provisions for the production of substances that deplete the ozone layer. The EC phaseout schedule for CFC-113 production is more stringent than the Montreal Protocol. It calls for a 50 percent reduction of CFC-113 by the end of 1993, a 67.5 percent reduction by the end of 1995, an 85 percent reduction by the end of 1996, and complete phaseout by June 30, 1997. For MCF, the production phaseout schedule is as follows: 30

percent reduction by the end of 1995, 70 percent by the end of 2000, and a complete phaseout by the end of 2004. While all members must abide by these dates, Council Regulation number 3322/88 of October 31, 1988 states that EC members may take even more extensive measures to protect the ozone layer.

Other Legislation

Several other countries have adopted legislation that is more stringent than the terms of the Montreal Protocol. Environment Canada, the federal environmental agency responsible for environmental protection in Canada, also has a reduction program in place that is more stringent than the Montreal Protocol. All production and import of CFCs, for use in Canada, must be eliminated by no later than 1997. Environment Canada has also announced a series of target dates for the phaseout of CFCs in specific end uses. For solvent cleaning applications, such as metal and precision cleaning, it mandates a phaseout of CFC-113 by the end of 1994. Pending final consultations with end-users and producers of MCF, the target date for the phaseout of MCF will be 2000.

Japan has ratified the revised Montreal Protocol. The recent Ozone Layer Protection Act gives the Ministry of International Trade and Industry (MITI) the authorization to promulgate ordinances governing the use of ozone-depleting compounds. MITI and the Environmental Agency have established the "Guidelines for Discharge Reduction and Use Rationalization." Based upon these guidelines, various government agencies provide administrative guidance and advice to the industries under their respective jurisdictions. Specifically, MITI, the ministry overseeing several aspects of Japanese industry including the production and trade of controlled substances, prepares and distributes manuals, and encourages industry to reduce ozone-depleting compounds consumption through economic measures such as tax incentives to promote the use of equipment to recover and reuse solvents.

The EFTA (European Free Trade Agreement) countries (i.e., Austria, Finland, Iceland, Norway, Sweden, and Switzerland) have each adopted measures to completely phaseout fully halogenated ozone-depleting compounds. Some of the EFTA

countries have sector-specific interim phaseout dates for certain solvent uses. Norway and Sweden will phaseout their use of CFC-113 in all applications except textile dry cleaning by July 1 and January 1, 1991, respectively. Furthermore, Austria will phaseout CFC-113 in some solvent cleaning applications by January 1, 1992 and 1994. Austria, Finland, Norway, and Sweden will completely phaseout their use of CFC-113 in all applications by January 1, 1995. Sweden also plans an aggressive phaseout date of 1995 for MCF.

Cooperative Efforts

The U.S. Environmental Protection Agency (EPA) has been working with industry to disseminate information on technically feasible, cost effective, and environmentally sound alternatives for ozone-depleting substances. As part of this effort, the U.S. EPA is working with the Industry Cooperative for Ozone Layer Protection (ICOLP*) to prepare a series of manuals to provide technical information on alternatives to CFC-113 and MCF. The manuals are based on actual industrial experiences that will serve as a guide to users of CFC-113 and MCF worldwide. These manuals will be updated periodically as technical developments occur.

The first manuals in the series are:

- Conservation and Recycling Practices for CFC-113 and Methyl Chloroform.
- Aqueous and Semi-Aqueous Alternatives to CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies.
- Inert Gas Soldering/Low Residue Flux and Paste Alternatives to CFC-113 and Methyl Chloroform.
- Alternatives for CFC-113 and Methyl Chloroform in Metal Cleaning.
- Eliminating CFC-113 and Methyl Chloroform in Precision Cleaning Operations.

* Appendix A presents more detailed information about ICOLP.

- Riveting Without CFC-113 and Methyl Chloroform.

This particular manual presents a simple structured program to help you reduce use and emissions of CFC-113 and/or MCF. The manual:

- Guides you through a characterization of your existing process;
- Helps you identify sources of emissions from your process;
- Outlines the selection criteria for appropriate conservation and recycling measures for your operations;
- Introduces several conservation and recycling technologies;
- Presents detailed case studies of solvent conservation and recycling measures.

The conservation measures for CFC-113 and MCF cleaning will help to reduce losses from:

- Convection and diffusion
- Dragout
- Maintenance
- Miscellaneous sources.

This manual will be helpful to all users of CFC-113 and MCF in solvent cleaning. However, the success of your CFC-113 and MCF reduction strategies will depend upon how effectively you can coordinate your conservation and recycling programs. The reduction of CFC-113 and MCF in solvent cleaning presents a demanding challenge for your organization. The rewards for success are the contribution to global environmental protection and the increase in your company's industrial efficiency.

STRUCTURE OF THE MANUAL

This manual is divided into four sections:

- **CONSERVATION AND RECYCLING ADVANTAGES**

This section outlines some of the advantages of conservation and recycling practices.

- **PROCESS CHARACTERIZATION**

This section helps to assess and understand the use of solvents in manufacturing processes.

- **CONSERVATION PRACTICES AND STRATEGIES**

In this section, conservation practices specific to batch cleaning, in-line cleaning, and cold cleaning are discussed with examples and ideas for reducing losses from these systems. Reclamation and recycling processes are also discussed.

- **CASE STUDIES OF INDUSTRIAL PRACTICES**

This section presents case studies of several companies that implemented conservation and recycling programs.

CONSERVATION AND RECYCLING ADVANTAGES

There are a number of compelling reasons to conserve and recycle CFC-113 and MCF solvents. Controlling solvent emissions from vapor degreasers has been important to reducing occupational exposure and minimizing solvent losses. With the added incentive of protecting the stratospheric ozone layer and mitigating the greenhouse effect, it is now imperative that your company reduce emissions of these chemicals through conservation and recycling.

- Solvent conservation and recycling protects worker health and protects the local environment.
- Solvent conservation and recycling improves operating practices.
- Understanding and controlling emissions of cleaning solvents supports the optimization of manufacturing processes.
- Reducing waste streams and chemical losses during operation saves money and can help your company comply with environmental requirements.

In all but the most efficient systems, vapor degreasing and cold cleaning systems emit relatively high amounts of solvents when compared to solvent emissions when proper engineering controls are implemented. Exhibit 4 shows typical emission factors in industrial practices. The results are based on a standard load, keeping variables such as thermal mass constant for the different operating settings.

In Exhibit 4, "base" represents the minimal amount of solvent emissions from a process unit that is

idling with its cover on. The amount of solvent loss during this idling period is arbitrarily given an emission factor of 1.0.

"Good" represents solvent loss rates for a properly operated unit with a representative load. The general procedure is a 30-second vapor rinse, 30-second ultrasonic immersion, 60-second vapor dry, and a 30-second residence in the freeboard zone (just above the vapor zone but still within the cooling coils). This emission factor represents a high level of conservation of emissions through strict adherence to proper procedure.

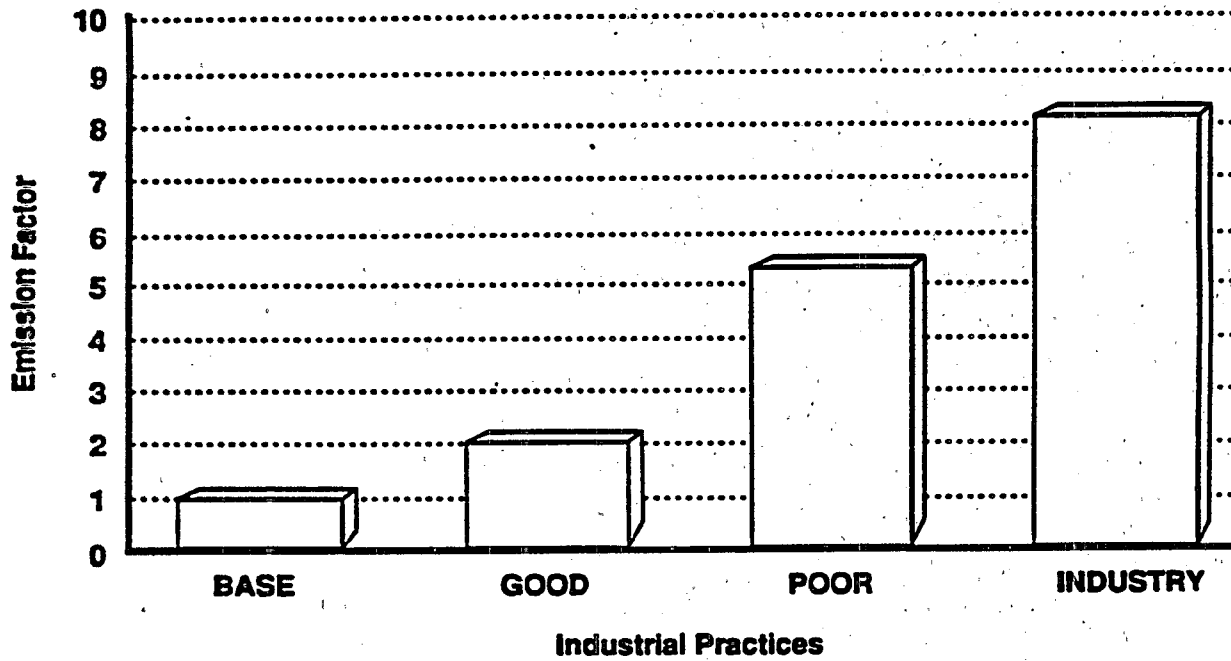
"Poor" represents solvent loss rates when some common shortcuts are taken in violation of "good" procedure. For example, when no freeboard residence is used and the vapor dry is reduced from 60 seconds to 30 seconds. As shown in Exhibit 4, these seemingly minor violations in procedure dramatically increase emissions by a factor of five compared to the "Base" case.

"Industry" represents a value that is representative of what is commonly found in industry. This value incorporates losses associated with liquid dragout, drafts, rapid entrance and exit speeds, uncontrolled sprays, and other procedural violations. This case represents an increase in emissions by a factor of eight compared to the "Base" case. This consumption level is generally found in high production situations where throughput is emphasized over solvent savings.

Identifying the sources of emissions is the first step in reducing emissions. In our discussions of the various technologies, we examine specific sources of emissions and cite actions which will help to reduce these losses.

Exhibit 4

RELATIVE SOLVENT EMISSIONS FROM REPRESENTATIVE INDUSTRIAL SITUATIONS



Source: Halogenated Solvents Industry Alliance

F1000-3

The three main sources of emissions are:

- Diffusive and convective losses of solvent vapor from the equipment;
- Leakage from the equipment and its associated piping;
- Liquid and vapor dragout on the work being processed.

Recent improvements in machine designs address the main sources of emissions. Solvent losses can be reduced either by replacing old machines with new equipment or retrofitting older machines with improvements. A partial list of vendors of equipment appears at the end of this manual.

Occupational Safety and Health regulations which are in place in the U.S. and Europe also motivate companies to reduce emissions of solvents. Permissible exposure limits require companies to monitor and control emission of certain solvents.

Economic Benefits

The U.S. tax on CFCs and MCF, and product shortages, will continue to improve the economics of recycling and conservation. As production cuts go into effect and prices continue to rise, the efficient use of solvents will become more profitable.

The elimination of waste streams in a manufacturing process increases the efficiency of the process and reduces costs associated with complying with state and local regulations on hazardous waste minimization and auditing requirements. Reclaiming and recycling solvents is one way to reduce both waste streams and the virgin use of expensive ozone-depleting solvents. It is important, however, to avoid mixing solvents in the recovery process. The quality of recovered solvents should be examined for suitability for intended future uses.

Solvent recycling can occur both on-site and off-site. While the magnitude of on-site recycling is difficult to quantify, it has been a significant component in the increased solvent efficiencies that have been achieved in recent years. Over 100 off-site solvent recycling organizations exist in the U.S. and Europe. Over the last several years these companies have proven that recycling is economical for both themselves and those who use solvents. As more companies perform solvent recovery, the recycling organizations are now poised to serve the needs of the industry. A partial list of solvent recyclers appears at the end of this manual.

Older equipment is generally less efficient and more likely to emit solvents than new equipment.

PROCESS CHARACTERIZATION

The first step in reducing use and emission of ozone-depleting chemicals is identifying them in your processes. CFC-113 and MCF are marketed as cleaning solvents under a variety of names and labels. They are also found in smaller concentrations in a variety of mixtures. The following is a partial list of these solvents by their trade names, and the companies that manufacture them:

CFC-113

<u>Trade Name</u>	<u>Manufacturer</u>
Algofrane 113	Montecatini
Arklone P	ICI
Asahifron 113	Asahi Glass
Daiflon 113	Daikin
Daiflon S 3	Daikin
Flugen 113	Atochem
Freon PCA	DuPont
Freon TMS (94%)	DuPont
Freon 113	DuPont
Freon TF	DuPont
Frigen 113	Hoechst
Frigen 113A	Hoechst
Frigen TR	Hoechst
Genetron 113	Allied Signal
Genesolv D	Allied Signal

Nomenclature/Chemical Names

1,1,2-Trifluorotrichloroethane
R 113
F 113

Methyl Chloroform

<u>Trade Name</u>	<u>Manufacturer</u>
Genklene	ICI
Propaklone	ICI
Aerotherne TT	Dow
Chlorotherne SM	Dow
Dowclene EC	Dow
Dowclene LS	Dow
Proact	Dow
Prelete	Dow
Solvent 1,1,1	Vulcan

Nomenclature/Chemical Names

1,1,1-Trichloroethane
MCF
TCA

Sources of Potential Savings

There are five steps involved in reducing emission of solvents. Incorporating these five steps in your evaluation process will significantly reduce emissions. The savings associated with each step can vary widely; a representative range is presented in the discussion below.

These five steps can be summarized as the following actions:

- Eliminate
- Isolate
- Automate
- Educate
- Maintain.

Eliminate. Eliminating solvents results in a 100 percent reduction in emissions. The first step in reducing the use and emission of solvents is to assess the need to employ solvent cleaning at each existing stage in the manufacturing process. Redundant or unnecessary cleaning of parts is common in manufacturing systems. Any stage in a process where cleaning can be eliminated will automatically reduce emission of the chemicals, while saving money.

If parts are cleaned a number of times before final assembly, consolidation (or centralizing) of cleaning processes and equipment will reduce unnecessary steps in the manufacturing process. It also concentrates activities to fewer machines -- an advantage in both maintenance and operating costs.

Isolate. Isolating open sources of emission and enclosing them can reduce emissions from 50 to 80

percent. Open-top vapor degreasers can be retrofitted easily to include a shroud or cover. Sealed doors and covers should be added where access is necessary but where emissions occur. Dedicated vents that can account for up to 75 percent of emissions should be turned down or off, if other measures can be taken to limit worker exposure.

Automate. Automating a vapor degreasing process can reduce emissions by 40 to 60 percent. Manual operation of vapor degreasing equipment often leads to unwanted emissions. Opening and closing covers, lids, and doors as well as moving the work pieces in and out of the solvent can cause emissions. Employing automatic hoists and transport systems will reduce operation emissions. Automated operation also minimizes operator error. Manufacturers should consider retiring older equipment and replacing it with modern systems which have been designed with emission reductions features. It is important to note that retrofitting a degreaser may require a permit modification. Replacing an old degreaser with a new one will likely require repermitting. A significant cost savings can be achieved with such investments, but plan ahead by purchasing equipment that can use the new solvents that are replacing CFC-113 and MCF. In many cases, however, different equipment designs will be required to use alternative solvents.

Educate. Education programs can lead to procedure changes, which in turn can reduce emissions by 20 to 30 percent. Training workers to be aware of the need to reduce emissions will ensure that programs are instituted correctly and that accidental emissions are reduced. Information sessions addressing emission issues of start-up, shut down, and idle time procedures should be included in basic operator training. Incentives for conservation should also be explained to the workers, including their own health and safety, environmental concerns, and company benefits.

Maintain. Improved maintenance procedures can result in 20 percent reduction in emissions. Maintenance of vapor degreasing equipment is essential to preventing potential emissions. Leak testing and usage logs can be used to track the use and emissions of solvents. Improving solvent change and boil down procedures will also reduce emissions. General equipment maintenance is important for proper operation. A critical

maintenance issue is the associated chiller package, where failures can result in the loss of excessive amounts of solvent overnight.

Extent of Usage

An effective program to reduce CFC-113 and MCF use requires a good knowledge of your plant operations, including quantities of solvents used for each process and areas where losses occur.

The following questions will help you understand your plant operations:

- Who purchases CFC-113 and MCF?
- Who takes delivery?
- How is the CFC-113 or MCF handled from arrival to ultimate use?
- How is CFC-113 or MCF used?
- Where do losses take place?

Have the manager of your solvents elimination program start with a survey. A copy of questionnaires that can be used are shown in Exhibits 5 and 6. This survey form should be sent to individuals in each plant location who are responsible for Material Safety Data Sheets (MSDS). All MSDS should be checked for 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113) and 1,1,1-trichloroethane (methyl chloroform) to help identify the trade name. The MSDS sheets should be cross-checked with the trade names listed previously in this section. Identify the quantities bought in the previous calendar year and start reporting on a regular basis (monthly or quarterly).

Some solvent losses will inevitably occur during operation. However, it is impossible to determine the extent of your emissions and potential reductions until a process assessment is performed. Monitoring your operations is also the best way to determine the success of your conservation programs.

Exhibit 5

CFC-113 AND METHYL CHLOROFORM USAGE PROFILE**A. Identification**

Name of Product: _____

Manufacturer: _____

Purchase Number: _____

CFC or MCF Components:

	Chemical Name	Percent or Concentration
1.	_____	_____
2.	_____	_____
3.	_____	_____

B. Quantification of Usage Patterns

Quantity Purchased: (specify units)

1989: _____ 1991: _____

1990: _____ 1992: _____

C. CFC and MCF Disposal Practices

	1989	1990	1991	1992
Annual quantity shipped as waste for disposal: (specify units)	_____	_____	_____	_____
Annual disposal costs:	_____	_____	_____	_____
Annual quantity shipped for reclamation: (specify units)	_____	_____	_____	_____
Annual cost of reclamation:	_____	_____	_____	_____
Annual quantity lost to the environment: (specify units)				
Through leakage:	_____	_____	_____	_____
Through spillage:	_____	_____	_____	_____
Through testing:	_____	_____	_____	_____
Through drag-out and evaporation:	_____	_____	_____	_____
By other means (specify)	_____	_____	_____	_____
Unaccounted:	_____	_____	_____	_____

Source: U.S. EPA 1990

*Exhibit 6(a)***AN EXAMPLE OF A PRINTED CIRCUIT BOARD
CLEANING EQUIPMENT PROFILE*****A. Identification***

Equipment Name: _____

Model Number: _____

Manufacturer: _____

Year Purchased: _____

Trade Name of
Chemicals Used: _____Annual Quantity of CFC or MCF
Purchased for Use in this
Equipment (specify units): _____Annual Quantity of CFC or MCF Waste
Requiring Disposal or Off-site
Recycling: _____***B. Equipment Usage Pattern***Annual Board Production
(specify units): _____Average Board Area:
(specify units): _____

Check appropriate blanks:

Single sided	_____
Double sided	_____
Multilayered	_____
Number of layers	_____

Average Number of Solder
Connections per Board: _____***C. Emission Controls***

Do you practice the following? If you do, briefly describe the procedures:

Leak Testing:

Alternate Testing Methods:

On-site Recovery/Recycling:

Improved Loss Control Procedures:

Operator Awareness/Guidelines:

Source: U.S. EPA 1990

*Exhibit 6(b)***AN EXAMPLE OF A METAL CLEANING EQUIPMENT PROFILE*****A. Identification***

Equipment Name: _____

Model Number: _____

Manufacturer: _____

Year Purchased: _____

Trade Name of
Chemicals Used: _____Annual Quantity of CFC or MCF
Purchased for Use in this
Equipment (specify units): _____Annual Quantity of CFC or MCF Waste
Requiring Disposal or Off-site
Recycling: _____***B. Equipment Usage Pattern***Annual Quantity of Parts Cleaned
(specify units): _____

Type of Part Cleaned: _____

Type of Cleaning Equipment:

Cold cleaner/dip tank _____
Open-top vapor degreaser _____
In-line vapor degreaser _____***C. Emission Controls***

Do you practice the following? If you do, briefly describe the procedures:

Leak Testing:

Alternate Testing Methods:

On-site Recovery/Recycling:

Improved Loss Control Procedures:

Operator Awareness/Guidelines:

Source: U.S. EPA 1990

The following two steps should be followed for printed circuit board processes:

- Determine total production of boards in square meters of surface area for a given time period (year, quarter, month). Only measure the area of one side of the board regardless of whether it is single sided, two sided, or multiple layer in configuration and regardless of whether any components are mounted on it.
- Divide total quantity of CFC-113 or MCF purchased by total manufactured board area for the same period to determine the ratio of pounds solvent used per square feet of board produced, expressed as lbs/ft².

In North American industry, this ratio is on the order of 0.41 lbs/ft² (2.0 kg/m²) for a production facility operated with today's technology and with minimal attention to chemical handling. Determine your use ratio before beginning your conservation and elimination programs.

For metal cleaning, this ratio can be determined by the following step:

- Divide total quantity of solvent purchased by total units or weight of parts cleaned for a given time period.

Regardless of the cleaning process used, calculate this ratio and report it on a regular basis -- monthly is recommended. This step is important because it enables you to monitor success as your conservation programs go into effect. It will also stimulate your employees to take an interest and participate in the drive to reduce solvent use.

Keep a log book for solvents used in each of your machines. The log tracks the amount of solvent

used and product cleaned and gives you information to compare machines. Log books will add incentive and a feeling of ownership to operators of the machines.

At this point, you have to make the following decision:

- If you have already reduced use by 75 percent, you probably have good conservation practices in place and will be ready to focus more time and effort on exploring alternate processes and technologies.
- If your usage has reduced by less than 75 percent of original, you can probably benefit from additional conservation programs.

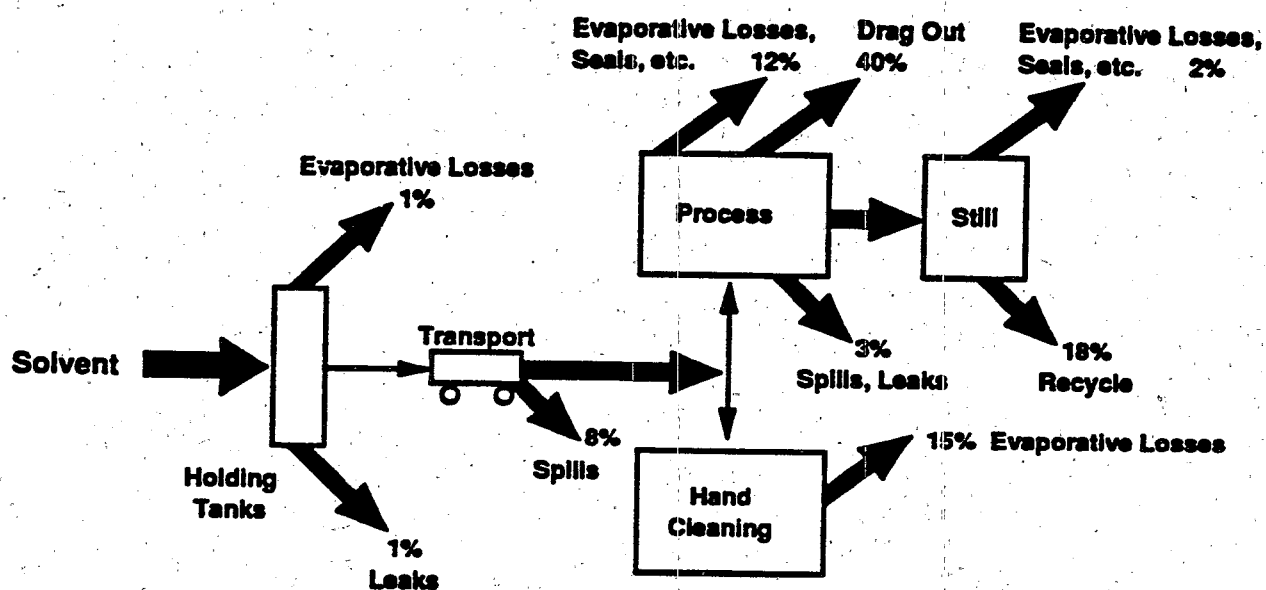
Next, do an assessment of where you are losing solvents. Do this for the whole plant beginning with the delivery of solvent. You may wish to develop a simple flow diagram as in Exhibit 7. This will give your project manager and your technical staff an understanding of the areas to focus on first. If you have more than one cleaning machine, you should do an analysis of each, since solvent losses may vary significantly from machine to machine.

With knowledge of solvent use and where losses are occurring, you can now select the appropriate conservation programs described in the next section.

Solvent Loss Mechanisms

Losses from convection, diffusion, dragout, maintenance, and spills occur in all solvent cleaning systems. Knowing which losses are the most significant in your operation and which can most easily be reduced will help improve your success.

In a vapor degreaser, there is a layer of relatively stagnant gas in the freeboard zone of the machine that is sandwiched between the layer of 100 percent solvent vapor at the bottom of the condenser and the layer of 100 percent air exiting at the top lip of the machine.

*Exhibit 7***SOLVENT LOSSES IN A TYPICAL PRINTED WIRING ASSEMBLY PLANT**

Source: Northern Telecom

F1000-4

Under these conditions, the solvent molecules tend to migrate or diffuse from the region of high vapor concentration at the condenser to the region of low vapor concentration at the top of the degreaser. The rate of diffusion is a function of the freeboard depth (the deeper the depth, the slower the diffusion rate) and the condenser temperature (the lower the temperature, the slower the diffusion rate). Auxiliary refrigerated condensers (-20°F/-29°C) located in the freeboard zone help to reduce the diffusion rate.

Diffusion, however, is an insignificant process of solvent loss compared to other loss mechanisms. Convection is the most significant physical loss process. Drafts or other air currents blowing across the top of the degreaser, referred to as convective losses, can be eliminated by locating the unit in a draft-free environment. Consider that moving a degreaser or installing a hood may subject some operations to repermitting requirements, depending on the regulatory requirements. Where excessive air movement is a problem, consider installing baffles or partitions on the windward side to divert the air currents away from the degreaser. Losses from drafts can also be reduced by using hooded enclosures in conjunction with automated work-handling facilities.

Insertion and withdrawal of the workload can lead to losses due to disruption of the vapor blanket, as well as dragout losses. Manual insertion and withdrawal tend to increase these losses.

Mechanical devices to insert and withdraw the work load can result in significant savings. Such devices can range from inexpensive hoist motors to sophisticated, programmable systems.

Emissions during maintenance of a solvent cleaning machine are also common and can be reduced through increased training and awareness on the part of maintenance personnel. Emissions from spills will also be diminished through user awareness and care.

Measurement and Monitoring

Several simple measurement and monitoring methods can be used effectively to determine sources of losses. Leak detectors sold as refrigerant detectors will identify leaks of solvents. Air currents which may cause diffusion should be monitored with smoke generation tubes.

Operators or system analysts should be given the time to verify the performance condition and calibration of solvent monitoring equipment. To be effective, the monitoring equipment must be both accurate and responsive in the range in which it is expected to perform. Below is a partial list of instruments that can be used for leak detection and vapor concentration monitoring. A partial list of vendors for monitoring equipment appears at the end of this manual.

MEASUREMENT/MONITORING EQUIPMENT

Type	Measurement Range	Use
Infrared	1-40,000 ppm	Concentration Monitoring
Infrared	100-9900 ppm	Leak Detection/Concentration Monitoring
Flame Ionization	1-10,000 ppm	Leak Detection/Concentration Monitoring
Detector Tube	50-1400 ppm	Concentration Monitoring
Electronic	Ounces/yr	Leak Detection
Thermal Printer Paper	-	Leak Detection

RECAP ON PROGRAM TO THIS POINT

If the recommendations presented above are followed, the program will have laid the groundwork for reducing solvent emissions, including:

- Commitment by management and workers to reduce emissions;
 - Better understanding of the costs and benefits of reducing emissions;
 - Recognition of CFC-113 and MCF under their various trade names and chemical names;
 - Characterization of cleaning processes to identify the extent of usage and the need for a conservation and recycling program;
 - Identification of the primary sources of emissions and means of reducing them.
-

CONSERVATION PRACTICES AND STRATEGIES

This section of the manual begins by discussing conservation practices in general and then presents specifics of different cleaning operations (e.g., batch, in-line, and cold cleaning). Finally, the section concludes with an overview of reclamation and recycling procedures. The section is organized in the following manner:

- Best practices to operate solvent cleaning equipment;
- Causes of emissions and reduction strategies for batch cleaning operations;
- Emissions during in-line cleaning and techniques to reduce them;
- Cold cleaning practices and emissions reductions;
- Reclamation and recycling practices;
- Other control technologies;
- A summary of emission causes and solutions.

Best Practices in Operation

Once current use of solvents is characterized, a conservation strategy can be developed. At first, choose conservation options that are easy to implement in the short-term. These will offer immediate results and will encourage employees to continue and accelerate their efforts. The following options for savings are typical for open-top vapor degreasers that do not have some of the more advanced control techniques, and that may differ for conveyorized equipment.

Operator Training Curriculum

Operator training is the second largest conservation opportunity, second only to control of air currents. Operating losses due to dragout average 40 percent of the total losses. Other practices such as basket overloading, vapor blanket disturbances, spraying above condensing zone, poor racking habits, and solvent removal for hand cleaning can increase total losses from operating habits to over 80 percent.

Operator induced losses obviously are reduced with increased automation. Fully automated systems, including part racking, are controlled by the programmed operation of the equipment. Therefore, production programmers should also be trained in good conservation practices.

It has been found that operators are generally unaware of the financial and environmental costs associated with the use of ozone-depleting chemicals. Increased operator awareness can translate into a reduction in consumption, since operating practices and methods can usually be improved.

Operator awareness of the ozone-depletion issue and training in the handling of solvents is recommended. Operators can change their methods and practices, such as keeping lids and windows closed, turning off the cleaner when not in use, conducting maintenance regularly, and exercising care while working with machines and equipment.

Access to CFC-113 and MCF can be restricted to strengthen management control.

Part basket designers, production scheduling managers, and equipment maintenance personnel should also be involved in training programs. Parts must move slowly through the cleaning cycle. Racking and basket design are critical factors in preventing or minimizing vapor blanket collapse and solvent dragout. Maintenance practices can contribute to losses from poor cleaning and handling techniques. On a warm day up to five gallons of solvent can be lost from an open container due to evaporation.

A training curriculum for most solvent vapor degreasing processes is shown in Exhibit 8. The training is most effective if given over a four- to six-week period and in at least four separate meetings. Any single training period should not exceed one hour.

Handling Practices for CFC-113 and MCF

With more stringent production and emissions controls on ozone-depleting chemicals, it is imperative that solvents containing CFC-113 and MCF be handled with the utmost care. These solvents should be stored in secure drums to prevent evaporation during storage and transfer and should be clearly marked. You should also store drums with the bung end up to eliminate the possibility of solvent spillage through a leaking bung.

If large quantities of solvents are used, consider a bulk storage system and delivery of the solvent through a piping system to the batch cleaners.

Solvent should be sampled periodically and tested for acidity, moisture content, azeotropic imbalance, and other signs of degradation. Solvent degradation is often symptomatic of a flawed unit which in turn can generate excessive solvent waste.

Follow solvent manufacturer's instructions for proper testing methods and guidelines to determine acceptable conditions for continued use of the solvent. If solvent cannot be used, be sure to follow appropriate procedures for off-site reclamation and disposal.

*Exhibit 8***TRAINING CURRICULUM FOR SOLVENT REDUCTION PROGRAM****I. OWNERSHIP**

- Encourage operator "ownership" of environmental concerns
- Operator tracking mechanism
 - Meter with calibrated solvent dispensing pump
 - Solvent log book
 - Solvent usage graph
 - Volume/area of work run
 - Report usage to management
- Understanding degreasing process
 - Condensing of solvent on cold part
 - Evaporation of solvent from warm part
- Introduction to types of losses
 - Evaporative
 - Vapor blanket collapse
 - Dragout
- Demonstration of vapor degreaser in operation
 - Start up and shutdown procedures
 - Condensing coil/distillation
 - Vapor blanket smoke tube highlighting

II. MANAGER/SUPERVISORY SUPPORT

- Training all operators
- Control of operators
 - Reduce number of operators
 - Reward mechanism
 - Monitor performance
- Provide sufficient equipment
 - Stills, filters
 - Hoists
 - Properly designed parts basket
- Degreaser placement
- Controlled ventilation

Exhibit 8 (continued)

- Maintenance program
 - Chiller package
 - Leaks
 - Cleaning
- Demonstration
 - Ventilation disturbances
 - Basket design
 - Insufficient cooling

III. VAPOR DEGREASER OPERATIONS

- Part racking
 - Part cupping
 - Cohesion of solvents between parts
 - Part/basket mass -- vapor blanket collapse
- Slow part submersion and withdrawal
 - Piston effect
 - Vertical rate less than 10 ft/min
 - Drying in condensing zone
- Spraying techniques
 - Low pressure
 - Below condenser area
 - Fixed spraying zone
- Solvent addition/removal
 - Utilization of open-top unit as a still
 - Add below vapor and liquid levels
 - No removal for hand or cold cleaning
 - Disposition of still bottoms, handling empty drums
- Demonstrations*
 - Vapor blanket collapse due to mass
 - Piston effect
 - Insufficient drying time
 - Solvent addition

* Demonstrations are an important tool in training. Artificial smoke from smoke-generating tubes can provide an excellent media for observing air currents and vapor blankets. Dry ice can also be used in a container to provide a nonsolvent demonstration. To minimize exposures to trainees and to limit solvent emissions, dry ice may be preferred. Either method provides a hands-on demonstration of operator control.

Pumping Practices

Carefully add solvent to the cleaner to minimize disturbing the vapor blanket. Solvent should be pumped into the cleaner through a submerged outlet. Makeup solvent should be added to a rinse compartment, or better yet, to the cleaner's condensate collection tank. In either case, it should be added below the solvent surface. Cold solvent definitely should not be added to a boiling sump: it may stop the boiling and cause the vapor blanket to collapse (see Exhibit 9).

Avoid pouring solvent with buckets or drums into an open-top degreaser because:

- Solvent falling through air evaporates rapidly, causing significant losses before entering the unit;
- The pouring action creates turbulence in the vapor blanket, leading to convection losses. This effect will be exacerbated if the cold solvent causes the vapor blanket to collapse;
- Spillage is increased; and
- Increased worker exposure may occur.

Equipment Strategies

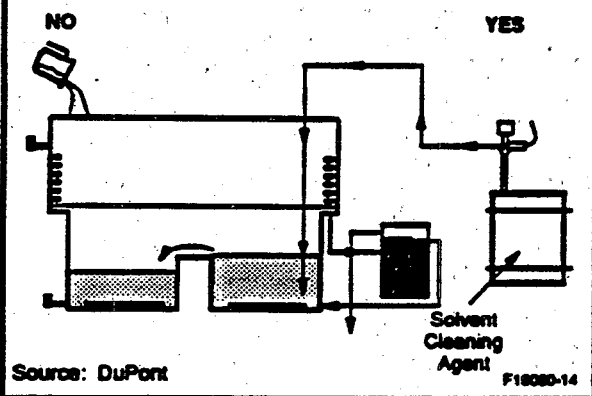
System optimization will improve the efficiency of your manufacturing process as well as reduce unnecessary emissions. Solvent cleaning units should be used to their maximum potential. One large unit costs less than two small units and is much more efficient.

Vapor emissions can be reduced by consolidating operations of several open-top units into a single, enclosed unit designed for continuous operation. Production scheduling, involving linear programming or other methods, can help streamline your process and reduce unnecessary steps as well as associated labor and process costs.

Ideally, you should size a machine to your required capacity. But if necessary, you should oversize your system rather than buy two machines. It is important to consider the ability of the unit to accept scale down. System operation at 20-30 percent of maximum capacity can be important.

Exhibit 9

SOLVENT REFILL PROCEDURE



Batch Cleaning Operating Practices

Process Description

Batch cleaning systems (also called open-top vapor degreasing) are used primarily in metal working operations, and defluxing operations. They can also be used for maintenance cleaning of electronic components, small equipment parts, and aircraft parts where a high degree of cleanliness is needed.

A batch cleaner is a tank with a heat source to boil solvent and a cooling zone to condense the vapor in the upper section. The soiled parts are suspended in an air-free zone of solvent vapor. The hot vapor condenses onto the cool parts, dissolving oils and greases and providing continuous rinsing with clean solvent. This process also warms the parts, thus decreasing the rate of condensation.

As the condensed solvent drains from the part, it carries off the soils and returns to the boiling liquid reservoir. This vapor treatment is often augmented by mechanical action such as liquid immersion, ultrasonic agitation, or spraying the with liquid solvent beneath the vapor level (as shown in Exhibit 10).

Convection

Because solvent losses result from air currents, batch cleaners should be placed in an area that is as draft-free as possible. Turbulence caused by drafts from adjacent windows, doors, fans, unit heaters, ventilators, or spray booths will greatly increase emissions of solvent vapor.

To avoid excessive air movement, consider installing baffles or partitions on the windward side to divert drafts away from the cleaning unit. You can reduce the velocity of the air flow over the top of the unit by eliminating dedicated exhaust ventilation. Air velocity over the top of the machine should not exceed 6 meters per minute (20 ft/min). However, it should be noted that in order to minimize worker exposure to high concentrations of solvent vapor, sufficient ventilation should exist around the vapor degreaser work areas.

For open-top equipment, problems with drafts can be avoided or corrected by using hooded enclosures with automated work-handling facilities.

Hinged covers, if opened too quickly, tend to drag some of the solvent vapor with them. Consider an alternate design such as a cover that slides or rolls open.

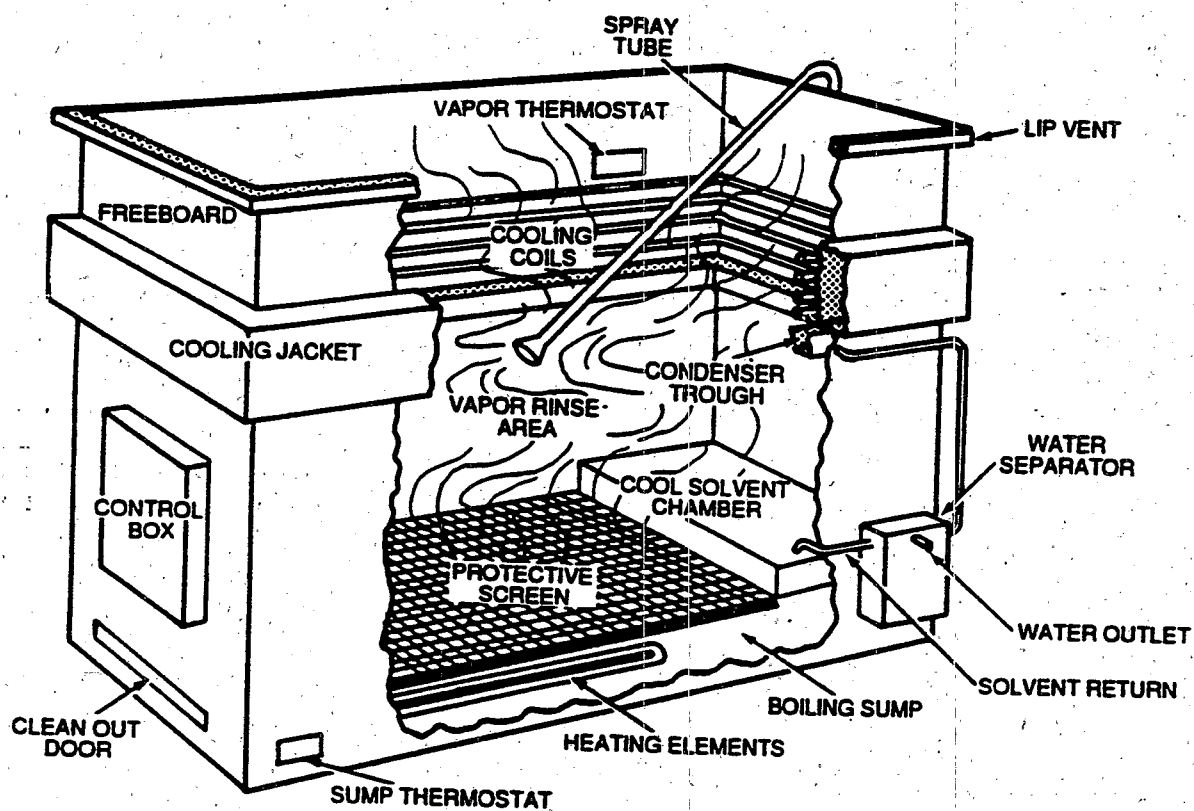
Most machines have covers or lids to limit solvent losses and contamination during downtime or idle time. Control of the solvent is also provided by the freeboard, which is part of the tank wall extending from the top of the vapor zone to the tank lip. The freeboard ratio (FBR), or ratio of freeboard height to machine width, usually ranges from .75 to 1.0, depending on the manufacturer's design.

It is sometimes possible to dramatically reduce convection losses by adding a supplemental water-cooled or refrigerated freeboard. The original covers should be abandoned and replaced by sliding covers on this new freeboard, which should be as deep as practically possible.

Superheated Vapor Drying

Superheated vapor drying is a relatively new technology that can be quite effective in minimizing or eliminating losses from dragout. In this process, the parts being cleaned come in contact prior to their withdrawal into the unit's freeboard zone, with solvent vapor that is superheated to a temperature above the normal boiling point of the solvent. The superheated vapor provides the heat needed to evaporate the equilibrium film of liquid and any additional solvent trapped due to work configuration.

The savings associated with superheated vapor drying are on par with that of automation. There are two procedures for effecting the contact of the work using superheated vapors. In one, the "static" method, the vapor zone of the degreaser is superheated using heat exchangers situated at an elevation below the condenser. In the other, the "dynamic" method, solvent vapor is recycled by a blower through a heat exchanger and then discharged through distributor nozzles onto the work prior to its withdrawal into the freeboard zone.

*Exhibit 10***BASIC VAPOR DEGREASER - BATCH CLEANING**

Source: PPG Industries

Dragout

Dragout is primarily a function of the geometry of the part being cleaned and the type of basket being used. You can reduce dragout losses if the work being cleaned is always positioned in baskets or on hooks, racks, or conveyor belts to permit maximum liquid drainage. Solvent trapped in pockets and recesses results in excessive dragout losses. Baskets containing a random fill of parts should be rotated during cleaning to facilitate drainage.

If possible, hold the workload in the vapor zone after the final cleaning step until its temperature equals that of the vapor zone and vapor stops condensing on the part. Work taken out earlier will emerge wet with solvent condensate. Ten feet per minute is an effective maximum speed for work entering/leaving a degreaser in batch operations.

Dwell times — the time spent in the vapor zone — that are too short are most often seen in open-top units where the work is manually moved in and out of the unit. A freeboard dwell of the workpart just above the vapor line is suggested until all solvent on the workpart has flashed off. Automatic hoists can help reduce excessive dragout due to insufficient dwell time. They can also reduce the piston effect and free the operator to perform other tasks.

Maintenance

Solvent losses during maintenance are common and can be remedied relatively easily. Training maintenance personnel is critical. Although the design of vapor degreaser units can vary greatly, some problems are common to all systems. Leakage losses are primarily a reflection of the quality of construction of the cleaning unit and of the attention paid to its subsequent maintenance.

Pump seals deteriorate when not in contact with solvent. A "running dry" condition erodes the seal surface and the seal prematurely fails. Systems should be equipped with gaskets that are suitable for contact with the solvent and mechanical burden they face. Note that CFC-113 and MCF may require different materials.

The design and maintenance of cleaners and stills requires special attention to the seals and gaskets on covers, lids, and panels. High volume leaks

often occur around corners and joints where two seals meet.

Equipment should be fabricated from materials that are chemically compatible with the solvent employed. Aluminum should never be used as a material of construction for storage and use equipment with halogenated solvents. Type 300 stainless steels are the preferred materials of construction for vapor degreasers and defluxers employing CFC-113 and MCF. They are also the preferred materials of construction for use with the new HCFC solvents. It is difficult to obtain leak-free joints in threaded stainless steel piping. Welded or soldered joint piping with flanged connections for removal of accessories (pumps, filters, dryers, etc.) is recommended to minimize leakages.

Without an effective cooling system, more solvent would escape, and these systems would evaporate dry. This is another maintenance area requirement.

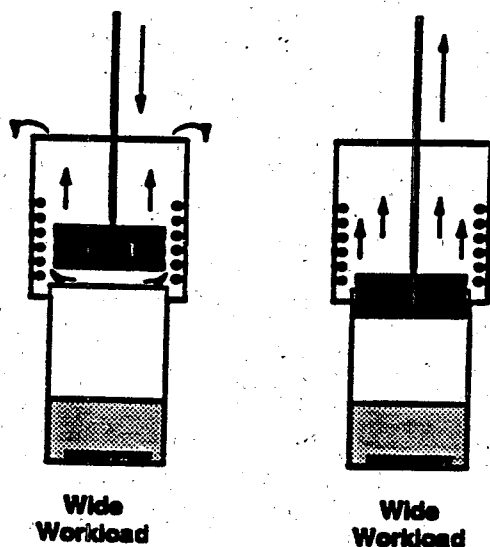
When possible take advantage of services offered by the machine manufacturers; they have experience in fine tuning the cleaner to minimize losses. You may wish to supplement this assistance with services offered by solvent suppliers who often have programs and information that can help operators manage the process better.

Piston Effect

The loss of solvent vapor can be decreased by avoiding the processing of workloads that exceed the cleaning system's design capacities.

A workload that is too large in physical size can displace vapor from the vapor degreaser by the "piston effect." Such losses can be minimized by making sure that the workload area is not greater than 50 percent of the horizontal cross-sectional area of the sump into which it is being introduced. You should also use baskets which minimize the area of the workload perpendicular to the surface of the solvent baths (see Exhibit 11).

Proper placement of baffles to contain the vapor as well as an increase in the freeboard ratio within the tank reduces losses from the piston effect.

*Exhibit 11***PISTON EFFECT**

Source: DuPont

113133-4

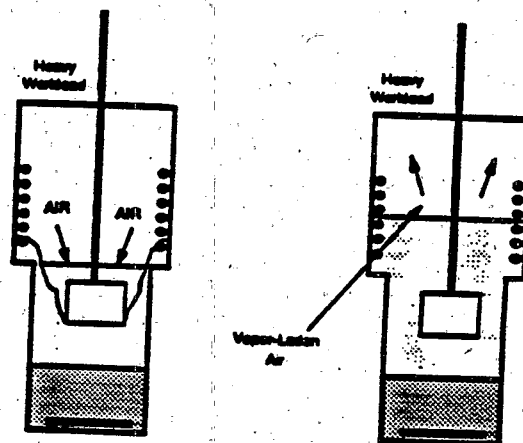
Vapor Blanket Collapse

The rapid introduction of a workpiece with a large thermal mass will condense too much of the vapor blanket. This will cause air to infiltrate the cleaner and cause the vapor blanket to collapse. When the vapor blanket is restored, the infiltrated air saturated with solvent vapors will be expelled from the vapor degreaser (see Exhibit 12). If this occurs on a regular basis, contact the equipment manufacturer to determine if additional heating and condensing facilities can be incorporated into the vapor degreaser.

Avoid spraying work pieces by spray lance or spray headers. If you must spray in this way, spray deep within the vapor zone, to avoid excess disturbance of the vapor/air interface.

Avoid liquid solvent ricochet into the freeboard zone or out of the machine when lance spraying. Do not spray cold solvent because its vaporization consumes heat from the vapor blanket, which increases the risk of collapsing the vapor blanket.

Use of solvent at a temperature near the solvent's boiling point minimizes the potential for vapor blanket collapse and the loss of solvent when the vapor blanket is reestablished. Typically this is part of the machine design.

*Exhibit 12***Vapor Blanket Collapse**

- A. 1. Work Introduced
2. Rapid Condensation on Work
3. Vapor Blanket Collapses
4. Air Pulled in
- B. 5. Condensation on Work Stops
6. Vapor Blanket Reestablished
7. Vapor-Laden Air Expelled

Source: DuPont

113133-5

Programmable Hoists

A recommended maximum speed for work entering and leaving the cleaner is less than 3 meters/min (10 ft/min). Higher throughput rates can cause disturbances at the vapor/air interface that result in high vapor losses. Automatic hoists and programmed work transporters are recommended because controlled speeds are difficult to sustain manually.

The inclusion of an integrated degreaser cover and hoist design is effective in reducing working solvent losses. The presence of a motorized, horizontal sliding, two-piece lid can be integrated with an automated programmable hoist. As the hoist lowers the workload to the degreaser, the lid

slides open to allow the product to enter into the vapor zone. When the workload clears the lid on its downward descent, the lid closes. Subsequent losses due to the "piston effect" or sprayers disturbing the vapor blanket are reduced.

Shortly after vapor condensation ceases, or spraying is terminated, the workload can be raised into the cooling coil zone of the degreaser with the lid still closed to minimize disturbance to the vapor zone and workload dragout losses. When the solvent has vaporized and the product is free of liquid solvent (dry), the hoist raises the product out of the degreaser. The lid opens to allow the product to exit, and then closes.

Such designs can be purchased as an integral part of many new degreaser designs. Retrofit kits consisting of a lid, hoist, or a combination of the two are also available to convert existing degreasers. Retrofitting degreasers may require repermitting.

Start-Up and Shut-Down Procedures

Start-up always results in some loss of solvent vapor as air is purged from the system. When the cleaner is used on an intermittent basis, emissions caused by frequent start-ups and shut-downs can be minimized by deferring cleaning until there is a full day's worth of work to process. Thus, there will only be one start-up of the cleaning equipment. If such scheduling is impossible, the unit should be left on with the lid closed when not in use.

Solvent emissions during start-up can be minimized through the following steps in the order shown:

- Start up the condenser cooling system and make sure that it is operating properly;
- Start up any auxiliary emission control equipment;
- Check and adjust solvent levels in all compartments;
- Turn on heaters;
- Start up the spray pumps once a stable vapor blanket is established; and

- Process work pieces only after the vapor blanket has been established. In order to determine if the vapor blanket has been established you must look inside the unit. Best practice is to do this only once. Time how long the blanket takes to form, and incorporate that time into the procedure.

When shutting down the system, use the following steps in the sequence shown:

- Stop work processing and clear the machine of all work;
- Close the cover on open-top units;
- Turn off the heaters;
- Activate sump cooling coils where provided; water-cooled sump cooling coils can be easily installed in many cases;
- Allow the vapor blanket to collapse completely. As before, time this step;
- Turn off the condenser cooling system where applicable. However, some units do not have sump cooling coils. In this case, the condenser cooling system should be kept on, on an intermittent basis.

Note: If cooling condenser is left running for extended periods after shut-down, it could cause moisture condensation on the coils from room air. The moisture would drip into the sump and contaminate the solvent. However, this can be prevented with the use of a water separator or desiccant dryer.

Idle Time Management

Simple procedures such as putting the unit on "cool" mode or turning it off whenever it is not in use can help reduce losses during idle time. However, start-up and shut-down losses must be factored into scheduling decisions. Each installation may warrant its own, customized plan.

Using rigid covers with tight seals is essential when a machine is not operating. Make sure covers are not discarded or lost.

In-Line Cleaning Practices

Process Description

In-line cleaning systems (also referred to as conveyorized cleaners) transport the work through the machine on an automated continuous basis. Most of the in-line cleaners that use halogenated solvents are vapor cleaners. In-line cleaners are used in many different industrial applications. However, they are most common in processes where production volumes are large enough to justify the higher capital costs of such equipment.

Except for the parts/conveyor inlet and exit openings, in-line cleaners are usually enclosed. Although this helps to control solvent losses from the system, it does not eliminate them. Most in-line systems have significant emission. In-line cleaning systems are usually custom made for an application.

There are five main types of in-line cleaning systems that use CFC-113 and MCF: cross-rod, monorail, belt, strip, and printed circuit board processing equipment. These systems differ in their methods of loading and unloading parts and in their methods of transporting materials through the cleaning process. Systems are chosen based on the needs of the manufacturing process, including the type of part to be cleaned, type of cleaning required, and speed and space requirements. Exhibit 13 shows one type of in-line cleaning system.

Convection

Excessive air currents around in-line solvent cleaners disturb the vapor blanket within the equipment which causes solvent losses. When excessive air movement is a problem, remove the source or install baffles or partitions on the windward side to divert the draft away from the cleaning unit.

In applications in the electronics industry, solvent cleaning units are often placed immediately following wave solder machines. This reduces the cooling time before cleaning. If the boards are entering the cleaner at a temperature greater than the vapor temperature, the heat will be transferred to the vapor and liquid solvent. This results in an additional heat load which may exceed the

condenser's heat adsorption capabilities, resulting in vapor discharge or machine shutdown by the vapor safety thermostat.

Mounting small fans above and below the conveyor to cool the boards before they enter the cleaning machine is one solution to the problem. To prevent disturbing the vapor blanket within the machine, which could result in increased solvent loss, fans should be directed away from the openings of the equipment.

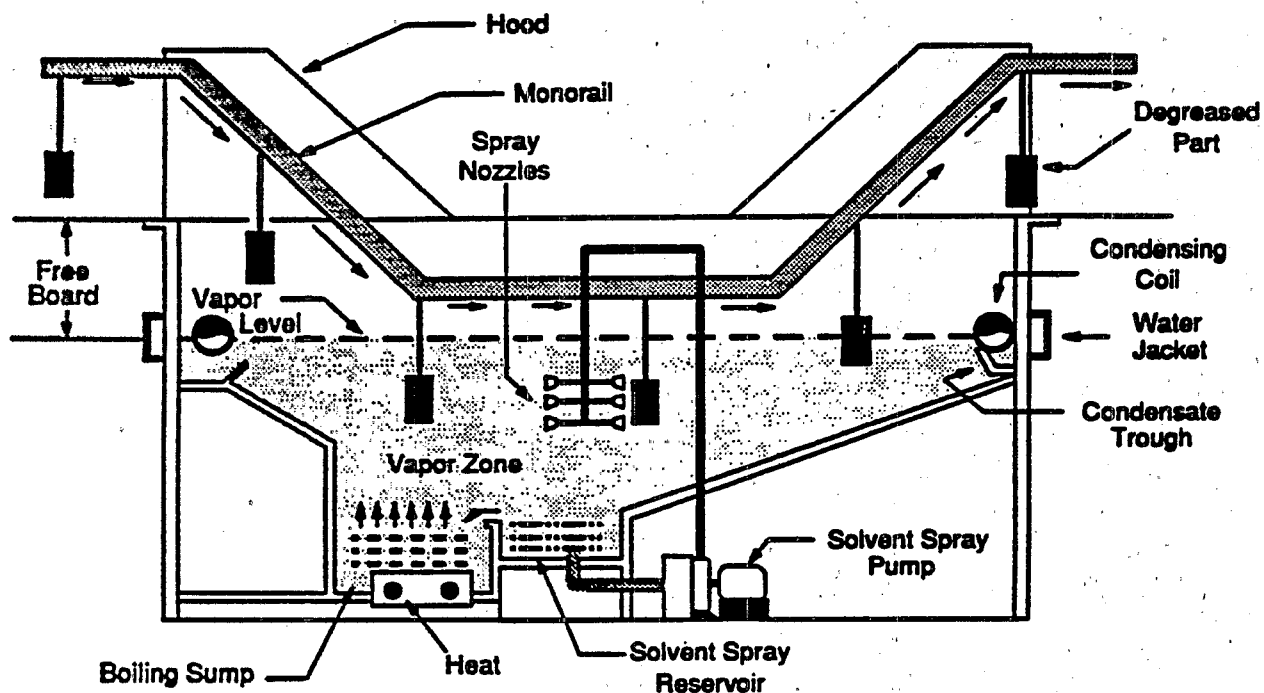
You may wish to consider a number of enhancements to the solvent cleaner. These are hardware add-ons or modifications that require capital expenditures and are not part of the machine optimization aspects previously described.

System enhancements include:

- Increased freeboard height
- Increased cooling system compressor capacity
- Additional cooling coils on inlets and outlets.

Cleaner manufacturers and experts in chilling/refrigeration should be consulted for their expertise. Consider reviewing the condensing effectiveness of your chiller/refrigeration system with the assistance of a knowledgeable contractor. Improved condensing efficiency through additional cooling coils at the entrance and exit of the wash and perhaps through compressor resizing will reduce evaporative and dragout solvent losses. Keep in mind that refrigerant changes can result in losses of other CFCs.

Use gas detectors to give accurate information on the location of emissions and to determine how effective your efforts are.

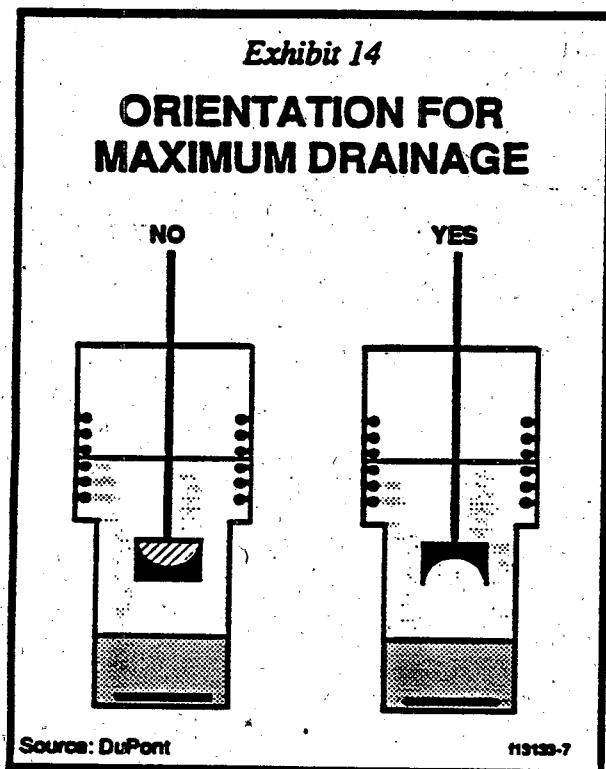
*Exhibit 13***IN - LINE CLEANING SYSTEM**

Source: Halogenated Solvents Industry Alliance

F18080-5

Dragout

Orientation of the part and part design plays a key role in the volume of solvent dragged out of the cleaners. For example, in many instances in the electronics industry, it has been found that solvent adheres to the underside of components and collects in pools in connectors. This could be minimized through reorientation (see Exhibit 14).



Reorientation can be as simple as changing the method by which the parts are processed. This may require an intelligent controller interfaced with a turntable located after the wave solder machine. The turntable may require a faster cycle time to reduce the adverse effects on production. In a less sophisticated operation, the operator can load the parts to optimize cleaning.

In optimizing the machine, examine the potential for reducing the conveyor belt speed. This keeps the board in the vapor zone longer for more complete evaporation of solvent, thus reducing dragout to a minimum. A recommended maximum speed for work entering and leaving an open-top cleaner is 3 meters/min (10 ft/min). For conveyORIZED belt in-line systems, consider 3 to 5

ft/min conveyor speed. Higher throughput rates can cause disturbances at the vapor/air interface that result in high vapor losses.

Maintenance

A bulk solvent handling system reduces solvent losses due to drum handling, transferring to small containers, and filling the cleaners. With appropriate real time alarms, personnel are alerted to possible leak conditions by monitoring consumption or loss in each cleaner as solvent is supplied. Careful visual inspection should supplement the use of alarm systems.

Solvent is delivered by bulk tanker and is then pumped into a bulk storage tank where it is held until needed. The tank is not pressurized and is commonly placed within the plant. Distribution to the cleaners is provided through a series of pumps and pipes. These pipes, valves, etc., should be made of appropriate materials. Therefore, the system eliminates all manual handling of solvents and minimizes losses. Control is provided by float switches within individual washer units.

A microprocessor can be used to monitor solvent consumption. This provides consumption data and activates an alarm in case consumption levels become excessive in the case of a leak.

Pump seals deteriorate when not in contact with solvent. A "running dry" condition erodes the seal surface and the seals fail prematurely. Pumps and seals are typical sites for leaks.

The design and maintenance of cleaners and stills require attention to the seals and gaskets on covers, lids, and panels. High volume leaks often occur around corners and joints where two seals meet. Check that new and replacement materials are compatible with the solvents in use.

Take advantage of services offered by the machine manufacturers; they have experience in fine tuning the cleaner to minimize losses. This can be a supplement to the services offered by solvent suppliers who often have programs and information that can help operators better manage the process.

Check all temperature-measuring devices and controls. Correctly calibrated instruments will

optimize machine performance and reduce solvent losses.

Under normal operating conditions, original filters reach the limit of their usefulness relatively quickly. Using more effective filters results in fewer changes over time and less solvent loss. Consider adding filters to extend machine solvent life.

For example, the use of a common motor vehicle oil filter and a pump can filter out additional impurities in the solvent distillation process. This filter can increase the time between preventative maintenance requirements which in turn decreases solvent losses.

Do not use solvent appearance as the only tool for cleaner drain and refill. Boil temperature should also be analyzed. Solvent/oil specific gravity can also be an easy method to determine the contamination level of the solvent.

Superheated Vapor Drying

Superheated vapor drying, as discussed under batch cleaning operations, can also be used with in-line cleaning operations.

Start-Up and Shut-Down Procedures

Solvent emissions during start-up can be minimized through the following steps in the order shown:

- Start up the condenser cooling system and make sure that it is operating properly;
- Start up any auxiliary emission control equipment;
- Check and adjust solvent levels in all compartments;
- Turn on heaters;
- Start up the spray pumps once a stable vapor blanket is established;
- Process work pieces only after the vapor blanket has been established. Determine if the vapor blanket has been established by looking inside

the unit. Best practice is to do this only once. Time how long the blanket takes to form, and incorporate that into the procedure.

When shutting down the system, use the following steps in the sequence shown:

- Stop work processing and clear the machine of all work;
- Close the cover on open-top units;
- Turn off the heaters;
- Activate sump cooling coils where provided;
- Allow the vapor blanket to collapse completely;
- Turn off the condenser cooling system where applicable. However, some units do not have sump cooling coils. In this case, the condenser cooling system should be kept on, on an intermittent basis.

Note: If cooling condenser is left running for extended periods after shut-down, it could cause moisture condensation on the coils from room air. The moisture would drip into the sump and contaminate the solvent.

Idle Time Management

Consider using one vapor degreaser to handle the boards from two or more soldering machines. Permitting requirements should be verified. Large losses are seen in degreasers that are under utilized and have an extended idle mode or that cycle as a result of frequent start-ups and shut-downs.

Idle time management could require reworking equipment placement, conveyor lines, controllers, and other features. Benefits include not only reduction of losses of solvent but also removal of extra equipment with a reduction in operating and maintenance costs. Well designed in-line systems are provided with covers for controlling emissions during idle times.

Cold Cleaning

Process Description

Cold cleaners use solvents at room temperature for parts cleaning. CFC-113 and MCF have been used extensively in cold cleaning because of their relatively low toxicity and resulting high workplace exposure limits. Cold cleaners are usually small maintenance cleaners or parts washers.

Cold cleaning operations can include brush or wipe cleaning, spraying, flushing, and immersion. The most common machines which use CFC-113 and MCF are of a type called carburetor cleaners.

Cleaning Methods and Emission Reduction

Wiping. The major sources of emissions from wiping operations are the disposal of used solvent during the cleaning operation and the disposal of solvent-soaked rags. Solvent evaporation and spillage from the solvent container can also result in substantial solvent emissions.

The best way to reduce emissions from wiping operations is to use covers for solvent containers, to dispose of used solvent-containing rags in closed containers, and to store used solvent in well sealed containers. Used solvents may be reclaimed or recycled. Several companies, listed on pp. 63-65, operate solvent reclamation and delivery services that may be suitable for your organization. Used solvents and spent rags can also be disposed of by incineration as a way of reducing solvent emissions. This should occur only in facilities that have been designed for and authorized to perform incineration.

Spraying or Flushing. When solvents are used in spraying and flushing systems, they are usually recycled because of their high cost. Distillation equipment for these solvents is relatively inexpensive and can be justified in terms of solvent savings alone. Containment systems and covers must also be employed during operation and downtime. Spraying equipment should be operated at low pressure (less than 10 psi), and air-agitation must be avoided. In addition, spray droplets should be as large as practical to minimize evaporation from the droplet surface.

Immersion Cleaning. Consumption of a large volume of solvent is common when immersion cold cleaning systems -- also known as dip tanks -- are used as part of a manufacturing process. If alternative solvents can replace CFC-113 and MCF, emission reductions can be significant. (See the other manuals in this series for alternatives to CFC-113 and MCF.)

Although air-agitation systems may be used to increase the cleaning efficacy of immersion systems, they also cause a higher evaporative emission rate. The use of covers and increased freeboard ratio are both effective means of reducing evaporative emissions. Covers can reduce emissions by between 20 to 40 percent. Increasing the freeboard ratio to 1.0 may reduce evaporation by up to 70 percent. The area around and above the cleaner should be kept free of drafts. Removing and replacing covers horizontally (rather than lifting them off) will reduce air currents and thus reduce evaporation losses.

Dragout and carry-out losses can be reduced by requiring operators to allow the parts being cleaned to drain for 15 seconds and rotating parts to ensure that solvent is released from recesses and blind holes in the work pieces. Proper storage and reclamation of used solvent can also reduce vapor emissions.

Parts that have been sprayed, dipped, or wiped may be drained on an inclined rack that is attached to the degreaser. Automatic hoists can also be used to drain parts over the degreaser.

Reclamation

External reclamation and recycle services are often available to purify contaminated solvent and return it to the original customer or to sell it to other users.

Reclamation and recycling can also be performed on-site. Several such systems are discussed below. Where recycling solvent waste is viable, the choice between on-site versus off-site recycling must be made. Major factors that may influence a decision are shown in Exhibit 15. In addition to these factors, Title VI of the Clean Air Act Amendments of 1990 has imposed recycling requirements. In all cases, the quality of the reclaimed solvents is an important consideration. ASTM currently is developing standards for recycled CFC-113 and MCF.

On-site Recycling

On-site recycling is currently economical if at least approximately 8 gallons of solvent waste are generated per day. The simplest form of solvent reuse is termed "downgrading," which is using a solvent that has become contaminated through initial use for a second cleaning process. For example, precision bearings need very high purity solvents for cleaning. The solvent acquires very little contamination in usage and can be downgraded for use in less demanding cleaning operations.

Because more effort is required to recycle solvent that is heavily contaminated, on-site and off-site recycling or reclamation should be explored. In vapor degreasing and cold cleaning, the soil removed accumulates in the equipment. Eventually, the solvent still bottoms become too contaminated for further use and must be reclaimed or disposed through incineration. For on-site recycling, many different separation technologies are available. Commonly used separation technologies for contaminated solvents include gravity separation, filtration, batch distillation, fractional distillation, evaporation, and steam stripping.

Gravity Separation. The use of settling to separate solids and water from solvent often permits the reuse of solvent. For example, paint solvents may be reused many times if solids are allowed to settle.

Filtration. Filters can be used to remove solids from many solvents, thus extending solvent life.

Batch Distillation. A batch still vaporizes the used solvent and condenses the overhead vapors in a separate vessel. Solids or high boiling residues ($>400^{\circ}\text{F}$) remain in the still as a residue. Solvent stills range in size from 5-gallon to 500-gallon capacity. A vapor degreaser can be used as a batch still for recycling solvent by employing proper boil-down procedures. Detailed discussion of these procedures is available from major solvent suppliers.

In many applications, it is necessary to keep the water content of the recovered solvent to less than 100 ppm. This can be accomplished by distilling the solvent-water azeotrope, decanting the water, and then drying the remaining solvent with a molecular sieve or other desiccant. The water removed in this operation must then be either treated or drummed for disposal.

Fractional Distillation. Fractional distillation is carried out in a reflux column equipped with either trays or packing. Heat is supplied by a reboiler located at the bottom of the column while heat is removed at the top of a column by a condenser. Fractional distillation allows for separation of multi-component mixtures or mixtures of solvent and oils with similar boiling points.

Evaporation. Evaporation can be employed for solvent recovery from viscous liquids, sludge, or still bottoms resulting from distillation. Scraped or wiped-film evaporators utilize revolving blades, which spread the liquid over a heated metal surface. The vapors are recovered by means of a condenser. Another type of system, a drum dryer, employs two heated counter-rotating drums through which the liquid feed must pass. While both systems can handle viscous wastes, the drum dryer is more tolerant of polymerizable contaminants.

Steam Stripping. Steam stripping is a solvent reclamation enhancement process commonly used for the processing of CFC solvent still-heels generated in one-plate distillations. These still-heels often can contain as much as 40 to 50 percent (by weight) of solvent. In general, steam stripping should not be used for MCF.

*Exhibit 15***FACTORS INFLUENCING THE DECISION
TO RECYCLE SOLVENT WASTES ON-SITE****Advantages**

Less waste leaving the facility.

Owner controls reclaimed solvent's purity.

Reduced liability and cost of transporting waste off-site.

Reduced reporting (manifesting).

Possible lower unit cost of reclaimed solvent.

Perceived Benefits

Favorable economics for recovery (e.g., reduced solvent requirements).

Reduction in disposal costs.

Lower liability.

Disadvantages

Capital outlay for recycling equipment.

Liability for worker health, fires, explosions, leaks, spills, and other risks.

Need for operator training.

Additional operating and maintenance costs.

Reported Difficulties

May be a need to restabilize the reclaimed solvent.

Installation problems.

Maintenance problems.

The vapor/liquid equilibrium associated with steam stripping permits a further separation of volatile solvent from relatively nonvolatile impurities. This is done at distillation temperatures lower than those encountered in the one-plate distillation of a contaminant-rich solvent mixture.

Steam stripping can be carried out either as a batch process or as a continuous process. Batch processing is more common, but continuous operation offers a number of advantages if the contaminants are liquids (e.g., lubricating oils) of low to moderate viscosity and the cleaning fluids are quickly contaminated.

Batch steam stripping is usually performed in the same still as was used for still-heel generation. However, in some high-volume solvent use applications, the provision of a separate still dedicated solely to the processing of heels from other one-plate stills can offer significant advantages in maintaining a high level of productivity in the cleaning system. An example of a steam stripping system is shown in Exhibit 16.

Off-site Recycling

If recycling of waste solvent on-site is impractical, several off-site recycling schemes are available. When selecting an off-site recycling scheme, one should consider or investigate all of the items listed in Exhibit 17. Some viable off-site recycling arrangements include toll recyclers and waste exchange/brokerage.

Toll Recyclers. Toll recyclers offer services to generators by supplying solvent wash equipment and solvent and waste recycling services. The solvent wash equipment is maintained by these companies and the solvent is replaced periodically. The used solvent is recycled at an off-site facility. Costs for these services range from 50 to 90 percent of new solvent cost.

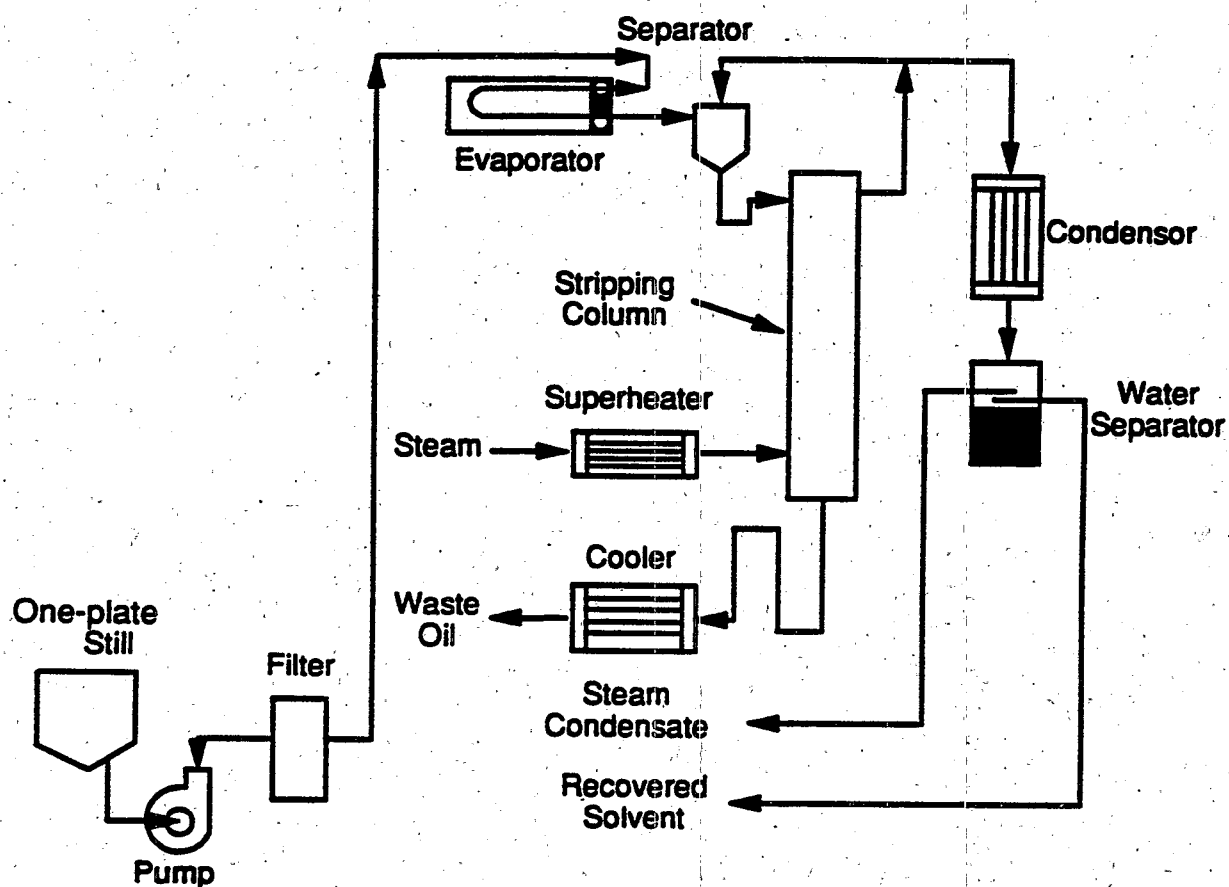
Waste Exchange and Brokerage. This is not a technology but an information service. A waste exchange can match a generator of waste with a facility that can use the waste as a raw material. Commercial waste brokerage services are also available. A waste generator is matched with a potential waste user who can utilize the waste as a feedstock. Matching generators and users is based on the knowledge of raw material inputs and

wastes and product outputs of individual industries and firms.

Both before and after recycling, solvent should be monitored for acceptability, including thermal breakdown (acidity) and azeotropic imbalance. It is important to ensure that solvents are not mixed at any time during the recovery process.

Off-site recycling services are offered by a number of licensed commercial operators. A partial listing of these firms is provided later in this document. After the maximum amount of solvent is recovered, the still bottoms and other residues from degreasing operations are destroyed thermally, generally through fuel blending.

Exhibit 16

CONTINUOUS STEAM STRIPPING

Source: DuPont

F1000-4

*Exhibit 17***FACILITY CONSIDERATIONS
IN CHOOSING AN OFF-SITE RECYCLER**

- Types of solvent wastes managed.
- Availability of laboratory facilities and suitable analytical procedures.
- Ability to meet solvent purity specifications.
- Availability of custom recycling services (e.g., vendor-owned recycling units that can be operated on the generator's property).
- Expertise on in-plant waste management strategies and process controls.
- Availability of registered trucks to transport the solvent wastes.
- Distance to the recycling facility and associated transportation costs.
- Completeness of recordkeeping.
- Adequacy of permits held by the facility.
- Sufficiency of insurance for recycling/treatment/disposal operations.
- Adequacy of disposal procedures for still bottoms and other solvent wastes.
- Compliance record of the facility.
- Reputation of the facility.
- Financial stability.
- Costs of using service.

Other Control Technologies

Carbon Adsorption

Because dragout losses are a major contributor to the overall solvent loss, causing high levels of solvent vapor in the manufacturing area, vapor capture systems should be considered. These systems adsorb the solvent molecule on an activated carbon bed which is subsequently extracted by steam. After water separation, the solvent is rebled with additives for reuse.

The intake and exhaust ports of the cleaner are vented to hoods where vapors are drawn under negative pressure through the activated carbon bed. Proper design of the collection hood at the cleaner discharge is vital since this is where dragout and drying losses are most significant.

Adsorption proceeds until the carbon bed approaches saturation. At that time, steam is injected onto the carbon surface to strip solvent molecules for later condensation and water separation. Exhibit 18 shows a point-of-use carbon adsorption process schematic.

Three material streams are produced: pure solvent, clean air, and wastewater.

- Solvent is rebled/reconstituted with additives for reuse;
- Air is returned to the plant or exhausted;
- Wastewater is treated and released to the sewer system. With circuit board cleaners, there could be some alcohol in the waste water streams and local legislation should be reviewed and considered in equipment selection. Alcohol in the wastewater increases the biological oxygen demand (BOD) load to the local sewage treatment plant.

Systems can be sized to suit the scale of application, and one adsorption system can service more than one cleaner. However, carbon adsorption systems are expensive to purchase and to operate unless there is a large quantity of solvent to capture.

For maximum emission reductions, the bulk storage tank, the stills, and the adsorption system

should all be located in an enclosed room so that air can pass through the adsorption system to capture and recycle any fugitive solvent losses.

MCF and Carbon Adsorption

Steam desorption of MCF results in the loss of stabilizers and the formation of hydrochloric acid. This leads to corrosion problems and damage to equipment. In addition, the MCF has to be restabilized after stripping for reuse.

New technologies to recover MCF vapors by carbon adsorption have been developed. These technologies eliminate the problem of MCF hydrolysis and associated corrosion present in traditional carbon adsorption/steam desorption systems. These new adsorption methods include replacing water with nitrogen as the stripping agent, employing a new condensation membrane technology, hot gas desorption cycle, and polymeric particle adsorption.

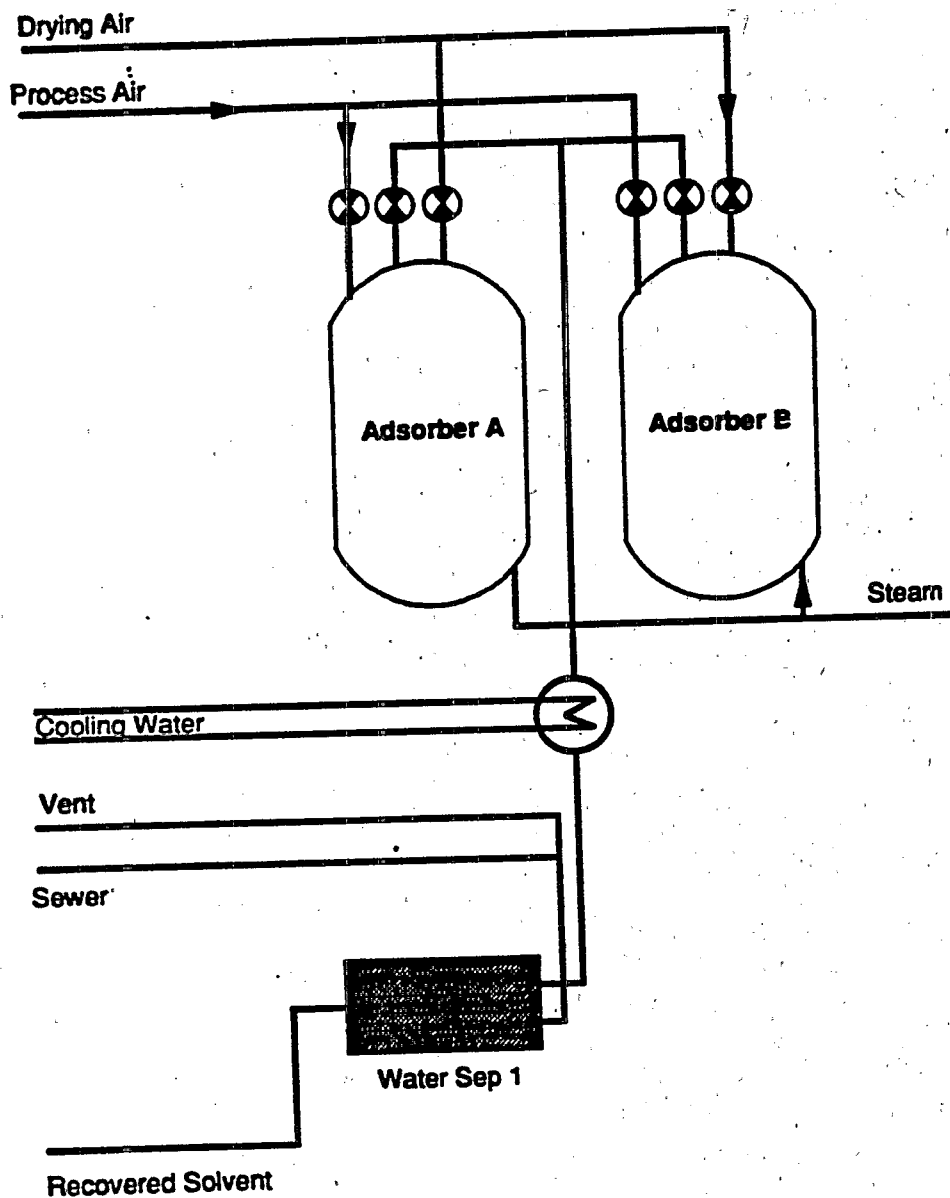
A carbon adsorption system using a hot gas desorption cycle is shown in Exhibit 19. In this process the solvent and the small quantity of water are expelled from the activated carbon by hot air in a closed circuit. The solvent/water mixture then passes through a condenser. The solvent is separated from the water in a subsequent gravity separator. Solvent residues in the "processing water" are then removed and the clean water is discharged.

Safety Note: When operating carbon adsorption systems, use proper chemical procedures, and include fire protection on beds.

Air Stripping

Air stripping, which is a process similar to distillation, can reclaim CFCs. In air stripping a contaminated stream is fed into a packed column from the top and air is injected at the bottom. As the two streams pass one another through the column, they exchange volatile materials. The air phase and the volatiles are then carried from the top for recovery usually by granular activated carbon. The bottom products containing the heavier phases are sent for recovery, perhaps by distillation. Emissions from air stripping are probably subject to environmental regulation.

Exhibit 18

**POINT-OF-USE CARBON ADSORPTION
PROCESS SCHEMATIC**

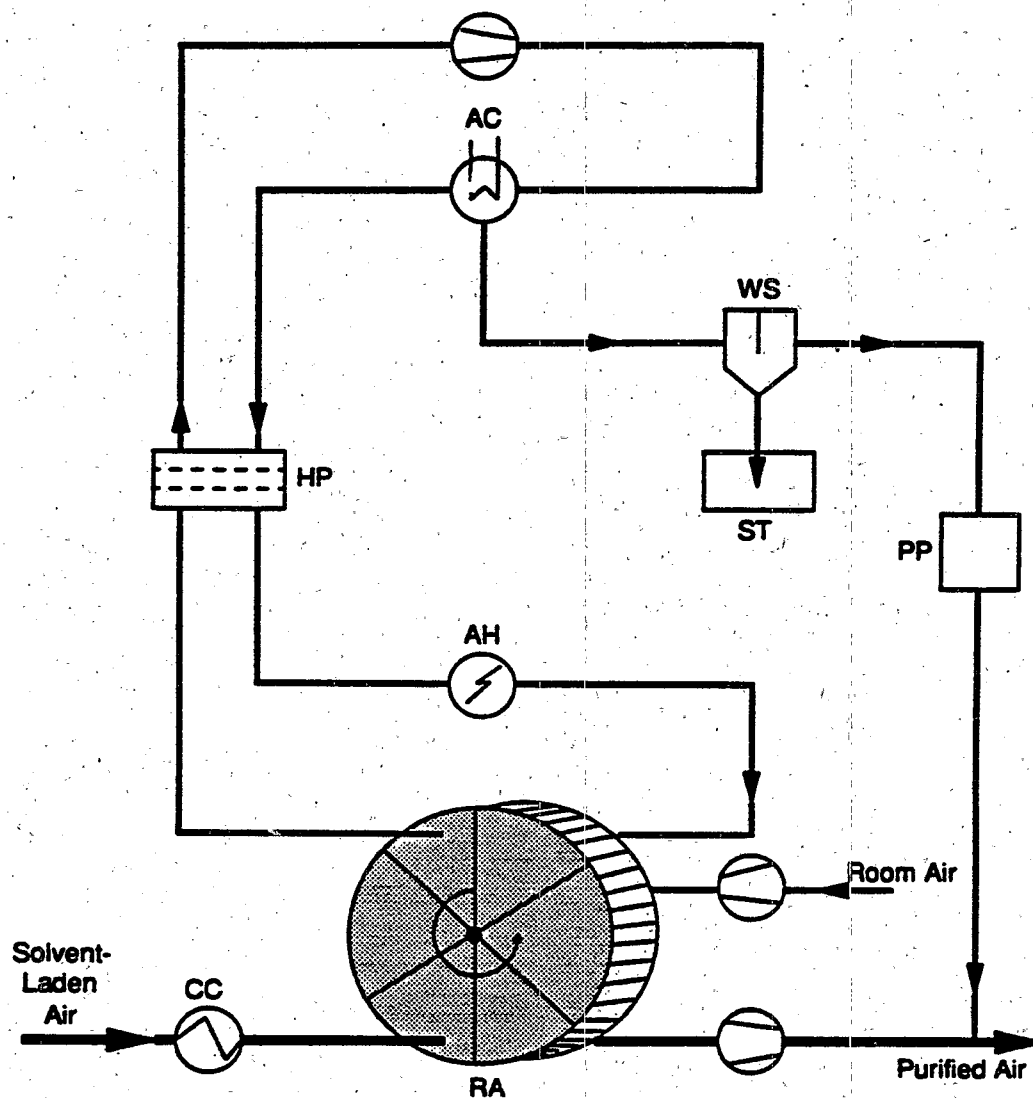
Source: Digital Equipment Corporation

F10000-6

Exhibit 19

ROTARY CARBON ADSORPTION SYSTEM

Flow Chart



RA Rotary Adsorbers
 CC Crude Gas Conditioner
 AH Air Heater
 HP Heating Pipe

AC Air Cooler
 WS Water Separator
 ST Solvent Tank
 PP Processing Water Purification

Source: Bowe

F16060-9

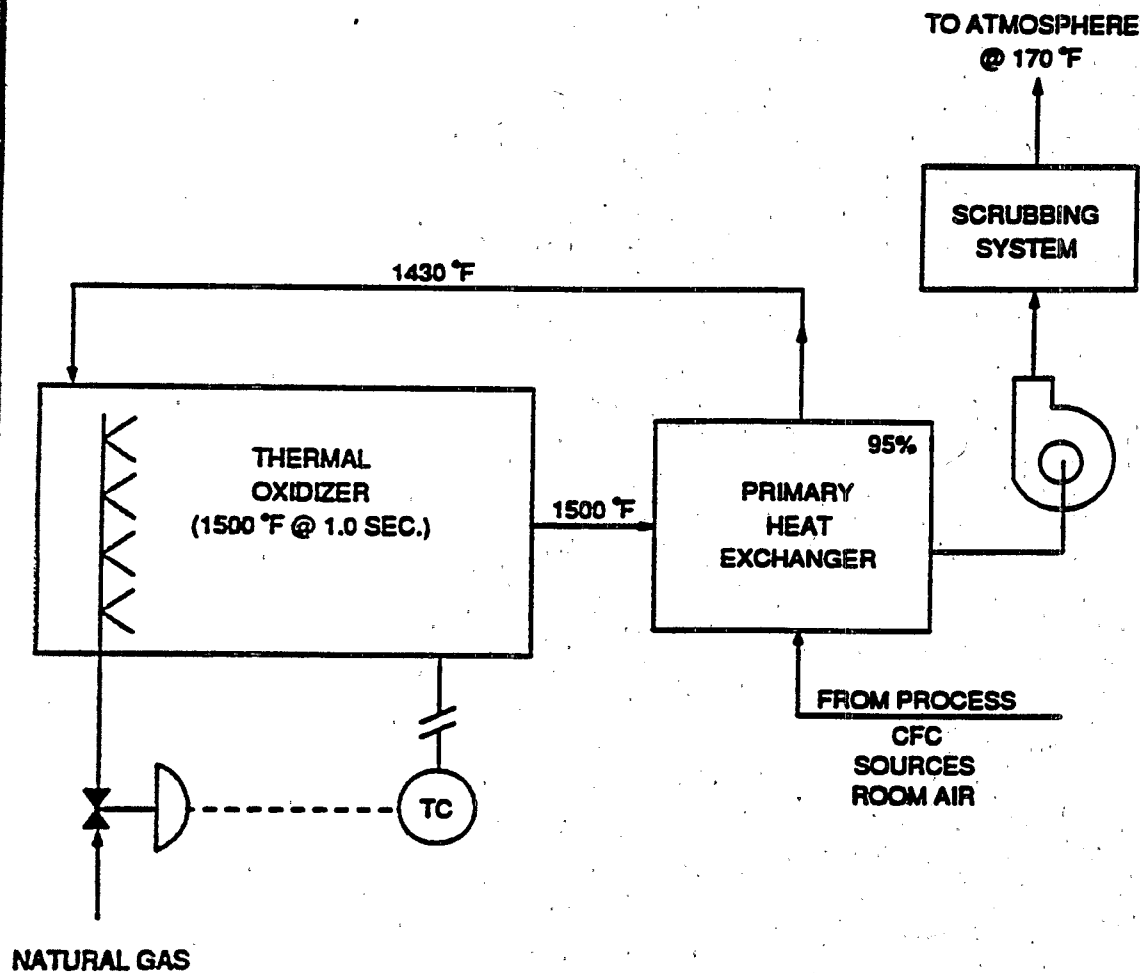
Thermal Destruction

In a thermal destruction unit, the CFCs and hydrocarbons are mixed and ignited and passed through a hot ceramic furnace to complete the destruction. Incineration of the gases is accomplished at approximately 1,800°F. A thermal destruction unit consists of two beds and the flame is alternated between one bed and the other to optimize efficiency (see Exhibit 20).

Recent developments in catalytic chemistry appear to make catalytic destruction of halogenated hydrocarbons a viable control option. In addition to significantly reducing the temperature required, these new catalysts allow complete destruction and have been shown to be resistant to deactivation.

Exhibit 20

THERMAL DESTRUCTION FLOW DIAGRAM



Source: Manchester Corp.

F10000-10

RECAP OF THE MANUAL

Previous sections of this manual have provided information on:

- Stratospheric ozone depletion and restrictions on the use of CFC-113 and MCF.
- Steps to characterize a process to determine solvent use and emissions.
- Conservation practices and strategies specific to batch cleaning, in-line cleaning, and cold cleaning.
- Rationale for conserving and recycling solvents in cleaning processes.
- Reclamation and recycling systems and services.

A summary of problems and solutions for solvent emission is presented in Exhibit 21.

Exhibit 21

EMISSIONS REDUCTIONS: PROBLEMS AND SOLUTIONS CHECKLIST

Possible Problems	Possible Solutions
Improper degreaser placement	<p>Cleaning system should be placed to avoid cross drafts from open doors, windows, fans, and air conditioning vents. If possible, enclose the unit.</p> <p>Remove or reduce dedicated vents.</p>
Failure to cover degreaser	<p>Degreasers should be covered when not in use. A tight sliding cover is best. A rolling cover is acceptable.</p>
Poor maintenance	<p>Clean-out doors, piping, pumps, and filter housings should be checked weekly for leaks.</p> <p>Chiller package should be maintained regularly.</p>
Spraying above the vapor zone	<p>Spraying should always be conducted at least 6 inches below the vapor line. Sprays should be directed downward.</p>
Excessive solvent dragout	<p>Work should be oriented and rotated to allow maximum solvent drainage.</p> <p>Immersion and withdrawal rates should be less than 10 fpm for open top units.</p> <p>Conveyor speeds should be approximately 3-5 fpm for in-line belt units.</p> <p>Work should remain in vapor zone until condensation stops.</p>
Product is too large for machine	<p>The area of the basket or work load should not exceed 50 percent of the area of the boil sump.</p> <p>The mass (weight) of the workload processes should not exceed the machine's rated capacity.</p>

Exhibit 21 (Continued)

EMISSIONS REDUCTIONS: PROBLEMS AND SOLUTIONS CHECKLIST

Possible Problems

Possible Solutions

Degreasing of absorbent materials

Absorbent materials (such as cloth, wood, porous plastics, etc.) should not be cleaned in vapor systems or used in the construction of baskets or carriers.

Improper start-up and shut-down procedure

Activate condenser prior to turning on heat.

Do not turn on sprays until a stable vapor level has been established.

After cleaning operations are complete, turn off heaters and continue to operate the condensing coils until the vapor zone has completely collapsed and the boil sump cools well below the solvent boiling point.

Solvent degradation

Hot spots on heating coils should be repaired, as they cause thermal breakdown of solvent.

Electric heater watt density should not exceed 20 watts/sq. inches.

Desiccant system should be checked for malfunction.

Cooling coil design should be altered.

Inadequate freeboard height

Freeboard height to degreaser width ratio for CFC-113 and MCF cleaning systems should be 1.0 or more.

Inadequate condensing capacity

Turn on water-cooled systems and check the condenser discharge water temperature. Vapor degreasers should be provided with chilled water at 40°F (4.5°C), and discharge water temperatures should be 50°F (10°C) for CFC systems and 70°F (21°C) for MCF systems.

Possible repermitting and attendant changes in regulatory requirements

Contact and work with your local air quality representative.

CASE STUDIES OF INDUSTRIAL PRACTICES

The following section presents industrial case studies of conservation and recycling.

The mention of any company or product in this document is for informational purposes only and does not constitute a recommendation, of any such company or product either expressed or implied by EPA, ICOLP, ICOLP committee members, or the companies that employ the ICOLP committee members.

- ***Case Study #1:*** CFC Reduction/ Elimination in Electronics Cleaning
- ***Case Study #2:*** Using Industrial Hygiene Techniques to Monitor and Reduce Solvent Losses
- ***Case Study #3:*** Solvent Equipment Selection -- A Case Study of Errors
- ***Case Study #4:*** Emissions Monitoring and Reduction
- ***Case Study #5:*** History of Equipment Upgrades.
- ***Case Study #6:*** Solvent Conservation and Recycling.

CASE STUDY #1: CFC REDUCTION/ ELIMINATION IN ELECTRONICS CLEANING

Case Study #1 describes the steps taken by Digital Equipment Corporation to reduce CFC emissions and to select an alternative cleaning method.

Digital has used CFC-113 to clean many different parts and sub-assemblies in the assembly and testing of disk drives (a storage device for computers).

The equipment is a 5-sump, open-top vapor degreaser that was emitting 124,000 lbs of CFC-113 fugitive emissions each year before reduction steps were taken.

Selecting a Technology to Reduce Emissions

Digital commissioned a study to investigate several technologies for reduction and/or elimination of CFC-113. The following summarizes each of the technologies and recommendations that came from the study.

Incineration

Thermal oxidation is a choice of last resort for CFC-113. Oxidized CFC-113 creates by-products of hydrochloric acid and hydrofluoric acid which react with the insulating materials used on commercial oxidizers. The acid vapors must also be scrubbed in a caustic scrubber. Thermal oxidation has no solvent recovery. It is, however, an effective means of reducing volatile organic compounds (VOCs).

Water scrubbing

Water scrubbing extracts solvent from the process air stream and, consequently, is most effective in

removing solvents that require one scrubbing. These solvents generally have high solubility in water. When this method is used to remove CFC-113, a solvent that has low solubility in water, the water after one scrubbing is so saturated with solvent that it loses its ability to remove any additional CFC-113 from the air stream. Two other factors also make this process questionable for removing CFC-113: Not only must the water coming out of the scrubber be air stripped before it can be reused or drained, but the exhausted air must also be treated to capture the solvent.

Oil scrubbing

Under certain conditions oil scrubbing has been demonstrated as an effective means of extracting solvent from the process air stream. However, there are no known installations for capture and recovery of CFC-113. The process air enters a 7' diameter column approximately 30' tall, while a low viscosity, high boiling point petroleum-based oil is sprayed downward from the top of the column over a 20' long mesh packed at intervals against the air flow. The solvent dissolves into the oil and collects at the base of the column. The scrubbed air exits the top of the column into the atmosphere. The oil/solvent mixture at the base of the column is pumped to a holding tank. The mixture then moves to a recirculating evaporator where the oil is heated to distill the solvent from the mixture. The solvent vapors and oil are sent to a cyclone separator. In the separator, the oil is captured and sent to a holding tank where it is pumped back up to the scrubber distributor. The solvent vapor is vented out the top of the cyclone separator, condensed, and gravity fed to a recovered solvent tank.

Refrigeration

Refrigeration is a means of recovering VOCs by condensation of the airborne solvent. Extremely low temperatures for first droplets are required to reduce the solvent vapor pressure to a point where 90 percent recovery by condensation can be achieved. Refrigeration recovery is best suited for applications where airflow is low and solvent concentrations high. This technique is widely used for storage tank vents.

Carbon Adsorption

Carbon adsorption, a good means of recovering and reusing solvents, is accomplished by adsorbing the solvent in a bed of carbon and later steam stripping for reuse. This technique was chosen because it is the best available technology known at this time, has a relatively low cost, and is proven in many actual installations.

The basic steps are:

- Solvent laden air is drawn from an enclosure built around the 5-sump, open-top degreaser to capture fugitive emissions. Solvent vapors are collected at the bottom and top of the enclosure (designed to minimize any drafts across the degreasers) and ducted to carbon adsorbers through a particulate filter to catch any particles. Air is collected by lip vents at the base of the cleaning chamber access door of the shear stress machine.
- At the carbon adsorber, the solvent laden air is drawn through the carbon beds by a process blower at 800 to 1,200 cfm. Blowers pull the air through one or two carbon adsorption beds, each bed filled with 600 lbs. of carbon (leaving the solvent deposited on the carbon (coconut).
- Two or three carbon beds (depending on the solvent loading and cfm required) are installed in parallel. One or two beds are adsorbing CFC while one is de-sorbing and drying CFC for reuse. The beds are switched by either the stack analyzer (typically set at 5 ppm) or a timer as a back-up to the analyzers.
- Upon completion of this phase of the process, steam is used to remove trapped solvent from the carbon pores by pushing steam in a reverse flow through the beds. A water/solvent mixture is created when the steam is passed through a condenser. From this condenser, the water/solvent mixture is sent to a separator tank where the water and solvent are separated by gravity with the water going out the top and the solvent out the bottom.
- The solvent then goes to a solvent holding tank. The solvent is pumped to a still where it is further refined and then transferred to another holding tank where the technician pumps it on

demand to the still on the open top or the solvent tank in the shear stress machines.

The carbon adsorbers are designed to meet the following specifications:

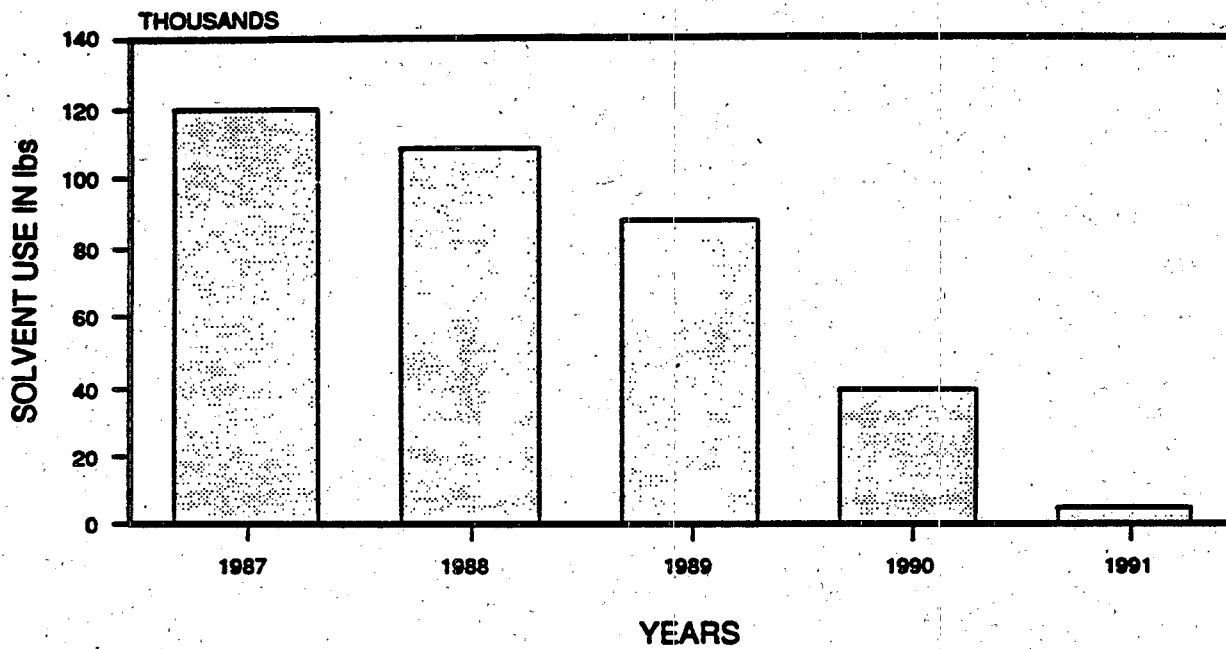
- 10 and 16 lbs per hour of CFC-113 loading for recovery;
- 800 and 1,200 cfm blower for solvent air stream;
- Stainless steel recovery vessels;
- Carbon granules designed specifically for CFC-113 recovery (charred coconut husk);
- Stack analyzer for bed switching when saturated with hour time as backup.

The project cost of the carbon adsorbers was:

- For a 2 bed, 10 lbs per hour, 800 cfm unit: \$62,000
- For a 3 bed, 16 lbs per hour, 1200 cfm unit: \$73,000
- Automated material handling unit: \$45,000
- Facility fit-up and miscellaneous: \$187,000

Total project cost, including start-up and operator training was \$380,000.

Currently there are two carbon adsorbers operating at Digital. Based on actual usage numbers for 1990, solvent emissions are projected to be reduced by 69 percent (see Exhibit 22).

*Exhibit 22***SOLVENT USAGE REDUCTION PROGRAM**

Source: Digital Equipment Corp.

F1000-11

A Three-Phase Plan

This study also resulted in a three phase plan to recover and reuse solvents and eventually to eliminate use of CFC-113.

PHASE 1

- Education and training
- Equipment enhancements
- Process engineering changes
- Operating disciplines
- Accountability (make one person responsible for managing the program)
- Limiting new applications

This phase reduced the solvent emission and usage by 20 to 30 percent, as shown in Exhibit 22.

PHASE 2

- Install new vapor recovery system (carbon bed adsorption), for point-of-use only.

This phase is projected to reduce the total emission and usage by 55 to 70 percent, as shown in the Exhibit 22.

PHASE 3

- Conversion to alternative methods of cleaning.

This phase will reduce the emission/ usage to zero.

Phases 1 and 2 have been completed. Phase 3 is being implemented and is expected to eliminate CFC usage by mid-1992.

CASE STUDY #2: USING INDUSTRIAL HYGIENE TECHNIQUES TO MONITOR AND REDUCE SOLVENT LOSSES

Case Study #2 shows how monitoring solvent emissions can identify ways to reduce solvent consumption and protect worker health.

A Problem with Excessive Emissions

At Honeywell a MCF vapor degreaser was losing large quantities of solvent and employees were complaining about strong solvent odors. The degreaser is an open top degreaser with no hoist. The maintenance departments showed through inspection of the heat and cooling systems that all systems were operating properly within the designated temperatures and there were no identifiable leaks.

Taking Action to Solve the Problem

An investigation was completed by the Industrial Hygiene staff to identify employee solvent exposures. During the investigation, air samples

were collected in operator breathing zones with length-of-stain calorimetric detection tubes. Readings were found to vary greatly between 50 and 300 ppm MCF. The current threshold limit value is 350 ppm. Further monitoring found a correlation between air monitoring results and air conditioner and elevator operations. Smoke testing of air currents and vapor blanket disturbances indicated that increased velocities across the top of the vapor degreaser, caused by air conditioning and elevator shaft drafts, broke down the vapor blanket. Detector tube readings in stable conditions were 50 ppm compared to turbulent conditions of 300 ppm solvent.

Partitioning the work area stopped air currents from passing across the vapor degreaser. To allow some air movement and reduce the chance of vapor buildup in the work area, the partitioning did not extend to the ceiling. Follow-up personal monitoring of the operator confirmed these levels.

Results

Worker exposures and solvent losses were reduced greatly. An immediate reduction in work area concentration was achieved with solvent levels dropping to between 25 and 50 ppm MCF. Improvements from the program are presented in the table below. The overall solvent losses were reduced by 75 percent. This easy-to-perform monitoring can be completed at a cost of less than \$100 per investigation and an initial equipment investment of approximately \$300. In this case study, the value of the MCF saved in one month exceeds the \$300 investment in equipment, and contributed to employee satisfaction.

<u>Conditions</u>	<u>Detector Tube Reading (ppm)</u>	<u>Approximate Solvent Losses (Gal/day)</u>
Steady	50	0.3
Air Conditioning on	125-200	3.2
Elevator Door Open	175-300	4.0
Partitioning in Place	25-50	0.2

CASE STUDY #3: SOLVENT EQUIPMENT SELECTION -- A CASE STUDY OF ERRORS

Case Study #3 illustrates errors that can be avoided during planning and implementation of a CFC reduction program.

With the growing concerns associated with CFC solvent usage, Northern Telecom, a large, multinational supplier of telecommunications electronics, began an aggressive campaign to eliminate the materials. While the conservation portion of this program was successful in reducing CFC emissions by about 50 percent, there are lessons from the experiences that will help others avoid investment mistakes.

Errors resulted in several areas:

- Ineffective use of an automated hoist
- Poor education of operators
- Incorrect equipment selection
- Improper equipment operations
- Poor control over use and handling of solvents.

Northern Telecom was using CFC-113 in an open-top batch cleaner for cleaning printed circuit board assemblies. The open-top unit had the following specifications:

- At 50 percent utilization, the unit cleaned 30,000 square feet of boards;
- The unit consumed 80 gallons of solvent per month;
- Energy costs were insignificant;

- Labor costs were \$12,500/yr;
- Total operating costs (labor + solvent) was \$45,000/yr.

Shortly after the open-top unit was installed, an automatic hoist was added for better process control and to conserve solvent. However, the hoist system was removed within six months of installation because operators complained of inefficiencies associated with its use. Failure to utilize the hoist represented management's reluctance to support a conservation process that would have reduced solvent use. Operators had not been educated about the importance of solvent conservation.

After two years of operation, Northern Telecom introduced a new product line. As part of this product line, the company purchased a new in-line solvent cleaning machine. The batch cleaner was replaced by an in-line cleaner and still. The in-line system was being used in other high volume corporate facilities, and was therefore was assumed to be appropriate.

The operating characteristics of the in-line unit included:

- Capital costs \$90,000 (with still);
- Capacity of 200 gallons of solvent;
- At idle the unit consumed 0.75 lbs of solvent per hour;
- Operating at 4 fpm, the unit consumed 14.3 lbs/hr of solvent;
- Average production was near 36,000 square feet of product per year;
- Average solvent use was 3 to 4 barrels per month. Solvent costs were \$78,000 per year;
- The unit required a part-time operator (25 percent of the time), even though at the time of purchase it was assumed to need no operator. Labor costs were \$6,250 per year;
- Annual utility costs were \$25,000;
- Total operating costs (labor, utilities, and solvent): \$109,250/yr, or over \$3.00/board.

In replacing the batch cleaning system with an in-line system and associated still, Northern Telecom encountered a number of problems. Although the new in-line system was more sophisticated, it was much more expensive (based on per square foot of boards cleaned) and used a greater amount of solvent than the batch machine.

The new cleaner was not the best machine for the specific needs and functions and was not entirely appropriate for the new product applications. A financial analysis of the break-even point would have identified the shortcomings of the new machine and the likelihood that CFC legislation would make the unit obsolete.

To conserve CFC-113, a reduced CFC-113 blend was used in this machine. The machine was not compatible with the blend and the ball valves used in the machine failed.

Besides specific problems related to the equipment choice, there were also errors in general handling of solvents. Throughout this entire process, the solvent was never treated as a chemical of concern. Operator awareness was not stressed, and as a consequence excessive solvent usage continued unabated.

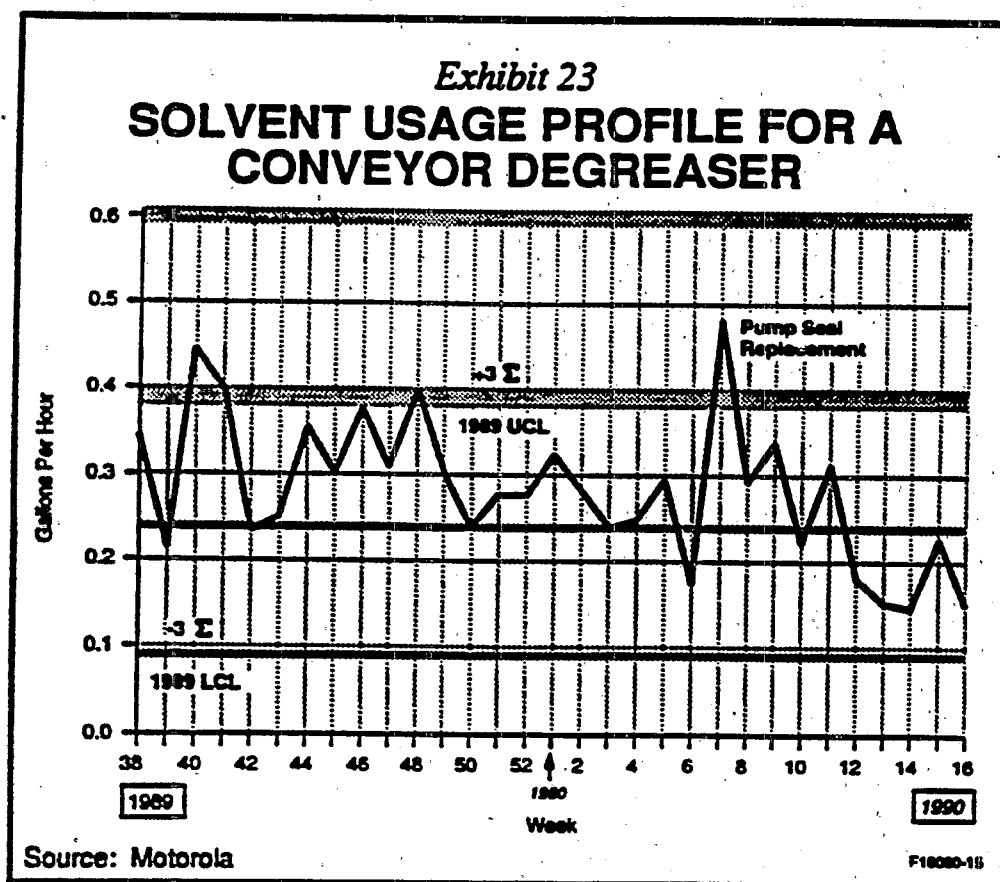
Excessive solvent consumption was not initially noticed because of two errors in the procedures implemented to track solvent usage. First, operators were asked to report solvent use on their respective machines, and who were initially assumed to be accurate, consistently made mistakes in reporting solvent use by over 50 percent. Because the measuring errors were random, several months were lost. The management group responsible for tracking the efficiency of the solvent cleaners from two solvent tracking reports somehow mishandled the data presented it out of context. It was not until all reports were channelled through one individual that confusion and misunderstanding was replaced by reliable reporting of data.

CASE STUDY #4: EMISSIONS MONITOR- ING AND REDUCTION

Case Study #4 outlines the 50 percent reduction of CFC-113 solvent consumption from a conveyor degreaser. Motorola accomplished the reduction with the following actions:

- The temperature of the vapor cooling coils was reduced until water started condensing on the coils. This required a system with a closed loop cooling unit with a refrigeration system. Water condensation initially caused the alcohol in the solvent to separate into a second phase, destroying the cleaning effectiveness and creating a fire hazard. To overcome this problem, the desiccant must be dried daily.

- Entrance and exit brushes were installed to contain vapors and fans and other air currents near the degreasing machine were eliminated.
- All system leaks were detected and eliminated on a regular basis. Solvent usage is tightly tracked and plotted. Any spikes in the usage level triggers a thorough systems check of all seals, fittings, covers, using a common refrigerant vapor detector. Note that solvent evaporates so quickly that leaks will not appear as drips. Exhibit 23 depicts a spike caused by a seal leak which was detected by close monitoring of the solvent usage. UCL and LCL are the acronyms for upper confidence limit and lower confidence limit respectively.
- Internal baffles were installed to reduce the disturbance to the vapor blanket caused by external air currents.
- Vapor leaks were sealed where possible.



CASE STUDY #5: HISTORY OF EQUIPMENT UPGRADES

Case Study #5 presents a history of six solvent users who switched from old to new systems to reduce solvent emissions. The case study was provided by the Halogenated Solvents Industry Alliance. Each example describes specific equipment and operating characteristics and the systems which replaced them.

1.

Type of product manufactured:	Cosmetic packaging
Previous method of cleaning:	Crossrod in-line vapor degreaser using trichloroethylene
Approximate age of equipment:	20 years
Reason for expenditure:	Regulation of trichloroethylene as an oxidant
New method of cleaning:	Crossrod in-line vapor degreaser using trichloroethylene, refrigeration chiller, carbon adsorber, negative pressure
Previous solvent consumption:	1,250 gal/mo.
New solvent consumption:	450 gal/mo.
Percent emission reduction:	64
Capital investment:	\$400,000
Hours operated per week:	120
Emission per hour:	1.8 lb. trichloroethylene/hr.
Solvent savings per year:	\$44,160

2.

Type of product manufactured:	Cosmetic packaging
Previous method of cleaning:	Crossrod in-line vapor degreaser using methyl chloroform
Approximate age of equipment:	15 years
Reason for expenditure:	Obtain better cleaning
New method of cleaning:	Crossrod in-line vapor degreaser using methyl chloroform, enclosed, superheat, no refrigeration, river water for cooling
Previous solvent consumption:	1,050 gal/mo.
New solvent consumption:	105 gal/mo.
Percent emission reduction:	90
Capital investment:	\$270,000 (includes new boiler)
Hours operated per week:	80
Emission per hour:	3.4 lb. MCF/hr.
Solvent savings per year:	\$49,900

3.

Type of product manufactured:	Small household appliances
Previous method of cleaning:	Crossrod vapor degreaser using trichloroethylene
Approximate age of old equipment:	20 years
Reason for expenditure:	Automate handling and reduce emission
New method of cleaning:	Crossrod vapor degreaser using trichloroethylene, enclosed cooling tower, primary cold trap, negative pressure, and carbon adsorber
Previous solvent consumption:	2,500 gal/mo.
New solvent consumption:	250 gal/mo.
Percent emission reduction:	90
Capital investment:	\$500,000
Hours operated per week:	120
Emission per hour:	6.0 lb. trichloroethylene/hr.
Solvent savings per year:	\$124,200

-
4. **Type of product manufactured:** Screw machine parts
 Previous method of cleaning: Crossrod vapor degreaser using methylene chloride
 Approximate age of old equipment: 15 years
 Reason for expenditure: Eliminate solvents or reduce emission
 New method of cleaning: Crossrod vapor degreaser using methylene chloride,
 enclosed, auto hoist, refrigeration chiller, superheat, down
 time chiller
 Previous solvent consumption: 750 gal/mo.
 New solvent consumption: 100 gal/mo.
 Percent emission reduction: 87
 Capital investment: \$350,000
 Hours operated per week: 80
 Emission per hour: 3.3 lb. methylene chloride/hr.
 Solvent savings per year: \$24,900
5. **Type of product manufactured:** Screw machine parts
 Previous method of cleaning: Crossrod vapor degreaser using methylene chloride
 Approximate age of equipment: 15 years
 Reason for expenditure: Eliminate solvents or reduce emissions
 New method of cleaning: Crossrod vapor degreaser using methylene chloride,
 enclosed, auto hoist, refrigeration chiller
 Previous solvent consumption: 750 gal/mo.
 New solvent consumption: 200 gal/mo.
 Percent emission reduction: 73
 Capital investment: \$80,000
 Hours operated per week: 40
 Emission per hour: 13.1 lb. methylene chloride/hr.
 Solvent savings per year: \$21,050
6. **Type of product manufactured:** Screw machine parts
 Previous method of cleaning: Open-top vapor degreaser using methylene chloride, two
 dip
 Approximate age of equipment: 15 years
 Reason for expenditure: Eliminate solvents or reduce emissions
 New method of cleaning: Open-top vapor degreaser using methylene chloride,
 enclosed, auto hoist, refrigeration chiller
 Previous solvent consumption: 350 gal/mo.
 New solvent consumption: 100 gal/mo.
 Percent emission reduction: 72
 Capital investment: \$50,000
 Hours operated per week: 40
 Emission per hour: 6.5 lb. methylene chloride/hr
 Solvent savings per year: \$9,570
-

CASE STUDY #6: SOLVENT CONSERVA- TION AND RECYCLING

Case Study #6 presents a solvent conservation and recycling project undertaken at Royal Ordnance Blackburn, United Kingdom. Royal Ordnance Blackburn was originally established to produce artillery fuzes, and continues to do so today although these are now electronic based as distinct from being purely mechanical. Additional expansion and diversification over the years into electronic control and communication systems of various kinds has seen the work pattern change, but essentially Royal Ordnance Blackburn still manufactures large numbers of small precision engineered components in brass, steel, and aluminum.

Royal Ordnance Blackburn's usage of CFCs is of three types:

- De-fluxing of printed circuit boards;
- Precision cleaning of assemblies/sub-assemblies; and
- Stain-free drying of components after processing.

In order to meet the requirements of the Montreal Protocol, a program of control and recycling was introduced. This program included surveying the usage of CFCs, and how individual plants operated. This survey showed that in some instances CFCs were being used (often in open containers) for general cleaning purposes when other solvents would have been more appropriate. Some working practices were also identified as being wasteful of solvent. An in-house training program which explained the problem and consequences of ozone layer destruction was instituted. This program was aimed at all levels of shop-floor staff. As a result of this program, a reduction in usage of CFCs coupled with improved methods of working were achieved.

A second phase was to examine recycling of solvents for reuse in the factory. All departments were required to drum their waste solvents

separately and return them to a central collection point, correctly identified and labelled. A solvent distillation plant was purchased and installed. The plant was designed to meet all present and foreseeable safety and legislative requirements and was to be capable of re-distilling most solvents used in the factory, e.g., trichloroethylene, in addition to CFCs. The plant, including some necessary conversion work on the building housing the plant cost some U.S. \$79,500. The solvent reclaimed over approximately six months indicates that the plant will pay for itself in 12-15 months. The plant is capable of distilling up to 500 liters per hour, depending on the solvent and operating parameters. It has considerable spare capacity, and is capable of meeting all future requirements. The quality of solvent obtained from the distillation process is of an acceptable quality for normal usage.

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Kohl, J.J., M. Person, Rose and P. Wright. 1986 (May). Managing and recycling solvents in the furniture industry. Industrial Extension Service, School of Engineering, North Carolina State University. Raleigh, N.C.

Kohl, J.P., Moses, and B. Triplett. 1984. Managing and recycling solvents: North Carolina practices, facilities, and regulations. North Carolina State University. Raleigh, N.C.

Massouda, Bill. 1988. Assessment of chlorinated solvent usage and control costs in metal cleaning and electronics cleaning. U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances. Washington, DC.

Ramsey, R.B. 1990 (September 1990). Vapor degreaser emission control. Presented at the International Machine Tool Show. Chicago, IL.

Thorstensen, Peter. 1990 (September 13). Process equipment modifications to reduce CFC emissions. Presented at the ICOLP Solvent Conservation Workshop. Chicago, IL.

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U.S. Environmental Protection Agency. 1989 (August). Waste minimization in metal parts cleaning. Office of Solid Waste. Washington, DC.

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U.S. Environmental Protection Agency. 1990 (March). Manual of practices to reduce and eliminate CFC-113 use in the electronics industry. EPA 400/3-90-003. Office of Air and Radiation. Washington, D.C.

List of Solvent Recyclers and Equipment Manufacturers*

Licensed Solvent Recyclers (provided by National Solvent Recycling Association)

Allworth, Inc.
500 Medco Road
Birmingham, AL 35217
(205) 841-1707

Arivec Chemicals, Inc.
7962 Huey Road
P.O. Box 549
Douglasville, GA 30122
(404) 942-1550

Baron-Blakeslee, Inc.
2001 North Janice Avenue
Melrose Park, IL 60160
(312) 450-3900

Chem Pak Corporation
P.O. Box 7151
Warwick, RI 02887
(401) 738-2200

Chemical Solvents, Inc.
3751 Jennings Road
Cleveland, OH 44109
(216) 741-9313

Chemtron Corporation
35850 Schneider Court
Avon, OH 44011
(216) 871-8048

CWM Resource Recovery, Inc.
P.O. Box 453
West Carrollton, OH 45449
(513) 859-6101

Gibraltar Chemical Resources
P.O. Box 1640
Kilgore, TX 75662
(214) 894-0270

Anachemia Solvents, Ltd.
3549 Mavid Road
Mississauga, Ontario, CN L5C 1T7
(416) 279-5122

Avganic Industries, Inc.
114 North Main Street
P.O. Box 208
Cottage Grove, WI 53527
(608) 257-1440

Berkley Products Company
P.O. Box E
Akron, PA 17501
(717) 859-1104

Chemical Reclamation Services
P.O. Box 69
Avalon, TX 76623
(214) 299-5043

Chempro
2203 Airport Way, South
Suite 400
Seattle, WA 98134
(206) 223-0500

Clayton Chemical Company
1 Mobile Street
Sauget, IL 62201
(618) 271-0467

General Chemical
P.O. Box 608
Framingham, MA 01701
(617) 872-5000

Hukill Chemical Corporation
7013 Krick Road
Bedford, OH 44146
(216) 232-9400

* This is not a comprehensive list of vendors. For more names check the Thomas Register. Licensed solvent recyclers and equipment manufacturers can be cited in subsequent editions of this manual by sending information to ICOLP. ICOLP's address is provided in Appendix A. Listing is for informational purposes only, and does not constitute any endorsement by EPA or ICOLP, either express or implied, of any product or service offered by such entity.

Hydrocarbon Recyclers
5354 West 46th Street South
P.O. Box 9557
Tulsa, OK 74157
(918) 446-7434

International Solvent Corporation
9800 190th Street
Surrey, Vancouver, CN V3T 4W2
(604) 888-4653

Liberty Solvents and Chemical
9429 Ravena Road
Twinsburg, OH 44087
(216) 425-4484

Marisol, Inc.
125 Factory Lane
Middlesex, NJ 08846
(201) 469-5100

Millsolv Company
P.O. Box 444
Butler, WI 53007
(414) 252-3550

Nortru, Inc.
515 Lycaste
Detroit, MI 48214
(313) 824-5850

Omega Recovery Services
12504 East Whittier Blvd.
Whittier, CA 90602
(213) 698-0991

Prillaman Chemical Corporation
P.O. Box 4024
Martinsville, VA 24112
(713) 638-8829

Rho-Chem Corporation
425 Isis Avenue
Inglewood, CA 90301
(213) 776-6233

Romic Chemical Corporation
2081 Bay Road
Palo Alto, CA 94303
(415) 324-1638

Industrial Solvents & Chemical
P.O. Box 158
Emigsville, PA 17318
(717) 938-4621

KDM Company
4303 Profit Drive
San Antonio, TX 78219
(512) 333-4011

M & J Solvents Company
1577 Marietta Road, N.W.
P.O. Box 19703
Atlanta, GA 30325
(404) 355-8240

Michigan Recovery Systems
36345 Van Born Road
Romulus, MI 48174
(313) 326-3100

North East Chemical Corporation
3645 Warrensville Center Road
Cleveland, OH 44122
(216) 961-8618

Oil and Solvent Process Company
P.O. Box 907
Azusa, CA 91702
(818) 334-5117

Pride Solvents & Chemical Company
88 Lamar Street
West Babylon, NY 11704
(516) 643-4800

Reclaimed Energy Company, Inc.
P.O. Box 418111
Indianapolis, IN 46241
(317) 241-9021

Rinchem Company
4115 West Turney Avenue
Phoenix, AZ 85019
(602) 233-2000

Safety Kleen Corporation
777 Big Timber Road
Elgin, IL 60120
(312) 697-8460

Sol-Pro, Inc.
P.O. Box 1781
Tacoma, WA 98401
(206) 627-4822

Spartan Chemical Company
2538 28th Street, S.W.
Wyoming, MI 49509
(616) 534-4921

U.S. Chemical Company
29163 Calahan
Roseville, MI 48066
(313) 778-1414

Southeastern Chemical & Solvent
170 South Lafayette Boulevard
Sumter, SC 29150
(803) 773-7387

Tricil Recovery Services, Inc.
Bartow Municipal Airport
Route 3, P.O. Box 249
Bartow, FL 33830-9504
(813) 533-6111

Waste Research & Reclamation
Route No. 7
Eau Claire, WI 54701
(715) 834-9624

Equipment Suppliers -- Carbon Adsorption Equipment

Ameg
Handelsges mbH 7 Co. KG
28 Bremen 66
Postfach 66032
Knechtsand 4
Germany
Tel: 0421-580038
Telex: 245445

BOWE Reinigungstechnik GmbH
Haunstetter Str. 112
D-8900 Augsburg
Germany
Tel: (0821) 57021

Ceilcote Company
140 Sheldon Road
Berea, OH 44017
(216) 243-0700

Detrex Corporation
Equipment Division
P.O. Box 5111
Southfield, MI 48086-5111
(313) 358-5800

Otto Dürr AG
Werk Bernhausen
Postfach 1260
7024 Filderstradt 1
Germany
Tel: 0711-790281
Telex: 7255850

Baron-Blakeslee, Inc.
2001 North Janice Avenue
Melrose Park, IL 60160
(312) 450-3900

Brechbuhl AG
Sihlquai 244
CH-8031 Zurich
Switzerland
Tel: 01-448950
Telex: 54195 PLAZU CH

DCI International
1229 Country Club Road
Indianapolis, IN 46234
(317) 271-4001

Hoyt Manufacturing Company
251 Forge Road
Westport, MA 02790
(617) 636-8811

Omniatex
40013 Castel Maggiore
Via Andrea Costa 4
Bologna
Italy
Tel: 051-70034
Telex: 213418 OTEX-1

Phillips Manufacturing Company
7334 North Clark Street
Chicago, IL 60626
(312) 338-6200

Rotamll Maschinenbar GmbH
Postfach 12053
5900 Siegen
Eisenhutenstrasse 26
0271 6711
Germany
Telex: 872352

Sutcliffe Croftshaw Limited
P.O. Box 2526
Columbus, OH 43216
Tel: (614) 258-9501

Vara International, Inc.
1201 19th Place
Vero Beach, FL 32690
(407) 567-1320

Equipment Suppliers -- Vapor Degreasing Equipment

Baron-Blakeslee, Inc.
2001 North Janice Avenue
Melrose Park, IL 60160
(312) 450-3900

Corpane Industries
1010G Bluegrass Parkway
Louisville, KY 40299
(502) 491-4433

Delta Industries
8137 Allport Avenue
Santa Fe Springs, CA 90670
(213) 945-1067

Electrovert Corp.
4330 Beltway Place
Suite 350
Arlington, TX 76017
(817) 468-5171

Rekuperator KG
Dr Ing Schack & Co.
Sternstrasse 9-11
Postfach 320960
D-4000 Dusseldorf 1
Germany
Tel: 0211-490055
Telex: 8584894

Sutcliffe Croftshaw Limited
Neills Road
Bold
St. Helens
Merseyside WA9 4TH
England
Tel: 0744-810107

Vic Manufacturing Company
1620 Central Avenue, N.E.
Minneapolis, MN 55413
(612) 781-6601

Branson Ultrasonics Corporation
Eagle Road
Danbury, CT 06484
(203) 769-0400

Crest Ultrasonics Corporation
Scotch Road - Mercer County Airport
P.O. Box 7266
Trenton, NJ 08628
(609) 883-4000

Detrex Corporation
Equipment Division
P.O. Box 5111
Southfield, MI 48086-5111
(313) 358-5800

Finishing Equipment, Inc.
3640 Kennebec Drive
St. Paul, MN 55122
(612) 452-1860

Hoshikawa Co., Ltd.
Tokyo, Japan
Tel: 03-643-6601
Fax: 03-643-6093

Kerry Ultrasonics, Ltd.
Hunting Gate, Wilbury Way, Hitchin
Herts SG4 0TQ England
Tel: 0462-50761-5
Fax: 0462-420712

Phillips Manufacturing Company
7334 North Clark Street
Chicago, IL 60626
(312) 338-6200

ICI Chemical & Polymers Ltd.
P.O. Box 19
Runcorn
Cheshire, WA7 4LW
Tel: 0928 514444
Fax: 0928 580742

Ohtsuka Technical Industry Co., Ltd
3-32 3 Chome, Kigawahigashi
Yodogawa-Ku, Osaka, Japan
Tel: 06-304-7963

Unique Industries
11544 Sheldon Street
Sun Valley, CA 91352
(213) 875-3810

Equipment Suppliers -- Monitoring Equipment

Foxboro Co.
151 Woodward Ave.
Box 5449
S. Norwalk, CT 06856

Mine Safety Appliances
Box 427
Pittsburgh, PA 15230

Sensidyne
12345 Starkey Rd.
Largo, FL 33543

Gastech
8445 Central Ave.
Newark, CA 94560

TIF
3661 NW 74 St.
Miami, FL 33147

Other Resources

Center for Emissions Control
1225 19th Street, N.W.
Suite 300
Washington, DC 20036
(202) 785-4374

Glossary

Carbon Adsorption -- A recovery process that captures solvent vapors from air on activated carbon. The solvent is recovered (by desorption) from the carbon by injecting steam into the carbon bed and condensing the resultant solvent and water vapor.

CFC -- An abbreviation for chlorofluorocarbon.

Chlorofluorocarbon -- An organic chemical composed of chlorine, fluorine and carbon atoms, usually characterized by high stability contributing to a high ODP.

Condensate -- Liquid solvent resulting from cooling solvent vapors. It is the clean solvent that condenses on the cooling coils of a vapor degreaser or still.

Desiccant Dryer -- A means of removing water from a solvent by adsorption with desiccant such as a silica gel or molecular sieve.

Desorption -- The process of regenerating a carbon adsorption unit by treating the carbon with steam to remove the adsorbed solvent.

Distillation -- A process of purifying a solvent by boiling, condensing the vapor, and collecting the condensate.

Dragout -- Solvent that is carried out of a vapor degreasing operation as a liquid trapped in or on the parts being processed, and a micro-layer of solvent on part surfaces.

Freeboard -- Distance from the top of the vapor level to the top of the degreasing tank.

Freeboard Ratio -- The ratio of freeboard height to width of the machine opening. It should be between .75 and 1.0 for reduced emissions.

Greenhouse Effect -- A thermodynamic effect whereby energy absorbed at the earth's surface, which is normally able to radiate back out to space in the form of long-wave infrared radiation, is retained by gases in the atmosphere, causing a rise in temperature. The gases in question are partially natural, but manmade pollution is thought to increasingly contribute to the effect. The same CFCs that cause ozone depletion are known to be "greenhouse gases," with a single CFC molecule having the same estimated effect as 10,000 carbon dioxide molecules.

Halogenated Solvents -- Liquid substances that contain carbon, halogen or carbon hydrogen, and halogen (such as fluorine or chlorine) atoms. In this text, the term refers to the commercial solvents, methylene chloride, perchloroethylene, 1,1,1-trichloroethane (MCF), trichloroethylene, and trichlorotrifluoroethane (CFC-113).

Halons -- Fire-extinguishing agents with high ODPs.

HCFC -- An abbreviation for hydrochlorofluorocarbon.

HFC -- An abbreviation for hydrofluorocarbon.

ODP -- An abbreviation for ozone depletion potential.

Ozone -- A gas formed when oxygen is ionized by, for example, the action of ultraviolet light or a strong electric field. It has the property of blocking the passage of dangerous wavelengths of ultraviolet light. Whereas it is a desirable gas in the stratosphere, it is toxic to living organisms at ground level (see volatile organic compound).

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

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

Ozone layer -- A layer in the stratosphere, at an altitude of approximately 10-50 km, where a relatively strong concentration of ozone shields the earth from excessive ultraviolet radiation.

Piston Effect -- Displacement of solvent vapors due to entry and exit of basket or part that is too large.

Refrigerated Freeboard Device -- A low-temperature heat exchange coil located in the degreaser freeboard zone, immediately above the water-cooled condensers. The freeboard chiller lowers the partial pressure of the solvent in the freeboard zone which results in a reduction in the solvent diffusion rate.

Shock Load -- A large part or load of parts which cause the solvent vapor level to drop substantially below the normal operating level.

Steam Distillation -- The practice of injecting steam directly into the still after normal distillation has ceased to recover more solvent from the residue.

Still -- A unit employed to purify solvent by distillation.

Vapor Line -- The line or level of the solvent vapor-air interface in the vapor degreasing unit.

Volatile organic compound (VOC) -- These are constituents that will evaporate at their temperature of use and which, by a photochemical reaction, will cause atmospheric oxygen to be converted into potential smog-promoting tropospheric ozone under favorable climatic conditions.

Water Separator -- A device designed to remove water from the solvent by flotation.

Work Capacity -- The load a degreaser is designed to process efficiently while maintaining a steady vapor level.

APPENDIX A

INDUSTRY COOPERATIVE FOR OZONE LAYER PROTECTION

The Industry Cooperative for Ozone Layer Protection (ICOLP) was formed by a group of industries to protect the ozone layer. The primary role of ICOLP is to coordinate the exchange of non-proprietary information on alternative technologies, substances, and processes to eliminate ozone-depleting solvents. By working closely with solvent users, suppliers, and other interested organizations worldwide, ICOLP seeks the widest and most effective dissemination of information harnessed through its member companies and other sources.

ICOLP corporate members include:

AT&T
 Boeing Company
 British Aerospace
 Compaq Computer Corporation
 Digital Equipment Corporation
 Ford Motor Company
 General Electric
 Hitachi Limited
 Honeywell
 IBM
 Matsushita Electric Industrial
 Company
 Mitsubishi Electric Corporation
 Motorola
 Northern Telecom
 Sundstrand
 Texas Instruments
 Toshiba Corporation

In addition, ICOLP has a number of industry association and government organization affiliates.

Industry association affiliates include American Electronics Association (AEA), Electronic Industries Association, Japan Electrical Manufacturers Association and Halogenated Solvents Industry Alliance (U.S.). Government organization affiliates include the City of Irvine, California, the State Institute of Applied Chemistry (U.S.S.R.), the U.S. Air Force, and the U.S. Environmental Protection Agency (EPA). The American Electronics Association, the Electronic Industries Association, the City of Irvine, California, the Japan Electrical Manufacturers Association, the Swedish National Environmental Protection Agency, the U.S. Air Force, the U.S. EPA, and the U.S.S.R. State Institute of Applied Chemistry have signed formal Memorandums of Understanding with ICOLP. ICOLP will work with the U.S. EPA to disseminate information on technically feasible, cost effective, and environmentally sound alternatives for ozone depleting solvents.

ICOLP is also working with the National Academy of Engineering to hold a series of workshops to identify promising research directions and to make most efficient use of research funding.

The goals of ICOLP are to:

- Encourage the prompt adoption of safe, environmentally acceptable, non-proprietary alternative substances, processes, and technologies to replace current ozone-depleting solvents;
- Act as an international clearinghouse for information on alternatives;
- 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.

One example of ICOLP's activities is the development and support of an alternative technologies electronic database "OZONET." OZONET is accessible worldwide and has relevant information on the alternatives to ozone-depleting solvents. OZONET not only contains technical publications, conference papers, and reports on the most recent developments of alternatives to the current uses of ozone-depleting solvents, but it also contains:

- Information on the health, safety and environmental effects of alternative chemicals and processes;
- Information supplied by companies developing alternative chemicals and technologies;
- Names, addresses, and telephone numbers for technical experts, government contacts, institutions and associations, and other key contributors to the selection of alternatives;
- Dates and places of forthcoming conferences, seminars, and workshops;
- Legislation that has been enacted or is in place internationally, nationally, and locally.

Information about ICOLP can be obtained from:

Mr. Steven B. Hellem
Executive Director
ICOLP
1440 New York Avenue, N.W.
Suite 300
Washington, D.C. 20005
Tel: (202) 737-1419
Fax: (202) 639-8685
