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Eliminating CFC-113 And Methyl Chloroform In Aircraft. Maintenance Procedures

Developed for the Thai Airways/Government of Thailand/U.S. EPA Solvent Elimination Project

ELIMINATING CFC-113 AND METHYL CHLOROFORM IN AIRCRAFT MAINTENANCE PROCEDURES

by

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[2] Dr. Stemniski's support for this project was provided by the U.S. Department of the Navy - Naval Sea Systems Command.

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FOREWORD

Thai Airways International, the Government of Thailand, the Industry Cooperative for Ozone Layer Protection (ICOLP), and the U.S. Environmental Protection Agency (EPA) have agreed to cooperate to phase out the use of ozone-depleting substances in aircraft maintenance solvent cleaning applications. The project is undertaken as part of the World Bank Global Solvents Project under the Multilateral Fund of the Montreal Protocol. This manual has been developed as part of this program. It will prove useful to other airlines because aircraft maintenance procedures apply to all airlines, regardless of location or size. The manual has been prepared by an international committee of experts from the airline and aerospace industries, the environmental agencies of Sweden and the United States, and the United States Air Force. Committee members represent both developed and developing countries..

The manual describes a step-by-step approach for characterizing the use of ozone-depleting solvents and identifying and evaluating alternatives. It is a "how-to", document which describes all of the steps necessary to successfully phase out the use of CFC-113 and methyl chloroform (MCF) in aircraft maintenance applications. Many of the alternatives described are currently in use at major airlines around the world. The manual addresses major maintenance cleaning applications and gives brief descriptions of the commercially available alternatives to CFC-113 and MCF. The manual provides sufficient technical information on the solvent alternatives to enable users to gather more detailed information on their alternatives of choice. A list of equipment and materials vendors is provided.

The manual's major findings remove misconceptions prevalent at many airlines. These findings are:

- Airlines can use any alternatives which meet aircraft standards without the explicit approval of the original equipment manufacturer (OEM)

  - At least two of the three large manufacturers of commercial jet aircraft have published and distributed performance-based standards recommended for use by airlines. Alternatives which meet these standards can be used without approval of the OEM.

- The OEM will provide the names of alternatives for some but not all applications of CFC-113 and MCF -- Several OEMs have explicitly stated that they are not actively qualifying solvent alternatives, and that this responsibility lies with the airline. There are, however, a few exceptions to this rule.

- CFC-313 and MCF have been unnecessarily used in many cleaning applications -- These solvents have been used for many years in applications for which they were never intended. Reductions in consumption of more than 50 percent have been reported as the result of eliminating use of CFC-113 and MCF in unnecessary applications.

Airlines have chosen to identify and test solvent alternatives on their own rather than wait for more direct involvement from the OEMs. Lufthansa and SAS have virtually eliminated their use of CFC-113 and MCF through this proactive approach. Others are well on their way towards significantly reducing their consumption. This manual documents these successful phaseouts.

The Montreal Protocol

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer and subsequent 1990 and 1992 amendments and adjustments control the production and consumption of ozone-depleting chemicals. As a result of the most recent meetings in Copenhagen in November 1992, 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 the year 1996, and by 2010 and 2015, respectively, in developing countries. In addition, the 1992 amendments include a freeze and reduction schedule for hydrochlorofluorocarbons (HCFCs), with a phaseout in developed countries by the year 2030.

Exhibit 1 lists the countries that are Parties to the Montreal Protocol as of May 1993. 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 schehules 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 eligible developing countries that are Party to the Protocol. Eligible countries are those with anannual consumption of CFCs and MCF of less than 0.3 kg per person.

Exhibit 1

PARTIES TO THE MONTREAL PROTOCOL

Algeria	Ecuador	Liechtenstein	Senegal
Antigua and Barbuda	Egypt	Luxembourg	Seychelles
Argentina	El Salvador	Malawi	Singapore
Australia	EEC	Malaysia	Slovakia
Austria	Fiji	Maldives	Slovenia
Bahamas	Finland	Malta	South Africa
Bahrain	France	Marshall Islands	Spain
Bangladesh	Gambia	Mauritius	Sri Lanka
Barbados	Germany	Mexico	Sudan
Belarus	Ghana	Monaco	Swaziland
Belgium	Greece	Morocco	Sweden
Botswana	Grenada	Netherlands	Switzerland
Brazil	Guatemala	New Zealand	Syrian Arab Republic
Brunei Darussalam	Guinea	Nicaragua	Tanzania
Bulgaria	Hungary	Niger	Thailand
Burkina Faso	Iceland	Nigeria.	Togo
Cameroon	India	Norway	Trinidad & Tobago
Canada	Indonesia	Pakistan	Tunisia
Central African Republic	Iran	Panama	Turkey
Chile	Ireland	Papua New Guinea	Uganda
China	Israel	Paraguay	Ukraine
Congo	Italy	Peru	United Arab Emirates
Costa Rica	Jamaica	Philippines	United Kingdom
Cote d'lvoire	Japan	Poland	United States
Croatia	Jordan	Portugal	Uruguay
Cuba	Kenya	Romania	Uzbekistan
Cyprus	Kiribati	Republic of Korea	Venezuela
Czech Republlc	Kuwait	Russian Federation	Yugoslavia
Denmark	Lebanon	St. Kitts and Nevis	Zambia
Dominica	Libyan Arab Jamahiriya	Samoa	Zimbabwe
		Saudi Arabia	

Date: May, 1993

Exhibit 2

OZONE-DEPLETING SOLVENT CORPORATE PHASEOUT DATES

Successful Phaseout:

A-dec
ADC Telecommunications
Advanced Micro Devices
Alcatel Network Systems
Apple Computer
Applied Magnetics
Aishin Seiki
Alps Electric
AT&T
Cadillac Gage
Calsonic
Canon
Corbin Russwin Hardware
Casio Computer
Chip Supply
Clarion
Compaq Computers
Conner Peripherals
Commins Engine
Diatek
Fuji Photo Film
Fujitsu
Harris Semiconductors
Hewlett Packard
IBM
ITT Cannon
Japan Aviation Electronics
Kilovac
Kyocera
Mabuchi Motor
Matsushita
MDM
Minebea
Minolta Camera
Mitsui High-tech
Motorola
Murata Erie N.A.
Murata Manufacturing
National Semiconductor
NEC
Nihon Dempa Kogyo
Nissan
Northern Telecom
NRC
Iki Electric
Omron
OTC/SPX
Pacific Scientific EKD
Ricoh
Rohm
Sanyo MEG
Sanyo Energy
Seagate Technology
Seiko Epson
Seiko-sha
Sharp
Shin-etsu Polymer
SMC
Sony
Stanley Electric
Sun Microsystems
Symmons Industries
Talley Defense Systems
Thomson Consumer Electronics
3M
Toshiba
Toshiba Display Devices
Toyota Motor
Unisia JECCS
Yokogawa Electric

Future Phaseout:

Citizen Watch -- 12/93
Funac -- 12/93
Hitachi -- 12/93
Hitachi Metals -- 12/93
Isuzu Motors -- 1993
Kohyo Seiko -- 12/93
Mitsubishi Electric -- 12/93
Mitsubishi Heavy Industry -- 12/94
Mitsubishi Motors -- 8/93
NHK Spring -- 12/93
Nissan Diesel Motor -- 1994
NSK -- 12/93
Olympus Optical -- 12/93
Sumitomo Electric -- 12/93
Sumitomo Special Metals -- 12/93
Suzuki Motor -- 1994
Taiyo Yuden -- 12/93
Victor Japan -- 11/93
Yamaha -- 12/93
Zexel -- 8/93

International Phaseout Schedules

Several countries have passed legislation to phase out CFC-113 and methyl chloroform (MCF) earlier than target dates set by the Montreal Protocol in an effort to slow ongoing depletion of the stratospheric ozone layer. These policies are summarized below.

Canada

Environment Canada, the federal environmental agency responsible for environmental protection in Canada, has proposed a reduction program that is more stringent than the Montreal Protocol. 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. Under the proposed schedule, production, imports, and exports of CFCs are to be eliminated by January 1, 1996, with a 75 percent reduction by January 1, 1994. For carbon tetrachloride, the phaseout date is January 1, 1995 -- one year earlier than that mandated by the Montreal Protocol. Halons are proposed to be eliminated by January 1, 1994. Production, imports, and exports of methyl chloroform will be halted by January 1, 1996, with interim reductions of 50 percent by January 1, 1994, and 85 percent by January 1, 1995.

European Community

Under the Single European Act of 1987, the twelve members of the European Community (EC) are subject to 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 an 85 percent reduction of CFC-113 by January 1, 1994 and a complete phaseout by January 1, 1995. For MCF, the production phaseout schedule calls for a 50 percent Cut in production by January 1, 1994 and a complete phaseout by January 1, 1996. 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.

European Free Trade Agreement Countries

The European Free Trade Agreement (EFTA) countries, Austria, Finland, Iceland, Noway, Sweden, and Switzerland, have each adopted measures to completely phase out fully halogenated ozone-depleting compounds. Austria, Finland, Norway, and Sweden will completely phase out their use of CFC-113 in all applications by January 1, 1995. Sweden also plans an aggressive phaseout date of 1995 for MCF. In addition, some of the EFTA countries have sector-specific interim phaseout dates for certain solvent uses. Austria is planning to phase out CFC-113 in a number of solvent cleaning applications by January 1, 1994. Norway and Sweden already eliminated their use of CFC-113 in all applications except textile dry cleaning on July 1, 1991 and January 1, 1991, respectively.

Japan

On May 13, 1992, the Ministry of International Trade and Industry of Japan requested its 72 Industrial Associations to phase, out CFC and . methyl chloroform usage by the end of 1995.

United States

The U.S. Clean Air Act (CAA), as amended in 1990, contains several provisions pertaining to stratospheric ozone protection. These ozone-depleting substances are defined as Class I and Class II substances. Class I substances include all fully halogenated CFCs, 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.

- ***Section 112: National Emission Standards for Hazardous Air Pollutants***

  This section of the CAA requires the EPA to develop emissions standards for 189 chemical compounds listed as hazardous air pollutants (HAPS). The list of HAPS includes the chlorinated solvents as well as many organic solvents likely to be wed in aircraft maintenance.

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

  The U.S. EPA is currently accelerating this phaseout schedule in response to former President George Bush's call for a more rapid phaseout and the recent amendments made to the Protocol in Copenhagen.

- ***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. and Class II substances during manufacture, use, storage, or disposal.

- ***Section 611: Labeling***

  This section of the CAA directed EPA to promulgate regulations requiring the labeling of products that contain or were manufactured with Class I and Class II substances and containers of these substances. Containers in which Class I and Class II substances are stored must also be labeled. 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 label must clearly identify the ODS by chemical name for easy recognition by average consumers, and must be placed so that it is clearly legible and conspicuous. This regulation took effect on May 15, 1993.

  No later than January 1, 2015, products containing or manufactured with a Class II substance must be labeled.

- ***Section 612: Safe Alternatives Policy***

  Section 612 establishes a framework for evaluating the overall environmental and human health impact of current and future alternatives to ozone-depleting solvents. Such regulation ensures that ozone-depleting substances will be replaced by substitutes that reduce overall risks to human health and the environment.

As an incentive to reduce the production and consumption of ozone-depleting substances in the U.S., Congress 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 chemical's ozone depleting potential. These taxes have recently been increased as a part of the U.S. Congress' comprehensive energy bill of 1992.

Calendar Year	Tax Amount Per Pound	
	CFC-113	MCF
1991	$1.096	$0.137
1992	$1.336	$0.167
1993	$2.68	$0.211
1994	$3.48	$0.435
1995	$4.28	$0.535

Cooperative Efforts

Japan

The recent Japanese 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 is working with the Japan Industrial Conference for Ozone Layer Protection (JICOP) to prepare a series of manuals which provide technical information on alternatives to CFC-113 and MCF. The manuals prepared are:

- Manual for Phasing-Out 1,1,1-Trichloroethane;

- Manual for reduction in the Use of Ozone-Depleting Substances.

MITI also encourages industry to reduce consumption of ozone-depleting compounds through economic measures such as tax incentives to promote the use of equipment to recover and reuse solvents.

Sweden

There are two major cooperative efforts within the Government/Industry/Research Institution sectors targeting the phaseout of ODSs and chlorinated solvents:

- The TRE-project (Technology for Clean Electronics); and

- The AMY-project (Cleaning of Metallic surfaces).

In addition, direct support is being provided to industry for industrial scale introduction of new technologies. These are, to name a few, closed looped systems, microbiological cleaning systems, ion exchange technologies, electrochemical cleaning systems, vacuum evaporation systems, reverse osmosis, and alternative solvent-based systems.

United States

The U.S. Environmental Protection Agency (EPA) has been working with industry to disseminate information on technically feasible, cost effective, and environmentally sound alternatives to 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. Additional information about ICOLP can be found in Appendix A. 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 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.

- Alternatives for . CFC-113 and Methyl Chloroform in Metal Cleaning.

- Eliminating CFC-113 and Methyl Chloroform in Precision Cleaning Operations.

- No-Clean Soldering to Eliminate CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies.

- Eliminating CFC-113 and Methyl Chloroform in Aircraft Maintenance Procedures.

* * * * * * *

This particular manual provides those in an organization involved in 'aircraft maintenance with a simply-structured program to help eliminate the use of CFC-113 and/or MCF. It presents alternative processes which can be used in aircraft cleaning, most of which are approved by major aircraft and engine manufacturers. Many are currently in use at airlines around the world. The goal of the manual is to:

- Warn users of CFC-113 and methyl chloroform of the impending halt in production and the consequences to their operations;

- Identify the currently available and emerging alternatives for CFC-113 and methyl chloroform;

- Provide an overview of the tasks which are required to successfully implement an alternative process or chemical;

- Provide an overview of the environmental, health, safety, and other factors associated with alternatives and the benefits achievable from the phaseout of CFC-113 and methyl chloroform;

- Present detailed case studies on the actual industrial applications of these technologies to:

  -- Identify unresolved problems in eliminating CFC-113 and methyl chloroform; and

  -- Describe the equipment configuration of a typical maintenance facility after it has eliminated its use of CFC-113 and methyl chloroform.

This manual will benefit all users of CFC-113 and MCF in the aircraft maintenance industry. Ultimately, however, the success of a CFC-113 and MCF elimination strategy will depend upon how effectively reduction and elimination programs are organized. Experience has also shown that a strong education and training program for workers using new processes results in greater efficiency and a smooth transition away from CFC-113 and MCF. The development and implementation of alternatives to CFC-113 and MCF for aircraft cleaning present a demanding challenge for most organizations. The rewards for success are, the contribution to global environmental protection and an increase in industrial efficiency.

STRUCTURE OF THE MANUAL

This manual is divided into the following sections:

- **EXISTING CLEANING PROCESS CHARACTERIZATION**

This section presents the initial steps a facility must take in order to reduce and eliminate CFC-113 and MCF usage in cleaning procedures. It emphasizes the importance of being familiar with the different aspects of the cleaning processes.

- **INTRODUCTION TO CLEANING IN AIRCRAFT MAINTENANCE PROCEDURES**

This section introduces the maintenance procedures which usually require cleaning, summarizes the types of cleaning which have been traditionally used, and presents a number of cleaning operations which apply to specific areas of aircraft and engine maintenance.

- **METHODOLOGY FOR SELECTING AN ALTERNATIVE PROCESS**

This section discusses various organizational, policy, technical, economic, and environment, health, and safety issues that should be considered when selecting a cleaning process.

- **QUALIFICATION TESTING OF ALTERNATIVE CLEANING PROCESSES AND MATERIALS**

This section discusses the importance of performing an aircraft or engine manufacturer's required tests of an alternative cleaning chemical or process and presents guidelines for conducting these tests.

- **INTRODUCTION TO ALTERNATIVE CHEMICALS AND PROCESSES**

This section describes the operational principles and outlines the advantages and disadvantages of several alternative technologies, including aqueous cleaning, semi-aqueous cleaning, aliphatic hydrocarbons, chlorinated solvents, other organic solvents, etc.

- **SUMMARY OF CLEANING APPLICATIONS**

This section presents summary sheets for a number of general aircraft cleaning procedures. These procedures are grouped into three categories: exterior surface cleaning, assembly cleaning, and component cleaning. It describes how CFC-113 and methyl chloroform may currently be used, the possible alternatives, relevant specifications, and associated environmental impacts.

- **USE OF CFC-113 AND METHYL CHLOROFORM IN SPECIALIZED FORMULATIONS**

This section presents information on how CFC-113 and methyl chloroform are used in additional applications, including non-cleaning applications.

- **CASE STUDIES OF SUCCESSFUL IMPLEMENTATION OF ALTERNATIVE PROCESSES**

This section provides examples of industrial applications of alternative technologies in aircraft cleaning.

EXISTING.CLEANING PROCESS CHARACTERIZATION

The first step in reducing and eventually eliminating the use of CFC-113 and MCF in aircraft maintenance cleaning is designating a multidisciplinary team to coordinate the effort. Team members should represent various shops within the maintenance facility, including electronics, instrumentation, engine, hydraulics, landing gear, plating, painting, and cleaning. The team should also include representatives from plant engineering, environmental control, occupational health and safety, quality control, and purchasing, if possible.

In order for the team to develop an effective program, it must first acquire a good overall knowledge of existing cleaning processes within its facility and the systems in which they are performed. This knowledge will help the team to identify and prioritize the cleaning operations to which it must direct its attention. Once these operations are identified, the team can analyze the processes to reduce CFC-l13/MCF usage and determine cleaning requirements so that an optimal alternative may be selected for each application.

Acquiring an adequate knowledge of the maintenance facility can be accomplished by conducting a facility-wide study using surveys. These surveys should be distributed to shop foremen for completion. If possible, the team should visit each shop to observe existing procedures, interview operators, and collect substrate and soil samples for laboratory tests. The study should include a flow chart of each manufacturing or maintenance process as well as tabular summaries of soils, substrates, and part geometry. Conducting the survey will allow the team to establish contacts and develop rapport with the individuals who will ultimately be affected by the process change. The cooperation and input of these individuals is essential to the success of the phaseout program.

After the study has been completed, the team should be able to characterize the different cleaning operations around the maintenance facility. The following sections suggest typical questions the team should be able to answer about existing cleaning processes, disposal practices, the substrates being cleaned, and the soils being removed.

Analyzing Existing Cleaning Methods

In order to reduce and eliminate the use of CFC-113 and MCF in aircraft maintenance cleaning, the team must identify and analyze all of the processes that use these substances. Questions the team should be able to answer include:

- What maintenance processes incorporate CFC-113 and MCF?
- .What quantity of CFC-113 and MCF is used in each process?
- Where do CFC-113 and MCF losses occur?
- Where does the cleaning take place in the facility?
- What percentage of time are the cleaning machines in use?
- How many parts are cleaned per day per machine?

Exhibit 3

CFC-113 AND METHYL CHLOROFORM USAGE PROFILE

SHOP NAME & LOCATION: ______________________________

NAME OF CONTACT IN SHOP ______________________________

A. PROCESS IDENTIFICATION

Aircraft Parts Cleaned (e.g. fuselage, engine components, seats - be as specific as possible): .

____

Current Cleaning Methlod (e.g. open-top vapor degreasing, conveyorized vapor degreasing, cold cleaning, dip tan!, hand-wipe, aerosol, etc):

____

Number of Cleaning Machines in Shop Which Use CFC-113 or MCF

____

Controls on Cleaning Equipment (e.g. covers, extended freeboard, cooling coils, etc.):

____

Other Uses (e.g., carriers, drying):

____

Substrates Typically Cleaned:

____

____

Soils Typically Removed (e.g., dirt, carbon deposits, grease) (attach MSDS for the soil if available):

____

____

Standards to be met (e.g. AMS, military, etc.):

____

____

B. PRODUCTS USED

Generic Name of Solvent (circle one; use one survey for each chemical):

CFC-113 **MCF (1,1,1-trichloroethane)**

Trade Name of Solvent (e.g. Daiflon 113, Freon TF, Chlorothene SM, Triethane) (see Appendix C for additional tradenames):

___

Manufacturer (e.g. Daikin, DuPont, Dow, PPG) (see Appendix C for additional manufacturers):

___

C. USE HISTORY

Quantity Purchased and Used Yearly; specify units (e.g. liters, gallons):

	PURCHASED (quantity of solvent purchased or requisitioned by this shop for cleaning)	USED (quantity of solvent consumed in this shop for cleaning)
1989		
1990		
1991		
1992		

D. CFC-113 AND MCF DISPOSAL PRACTICES

	1989	1990	1991	1992
Quantity shipped out as waste for disposal (specify units):				
Disposal costs:				
Quantity shipped out for recycling (specify units):				
Cost of recycling:				
Quantity recycled on site (specify units):				
Quantity lost to the environment[1] (through leakage, spillage, testing, dragout, evaporation, etc.) (specify units)				

[1] This quantity can be calculated as follows: Quantity Lost = Quantity Purchased - Quantity shipped out as waste.

An effective way to collect such information is through a written survey. Exhibit 3 shows an example of a survey that can be used to characterize CFC-113 and MCF usage in all aspects of the facility's operations.

The information gathered using surveys and other means can be stored in an electronic database for future use. The creation of such a comprehensive database will allow the team to monitor progress and to pinpoint areas in the facility where consumption of ODSs remains high. Facilities may choose to design the tracking system themselves, hire a firm to create a custom system, or purchase an existing system from another facility. At least one European airline has created such a system which it offers for sale to other facilities.

Through familiarizing itself with current usage patterns, the team will not only know which cleaning operations can utilize: currently available alternative cleaning methods, but also which operations can reduce their use of CFC-113 and MCF until another method becomes available.

For example, when the maintenance facility of one large airline became aware of the environmental problems caused by CFC-1.13 and MCF, it examined its cleaning processes to determine where reduction and elimination could occur. It identified areas where it could make the greatest reduction with the least amount of difficulty. In one situation, it discovered that the instrumentation shop was cleaning small parts by running them under MCF dispensed by a faucet. This faucet mechanism resulted in a great deal of MCF being wasted. The company decided to switch the cleaning operation to an MCF aerosol spray. Although it will still need to be eliminated, this new cleaning method provided a much more controlled use of the solvent, thus greatly reducing the shop's consumption of ODSs.

If several similar cleaning operations exist throughout the maintenance facility, the team may choose to consolidate some of them into a central location. This could also allow for more efficient use of the cleaning materials and facilities.

If the team finds that CFC-113 and MCF losses are fairly high, they may suggest ways to curb the loss, such as using covers on vapor degreasers and using wipe cloths and storage bags to save spilled CFC-113/MCF. Taking such measures will help the maintenance facility to reduce its use of ozone depleting substances until an alternative, ODS-free method is chosen.

Analyzing Solvent Disposal Procedures

In addition to analyzing the cleaning processes, the team should also analyze the facility's disposal practices. Being familiar with disposal practices will aid the team in further reducing CFC-113 and MCF usage. Questions the team should be able to answer include:

- How is CFC-1.13 . and MCF reclaimed/disposed of after use?
- How often is the CFC-113 and MCF replaced in degreasing processes?

The team should ensure that the used CFC-113 and MCF is being treated and disposed of safely. An evaluation of disposal techniques will allow the team to investigate whether these solvents can be used for longer periods of time prior to disposal, thus further reducing the facility's usage of CFC-113 and MCF. In addition, the team will be able to evaluate the possibility of using spent solvent in subsequent cleaning operations where pure solvent is not needed.

Characterizing the Substrate

When studies are conducted regarding alternative cleaning methods, it is critical that the team is familiar with the substrates being cleaned in each operation. Often, cleaning processes that are effective on one substrate cannot be used on another substrate, even if the soil is identical. Questions that the team should consider include:

- What material/substrate is being cleaned?
- What degree of cleanliness is required?
- What is the surface finish required?
- What coatings are on the surface?
- What is the size and geometric configuration of the part? Is there solvent entrapment potential associated with the part? How rough is the surface of the part?
- To what level of assembly has the part been dismantled?

As the team learns more about the substrates that are being cleaned, they will become aware of the properties that they must look for and the choices that they will be limited to in choosing a new cleaning chemical or process.

For example, one material that requires special attention is titanium (and its alloys). It can be sensitive to attack (e.g., stress corrosion cracking) by residual chlorinated and fluorinated solvents, particularly if subjected to processes at temperatures greater than 662°F (350°C). It can also be vulnerable to a reduction in fatigue strength if subject to dry abrasive blasting. The team should be familiar with the parts of the aircraft that contain this metal. Another material which may warrant special attention is beryllium, a product often used in guidance systems.

Composite materials in aircraft also require special attention. Composite materials are widely used in the construction secondary structure and flight control surfaces, where high strength and stiffness and low density are required. For example, graphite/epoxy is often used to make the rudder, elevators, spoilers, and ailerons. Kevlar is found in cargo linings, outboard stowage bins and center supports, nacelle strut and thrust reverser fairings, and various other components. Kevlar/graphite is used in the construction of cowl components, main landing gear doors, fixed tie panels, tips, wing to body fairings, and other important parts.

Parts with excessive porosity,. parts that have severely rough surfaces, parts that have permanent overlapping joints, parts with blind holes, honeycomb core structures, and tubing can retain cleaning solution, which may cause 'corrosion. Care must be taken to thoroughly dry these parts after cleaning.

Special care is also required during cleaning prior to nondestructive testing procedures such as penetrant inspection. In order to conduct an accurate penetrant inspection test, the product surface must be completely free of residual surface contamination. The presence of cleaner residue or other contaminants may shield flaws in the structure and prevent the inspection fluid from penetrating surface flaws or cracks. 'Therefore, care must be exercised to ensure that the cleaning method employed results in a sufficiently. clean surface prior to inspection.

Honeycomb structures in airplane parts such as the nose radome require even 'greater caution when cleaning. Cleaning occurs prior to bonding to ensure maximum bond strength and integrity. Alkaline and aqueous cleaning methods must be applied with great care because at flight altitudes, any remaining vestiges of moisture in the honeycomb structures may freeze, possibly causing the structure to crack.

During aircraft maintenance, components of the airplane are disassembled into varying levels of disassembly for cleaning, inspection, and repair. Knowledge of the level of disassembly is important because it may help the team in choosing a new cleaning process that does not use CFC-113 or MCF. For example, a structure may be disassembled to subassembly level and cleaned using vapor degreasing. However, if the part were further dismantled to a component level, thus reducing its geometric complexity, the cleaning process may be switched to aqueous or alkaline cleaning without any impact on cleaning effectiveness.

Characterizing the Soils

Another important step in characterizing existing cleaning processes is identifying the soils to be removed. To gain familiarity with the wide variety of soils cleaned in normal aircraft maintenance, the team should evaluate the soils being cleaned in each operation individually. This can be accomplished in part by asking the following questions for every cleaning operation being evaluated:

- What type of soils are being removed?
- Where are the soils coming from?
- What are the performance conditions around the substrate and soil (heat, cold, high stress)?
- Why is the soil being removed (overhaul, inspection, repair)?

The use of CFC-113 or MCF in cleaning is often a precursor to further processing, such as inspection and repair. Typical soils found on aircraft include:

- *Organic Liquids and oils* such as formulated hydraulic fluid, lubricants, oil base rust preventatives, etc.
- *Semi-solid* soils such as viscous oils, greases, heavy rust preventives, etc.
- Solids such as mud, salts, carbonized oils oxides, corrosion products, etc.

Usually, the longer the soil remains on the substrate, and the higher the temperature to which the part has been exposed, the more difficult the soil becomes to remove. The sooner the part is cleaned after contamination, the easier it will be to remove the soil.

Proper and thorough identification of the soils, their sources, and their properties will enable the team to more accurately identify the requirements for the new cleaning process.

INTRODUCTION TO CLEANING IN AIRCRAFT MAINTENANCE PROCEDURES

Chlorofluorocarbon 113 (CFC113) and methyl chloroform (MCF) have been used for many solvent cleaning applications. .These solvents exhibit good solvency for a wide variety of organic contaminants and are noncorrosive to the metals being cleaned. They have low heats of vaporization and high vapor pressures that are beneficial in vapor cleaning processes and allow evaporative drying of cleaned parts. Additionally, these solvents are non-flammable, have low toxicity, and remain chemically stable when properly formulated with adequate stabilizers.

Cleaning is an essential process in the production, maintenance, and repair of commercial and military aircraft. As a surface preparation process, cleaning removes contaminants and prepares parts for subsequent operations such as inspection, repair, bonding, coating, and testing. Cleaning is used in the maintenance of a wide variety of aircraft parts and fixtures. Generally speaking, the cleaning which is performed in maintaining aircraft can be grouped into three categories: metal cleaning, electronics cleaning, and precision cleaning.

Metal cleaning is defined as the removal of oil, grease, and other contaminants from metal parts during manufacture, maintenance, or repair procedures. In maintenance procedures, aircraft assemblies are often inspected, removed, disassembled, cleaned, repaired if necessary, reassembled, and reattached to the aircraft. Examples of aircraft assemblies on which CFC-113 and MCF have been used in metal cleaning operations include landing gear, and control surfaces.

Electronics cleaning usually refers to the removal of flux residues which remain after soldering operations are completed. Large-scale electronics cleaning is often performed in continuous cleaning equipment, while smaller operations are carried out by hand using an aerosol cleaner or solvent on a swab. In aircraft maintenance procedures, the primary example of an area in which electronics cleaning is required is the avionics of an aircraft. These operations usually consist of rework performance by hand and thus require only small-scale cleaning operations.

Precision cleaning is either metal cleaning or electronics cleaning (although it is usually used in reference to metal cleaning operations) which is characterized by the need for an extremely high level of cleanliness. Examples of equipment in aircraft which require precision cleaning include gyroscopes and other components of guidance systems. In systems such as these, contaminant particles one micron or less in size could result in a system failure.

Solvent cleaning may be divided into two types: cold cleaning and vapor degreasing. Cold cleaning is usually accomplished with solvents at, or slightly above, room temperature. In cold cleaning, parts are cleaned by being immersed and soaked, sprayed, or wiped with the solvent.

The majority of solvent cleaning in aircraft maintenance has traditionally been performed by vapor degreasing. In this process, the solvent is heated to its boiling point and the solvent vapor is used to remove contaminants. A basic vapor degreaser consists of a steel tank (with or without a cover) that has a heat source at the bottom to boil the solvent and cooling coils near the upper section to condense the vapors:

Heat, introduced into the reservoir, boils the solvent and generates hot solvent vapor which displaces the lighter air and forms a vapor zone above the boiling solvent up to the cooling zone. The hot vapor is condensed when it reaches the cooling zone by condensing coils or a water jacket, thus maintaining a fixed vapor level and creating a thermal balance. The hot vapor condenses on the. cool part suspended in the vapor zone causing the solvent to dissolve or displace the contaminants or soils.

Vapor degreasing is, in most #applications, more advantageous than cold cleaning. This is due to the fact that the solvent bath in a vapor degreasing process is less contaminated over time than a similar bath in a cold cleaning operation. Although the boiling solvent contains' the contaminants from previously cleaned parts, these usually boil at higher temperatures than the solvent, resulting in the formation of essentially pure solvent vapors. In addition, the high temperature of vapor cleaning aids in wax and heavy grease removal as well as significantly reducing or eliminating drying the for the cleaned parts.

The impending phaseout of ozone-depleting substances has led the aircraft maintenance industry to undertake an extensive search for alternative cleaners and cleaning processes which will replace the use of CFC-113 and MCF. In some cases, these alternatives can make use of existing vapor degreasing equipment, but in the majority of cases, new technologies are being implemented. This manual will describe technologies which are currently being used successfully in aircraft maintenance cleaning operations, and will summarize alternatives which apply to the most frequent maintenance cleaning operations.

Eight general cleaning applications which apply to specific areas of aircraft maintenance are discussed in this manual. Specifically, the areas covered are:

- Aircraft exterior surface cleaning
- Landing gear cleaning
- Cleaning of engines or engine modules
- Cleaning of flight control surfaces
- Electrical equipment cleaning
- Cleaning of hydraulic lines
- Cleaning of aircraft seat covers and draperies
- Cleaning prior to subsequent operations.

The remainder of this section provides a brief description of each of these application areas.

Aircraft Exterior Surface Cleaning

Exterior surface cleaning refers primarily to the cleaning of the aircraft fuselage. Through frequent . cleaning of the aircraft's exterior, a wide variety of everyday soils will be removed. Typical soils include traffic dirt, oxidation deposits, and exhaust deposits. The removal of these contaminants is vital to ensure the prevention of corrosion on uncoated surfaces.

While removal of soils is necessary to ensure safe . aircraft operation, a large portion of the exterior surface cleaning performed is for cosmetic reasons only. Cleaning and subsequent polishing will give the aircraft fuselage a shine which should be aesthetically pleasing to passengers. In addition by maintaining a clean aircraft, the total weight of the aircraft will be reduced and less fuel will be used in normal operations.

Landing Gear Cleaning

The landing gear on a typical commercial aircraft consists of main gear and nose gear. Both the main gear and the nose gear consist of a number of components. These include, but are not limited to: doors, extension and retraction systems, wheels, brakes, steering system, and a position/warning system. Typical landing gear assemblies are shown in Exhibit 4.

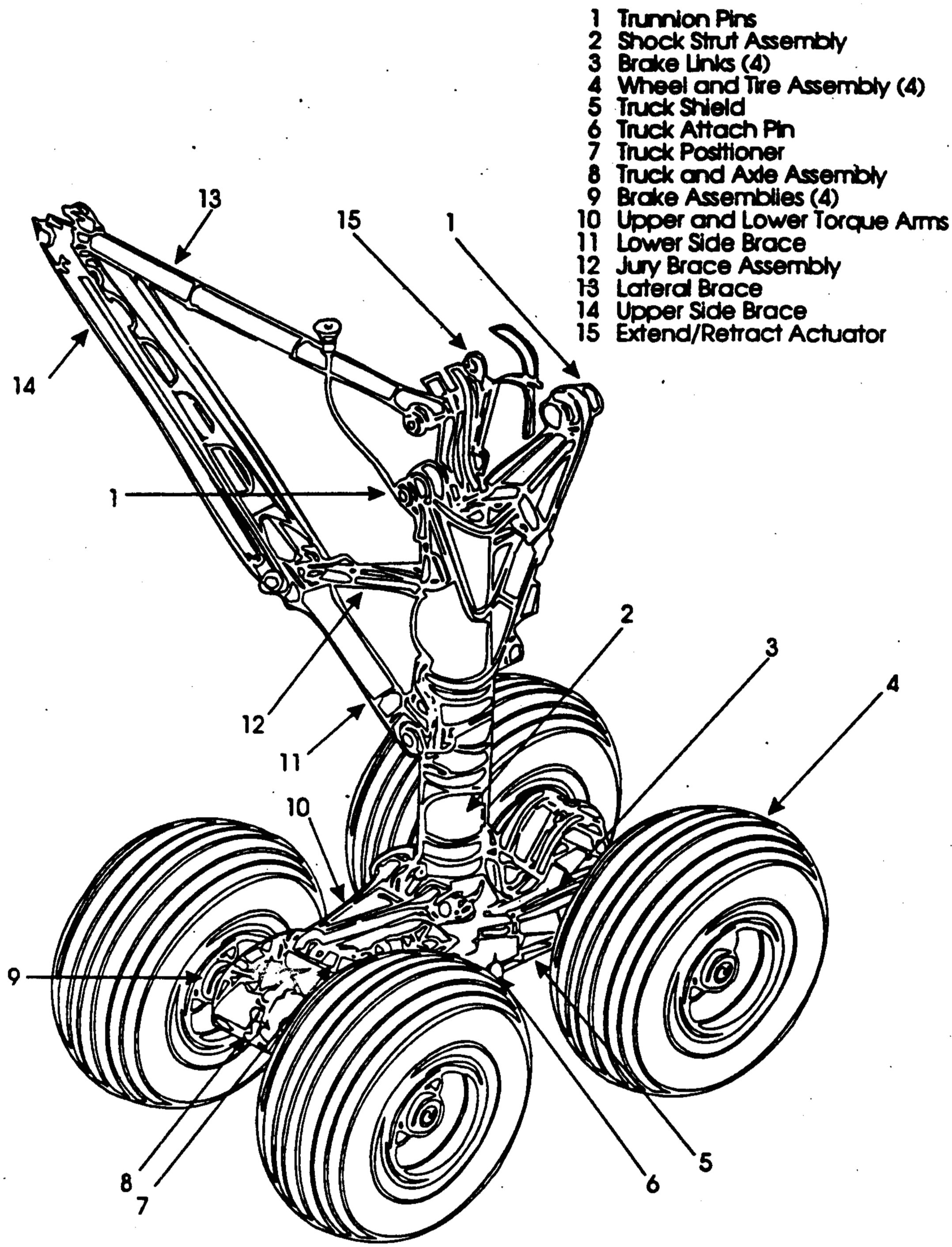
Cleaning of landing gear assemblies can be performed on the aircraft in the case of standard maintenance work, or off the aircraft for complete overhaul procedures.

Cleaning of Engines or Engine Modules

Engine cleaning in aircraft maintenance procedures is complex and often involves breaking down assembled engines into modules for work. An example of a typical jet engine and' its component modules is shown in Exhibit 5. Cleaning of

Exhibit 4

MAIN LANDING GEAR

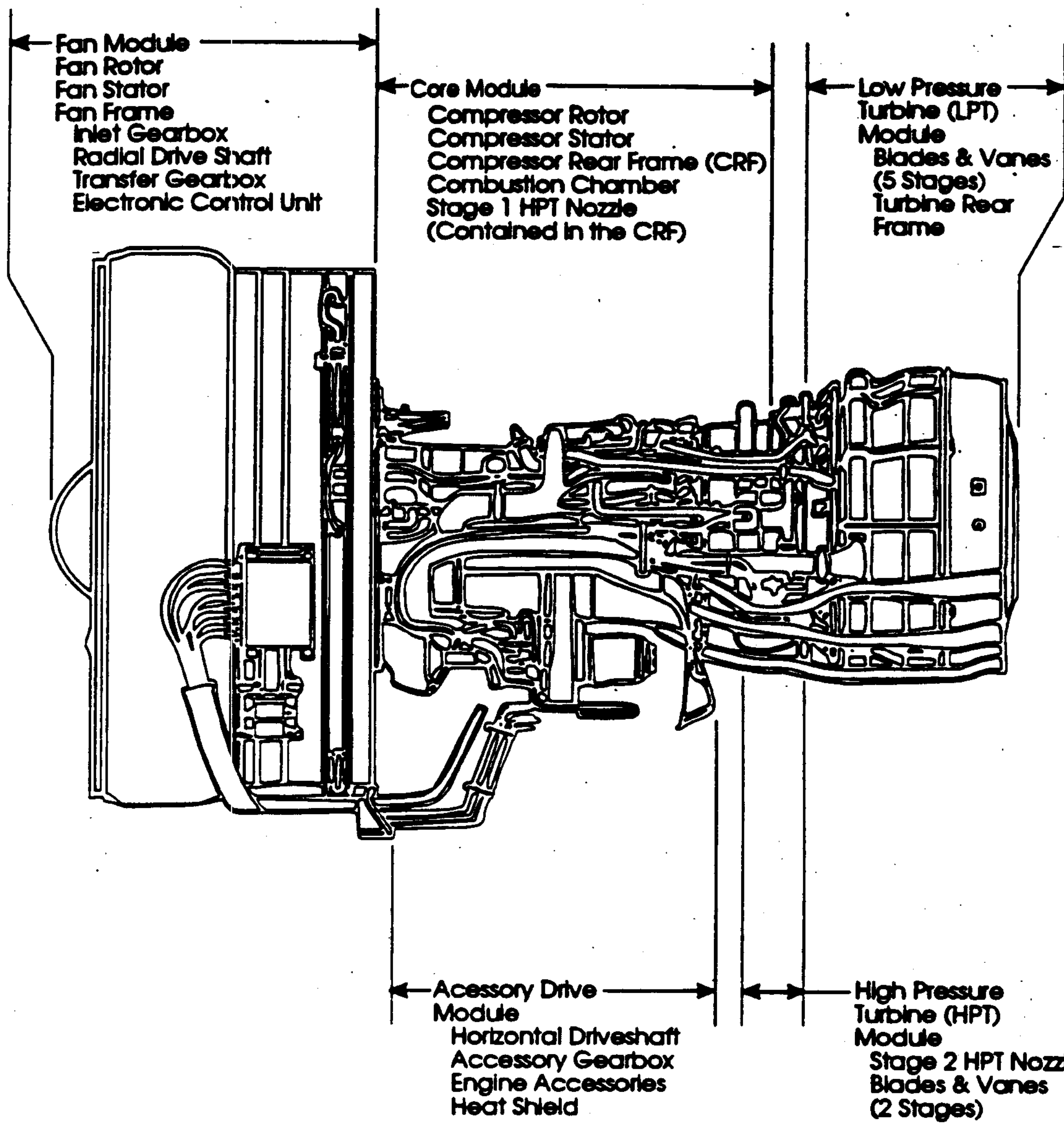


Source: Lockheed L-1011 Tristar Maintenance Manual, 32-11-00 p.3, rev. 5/1/92.

c2n004-2

Exhibit 5

ENGINE MODULE



Source: GE Aircraft Engines CF6-80C2 Engine Manual, 72-00-00 p.3, rev. 12/1/90.

c2r004-3

engines is necessary in order to allow for accurate inspection of individual modules. In engine cleaning Operations, workers must be careful to accurately identify all of the materials being cleaned, since certain metals cannot be cleaned using all methods. These metals include titanium, titanium alloys, and aluminum alloys, all of which are frequently found in aircraft engines.

Cleaning procedures for engines and engine modules can be loosely grouped into three categories -- aqueous alkaline cleaning, solvent cleaning, and media blasting. These techniques will be described in detail in a later section of this manual.

Cleaning of Flight Control Surfaces

Flight control surfaces are those parts of the aircraft structure which influence aerodynamics and which control operational variables such as speed altitude, and direction. Flight controls found on a typical aircraft are shown in Exhibit 6 and include: ailerons, elevators, rudder, speedbrakes, horizontal stabilizer, leading-edge slats, and trailing-edge flaps.

All flight control surfaces are smooth, and can be cleaned either on the aircraft or after being removed. Special consideration must be given to those flight controls which are comprised of composite materials. These controls vary from aircraft to aircraft. .For instance on the Boeing 767 aircraft, the spoilers, ailerons, rudder, and elevators are composed of graphite and epoxy. In addition to the surfaces themselves, the hydraulic lines which are vital to the operation of the various flight controls also require cleaning.

Electrical Equipment Cleaning

Aircraft avionics often require cleaning after maintenance operations before they can be reinstalled in the aircraft. The majority of the maintenance work performed on electrical equipment is manual soldering rework. As in original production, flux residues must be removed from avionics after touch-up soldering work has been completed in order to ensure that residues do not interfere with the proper functioning of the equipment.

Cleaning of Hydraulic Lines

Hydraulic lines in aircraft carry hydraulic fluid to the flight control surfaces. so that free movement of the flight controls is maintained. During scheduled maintenance, hydraulic lines are removed and inner and outer surfaces are cleaned. This has traditionally been accomplished using MCF vapor degreasing and ambient temperature immersion. In addition, during maintenance, a number of activities may occur which would result in the spillage of hydraulic fluid on the outside of the lines. These activities include addition of hydraulic fluid and maintenance on the pumps which move the fluid through the lines. Prior to reassembling the aircraft, any spilled hydraulic fluid must be cleaned off the hydraulic lines. This has traditionally been accomplished using a wipe or spray technique and MCF.

Cleaning of Aircraft Seat Covers and Draperies

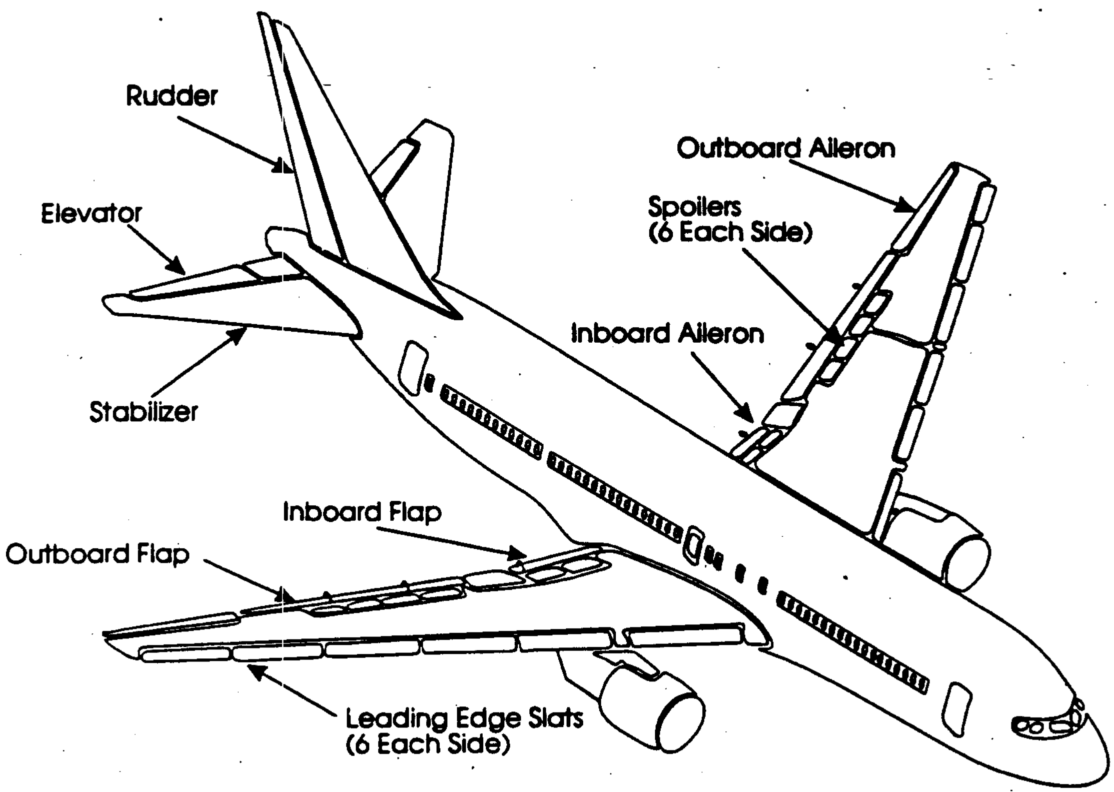
As a part of regular aircraft maintenance, seat covers and draperies are removed from an aircraft and cleaned. A drycleaning process is used to remove dirt and other soils from the fabrics. While many drycleaning operations currently use perchloroethylene, a nonozone-depleting chlorinated solvent, as the cleaning agent, some may use CFC-113. In these processes, it is necessary to eliminate the use of CFC-113.

Cleaning Prior to Subsequent Operations

Cleaning of surfaces on components or assemblies prior to performing a subsequent operation is

Exhibit 6

FLIGHT CONTROLS



Source: Boeing 767 Maintenance Manual, 27-00-00 p.2. rev. 8/1/82.

c2n004-1

often vital to the integrity of that operation. For example, cleanliness prior to fluorescent penetrant inspection (FPI) (to confirm the condition/air-worthiness of the component) will rely on there being no residual contaminants prior to or during the FPI procedures. Similarly, the integrity of repair processes used to re-establish service capability of components will depend on achieving the requisite cleanliness standard for the subsequent process. This manual will provide alternatives to the use of CFC113 and methyl chloroform in five such cleaning applications:

- Cleaning Prior to Coating
- Cleaning Prior to Adhesive Bonding
- Cleaning Prior to Nondestructive Testing
- Cleaning Prior to Reassembly
- Cleaning Prior to Welding

METHODOLOGY FOR SELECTING AN ALTERNATIVE CLEANING PROCESS

In developing and selecting an alternative chemical or process for use in aircraft maintenance cleaning processes, a wide variety of criteria should be considered. These criteria can be broadly grouped into the following categories:

- Organizational
- Policy and Regulatory
- Technical
- Economic
- Environment, Health, and Safety

Organizational

The most important aspect of a corporate phaseout of ozone depleting substances (ODSs) is the commitment of the corporate management to such a program. Without such a commitment, a facility will be hard-pressed to successfully complete its phaseout. Important considerations which pertain to the corporate organization include:

- *Compatibility with other corporate goals.* Corporate policy might disallow the use of particular solvents if the company is sensitive to public opinion. This would result from a corporate policy in which the opinions of the general public are to be considered in all decision-making.

- *Compatibility with corporate environmental policy.* Some alternatives generate other forms of emissions, effluents, or wastes that are also the subject of corporate environmental goals.

- *Feasibility given aiding organizational structure.* Environmental concerns may already be the responsibility of a particular task force within the company. Some companies have made environmental performance a criterion for evaluating managerial performance.

- *Willingness to provide capital.* Corporate management must be willing to make capital investments in new equipment in order to facilitate a phaseout of ODSs. They should understand that a capital outlay at the present time may result in significant cost savings in future years.

Policy and Regulatory

Any potential alternative chemical or process must be evaluated as to its compliance with a variety of government regulations and laws. At the very least, alternatives must comply with the mandates of the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer and its subsequent amendments. In addition, alternatives must meet with federal and local regulations which apply in the country in which the alternative is to be implemented. In the United States for example, alternatives must be evaluated in regards to several sections of the Clean Air Act Amendments of 1990, as well as strict regulations on emissions of volatile organic compounds (VOCs) in .some metropolitan areas.

Technical

The technical feasibility of an alternative process must be evaluated on a case-by-case basis and is dependent on a number of important considerations. While these considerations will vary from facility to facility depending on location and function, a number of these considerations are universal in their applicability. Important criteria to consider when evaluating an alternative cleaning process for its technical adequacy include the following:

- Cleaning ability
- Compliance to specifications
- Material compatibility
- Effect on subsequent processes
- Process control
- Throughput of the cleaning process
- New process installation
- Floor space requirements
- Operating and maintenance requirements.

Cleaning Ability

The degree of cleanliness required when cleaning a part varies from. industry to industry and from process. to process. In some metal cleaning applications, cleanliness requirements are less stringent in terms of measurable residue while in industries where critical components are being cleaned, requirements may be more stringent. Meeting cleanliness standards in the aerospace industry may require the removal of all contaminants. The high performance coatings and adhesives used on jet aircraft require, for example, a high degree of surface cleanliness to insure the integrity of the coatings.

The successful removal of contamination from a surface is not a property of the solvent alone, but a combined relationship of the cleaner, the substrate, the soils, and the cleaning conditions. Characteristics of the cleaner or solvent which greatly affect its cleaning ability include wetting, capillary action, detergency, solubility, and emulsification.

Several standard tests can be used to determine the cleaning ability of an alternative chemical or process. Some of these tests can be run on the shop floor (visuals, tissue paper, water break, and acid copper test), whereas other tests would have to be performed in a laboratory. Realizing that many aircraft maintenance facilities have limited, if any, laboratory facilities, the shop-floor tests become more important. Ultimately, the most important question to ask regarding any cleaning process is, “Will the part pass inspection?”

- *Visual Examination.* This test is useful only for visible contamination, but it can be done in a production/plant environment.
- *Tisssue Paper Test.* The cleaned surface is rubbed with white tissue paper and the tissue is observed for discoloration. This test is simple and can be done in the production/plant environment.
- *Water Break.* If the last clean rinse forms a continuous water film on the part as it is removed, the surface can be considered clean.
- *Acid Copper Test.* A ferrous panel is immersed in a copper sulfate solution. On clean surface areas, copper will be deposited by chemical activity, forming a strong adherent, semi-bright coating that is spot free.
- *Atomizer Test.* Water mist is applied to a clean dry surface with an atomizer. The cleanliness is determined by the value of the advancing contact angle.
- *Contact Angle of Water Drop.* A drop of water is placed on the test surface; the contact angle is then measured either photographically or by a contact angle goniometer. Although this is an accurate method of determining relative surface cleanliness, it can only be used under laboratory conditions. In addition, the presence of a surfactant on the test surface may result in a false reading.

- ***Kerosene Viewing of Water Break.*** The test panel is withdrawn from water and is immediately submerged in a transparent container of kerosene that is lighted from the bottom. Water breaks are displaced by kerosene.

- ***Radioactive Tracer.*** A radioactive soiling compound is applied to the test piece, and the residual radioactivity is measured after cleaning. This is the most sensitive of the quantitative tests now available; Use standard precautions when working with radioactive materials.

- ***Elemental Analysis.*** A surface carbon determination is one of the most accurate methods of identifying small amounts of organic residues such as oils remaining after the cleaning of metal parts. A test part is introduced into an electric resistance furnace and carbon dioxide is introduced at 958°F (500°C). Measurements are taken using a non-dispersive infrared analyzer (wave length = 4240 nm). The sensitivity is 0.01 mg/m^2 and the accuracy is 0.5 percent carbon content.

- ***Fluorescent Dye.*** An oil soluble fluorescent dye is mixed with an oily soiling material and applied to the test panels. After the panels are cleaned, the retained soil is visible under ultraviolet or black light. Note that some cleaners may selectively remove tracer or fluorescent dyes.

- ***Gravimetric.*** The test panels are weighed before and after cleaning. The sensitivity of the method depends upon the sensitivity of the balance and the 'size of the panel.

- ***Oil Spot.*** A drop of solvent is used to degrease an area the size of the drop. The drop is picked up with a pipette and evaporated on ground glass. An evaporation ring indicates contamination.

- ***Particulate Contamination.*** A thin film of polyvinyl chloride is pressed against the test surface, heated to 240°F (115°C), and cooled. It is then carefully stripped from the surface and examined under the microscope. The particulate contaminants will be embedded in the vinyl sheet.

- ***Particle Removal Test.*** Particle removal can be tested by artificially contaminating surfaces with known panicles of various sizes down to and below the size of interest for removal. Precision particles from submicron to tens of microns in size can be obtained. Nephelometric methods and membrane filtration methods, such as ASTM-F24 are useful low-cost techniques for evaluating general cleaning.

- ***Chemical Analysis.*** Surface cleanliness can be evaluated and surface contaminants identified and qualified by using a number of analytical chemical techniques. The techniques most often used are Auger electron spectroscopy (AES), secondary ion mass spectroscopy (SIMS), x-ray photo-electron spectroscopy (XPS), and microscopic Fourier-Transform infrared spectroscopy (micro FT-JR).

- ***Optical Monitoring and Polarized Light Microscopy.*** Visual inspection using microscopy is relatively inexpensive and gives fast results.

- ***End Use Tests.*** These tests can be conducted to examine the effect of cleaning on subsequent process steps such as the application of protective coating (some of these are discussed later in this section).

Compliance to Specifications

Standards and specifications often complicate the search for alternative chemicals or processes by requiring the use of a specific cleaner or solvent for a specific cleaning application. This is a particularly important consideration in the maintenance of military aircraft.

In instances where cleaning requirements are governed by military or other specifications, it is necessary to either verify compliance by using the indicated cleaners or solvents only, or renegotiate existing specifications before switching to alternative technologies. Types of specifications which apply directly to aircraft maintenance procedures include military specifications (milspecs), SAE/AMS (Society of Automotive Engineers/Aircraft Maintenance Standards) specifications, and ASTM (American Society for Testing and Materials) standards.

Material Compatibility

In the selection of an alternative process, material compatibility is as important as the cleaning ability of the cleaner itself. issues to be considered include: the possibility for corrosion or chemical attack of metals, plastics, composites, and other sensitive materials; swelling or deformation of elastomers; and damage to coating or adhesives present on the surface. In the aircraft industry, compatibility of materials is extremely important when dealing with surfaces of titanium alloys, high temperature superalloys, and/or composite materials.

Compatibility can be evaluated by performing a number of tests including:

Stress corrosion (ASTM-G38) cracking (SCC) of parts can occur when susceptible materials (from which the parts are made) are corrosion sensitized during cleaning and are subsequently aged in a tension stress application, possibly with variations in temperature. In general SCC tests are run by subjecting a test specimen of the same composition and beat treatment as the part, to a constant tension stress load after being exposed to the corrosive medium. A number of ASTM test methods specify complete test details for specimen configuration and stress loading. See TM-01-69 MACE standard "Laboratory Corrosion Testing of Metals for the Process Industry."

Total immersion corrosion (ASTM 483) testing evaluates the general corrosive attack of a cleaner which can cause unacceptable dimensional changes in a metal surface. .A number of specifications describe variations on this test (MIL-C-87936, ASTM F483). Metal cleaners for aluminum and aluminum alloys can be evaluated in accordance with ASTM D930. Cleaners for all other metals can be evaluated using ASTM D1280. For example, the test can be conducted by completely immersing a tared specimen into the test solution so that there is no air/solution interface. The specimen is allowed to sit undisturbed for 24 hours after which it is removed, rinsed, dried, and reweighed. Corrosion is measured as weight loss or gain. The amount of allowable loss should be predetermined depending on the kind of material and use, but should' be restricted to a few milligrams.

- Sandwich corrosion (ASTM F1110) testing measures the corrosivity of a cleaner confined between faying surfaces and periodically exposed to specified temperature and humidity conditions.

- Hydrogen embrittlement (ASTM F51P77) testing is conducted to determine if cleaners will adversely affect high strength steel. Testing can be conducted in accordance with. ASTM F519, using both cadmium plated and unplated Type 1A steel specimens. The specimens are subjected to 75 percent of their. ultimate tensile strength while ·immersed in the test solution. The specimens must not break for a minimum of 150 hours.

Effect on Subsequent Processes

since cleaning an integral part of manufacturing processes, it is critical to examine cleaning effectiveness and the effect of cleaners on subsequent manufacturing steps. The manufacturing steps in aircraft maintenance before which cleaning is usually considered necessary include:

- ***Inspection.*** Visual inspections may be numerous, making speed and ease of part handling very important. Parts are cleaned to meet customer requirements and have to be inspected to identify any defects.

- ***Assembly.*** Assembly requires that parts be free from inorganic and organic contaminants. The cleaning process should leave the parts clean and dry, ready for assembly, and/or subsequent finishing.

- ***Further Metal Working or Treatment.*** Inmany instances, parts must be prepared for subsequent operations such as welding, heat treating, or further machining. Cleaning between steps allows the operator to start each new step with clean, dry parts. Before heat treatment, all traces of processing oils should be removed from the surfaces; their presence causes smoking, nonuniform hardening, and heat treatment discoloration on certain metals. Through heat treatment, residual contaminants can cause intergranular attack, and therefore the loss of fatigue strength, or stress corrosion mechanisms.

- ***Machining.*** By starting a machining operation with a clean surface, the chance of carrying imperfect parts through to other operations is minimized. Cutting oils used during machining give best results when applied to clean surfaces.

- ***Application of Protective Coatings.*** Cleaning is used extensively before and after the application of protective and/or decorative finishes. For example, surfaces cleaned before painting, enameling, or lacquering, give better adhesion of finishes. Similarly, cleaning is used to remove large amounts of oil contamination, prior to electroplating and passivation of ferrous metal alloys, and anodizing and chemical conversion coating of aluminum.

Potential residues remaining after cleaning with an alternative product or process must be evaluated for their compatibility with 'subsequent processes. This is especially important in cleaning prior to nondestructive testing (NDT) inspection.

Process Control

Process control is part of a quality assurance program. Being satisfied with a process is vital to a successful program. One example of good process control is checking cleaner solution composition on a routine basis. Maintaining proper solution concentration by making small, frequent additions is much more effective than making a few large additions. The proper automated chemical dispensing equipment, which can he activated by a timer or by conductivity of the solution, is a good method for control.

Throughput of the Cleaning Process

Although most of the cleaning processes associated with aircraft maintenance are not continuous processes, throughput can be an important parameler. For example, adhesion of finishes can be affected by moisture remaining on a surface to be coated. The rapid drying time associated with solvent cleaning provides an advantage in speeding up production processes. For batch cleaning processes, this factor may not be critical. Some alternative processes may require slower throughput for optimized operations along with special drying stages.

New Process Installation

The ease with which a solvent cleaning process using CFC-113 or MCF can be converted to or replaced by an alternative cleaning process will have a direct bearing on the choice of alternative. Issues associated with-the installation of the new process include facility preparation, production/ service downtime, user awareness/education, qualification testing, and transition between the two processes. In some cases, wastewater treatment facilities may be required.

Floor Space Requirements

Equipment must be compatible with the plan and space constraints of the facility's manufacturing floor. A new process might require rearranging subsequent processes to optimize the floor plan. In many cases, alternatives take up more space than solvent cleaning processes. For example, compared to a single vapor degreaser, most aqueous cleaning processes include a minimum of two wash/rinse tanks and a drying device. The result often is an increase in the amount of floor space required. However, some cabinet spray washers are designed to wash, rinse, and dry in the same cabinet, thereby minimizing the need for multiple tanks. Rearranging existing equipment or installing a new process may also affect environmental permitting requirements.

Operating and Maintenance Requirements

Each new process may require a modification or rewriting of standard operating and maintenance procedures. In these cases, not only will there be the need to develop and test the new procedures, but special operator training may be needed to familiarize operators with the proper procedures associated with the new cleaning technologies.

Due to the fact that process parameters are likely to require more close control when substituting an alternative process, maintenance of process equipment on a regular basis is critical.

In some alternative processes, as the concentration of soils in the cleaning solution increases, parts may leave the cleaning solution with unacceptable amounts of residual soil. Regular monitoring, control of solutions, the use of filtration, and adequate post-rinsing/washing procedures must be considered.

Economic

Process economics is a key factor in the selection of alternative processes. Initial costs associated with an alternative process include capital costs of equipment, possible costs associated with waste treatment/handling equipment and costs for permit changes for new construction or new operating procedures. In addition, operating cost equations include material, labor, maintenance, and utility costs. Cost estimates for an alternative process can be developed through preliminary process design.

One simple approach is to calculate net present value (NPV) based on the discount rate and period of investment the company uses. The NPV is calculated as follows, where (n) is the number of years, and (i) is the discount rate.

$$NPV = Cost_{\phi} + Cost_1/(1+i) + Cost_2/(1+i)^2 + \ldots + Cost_n/(1+i)^n$$

While traditional economic considerations such as rate of return and payback period are important, the CFC-113 and MCF reduction program can be justified on a basis of environmental protection and solvent supply reliability. It is important to recognize that the price of CFC-113 and MCF will rise rapidly as the supplies are reduced and taxes are imposed. Bemuse. of the considerable difference in ozone-depleting potential, the price increases of CFC-113 and MCF will vary. Include the cost savings resulting from savings in solvent consumption in all cost calculations. Many of the alternative processes can be much less expensive than the Current CFC and MCF processes being used.

Environment, Health, and Safety

Important environment, health, and safety issues to consider when evaluating an alternative cleaning process include:

- ***Compatibility with appropriate federal and local regulations.*** Local regulations on ozone-depleting chemicals, VOCs, and waste effluent can be more stringent than their federal counterparts. For example, some areas have strict laws regulating the use of VOCs, while others have very few controls. In addition, there are often additional regulatory requirements which accompany the phaseout of ozone-depleting substances. For example, in addition to the phaseout requirements under the 'Clean Air. Act in the United States, there are a number of provisions either in effect or which will go into effect over the next few years that will also 'impact the selection of alternatives. These provisions include Section 610: Nonessential Products Containing Chlorofluorocarbons, Section 611: Labeling, and Section 612 Safe Alternatives Policy. These and other provisions must be considered before selecting alternatives. In Europe, "Best available technology (BAT)" guidelines have been developed in order to control VOC emissions from solvent cleaning processes. These guidelines outline recommended equipment design and operating practices for use in cold cleaning, vapor degreasing, and "in-line" cleaning. The guidelines also address treatment and disposal of waste materials from solvent cleaning operations. This includes not only spent solvent, but contaminants such as. solids and oils as well.

- ***Compatibility with regulatory trends.*** Since new environmental policy is emphasizing pollution prevention and risk reduction, it is prudent to move to cleaner products and processes that are less polluting, less energy-intensive, less toxic, and less dependent on raw-materials.

- ***Public perceptions.*** Legislation such as "right-to-know" laws has provided the public in many countries with more information about the chemicals used by specific plants and their associated risks. Public information has made plants more accountable to the concerns of neighboring communities.

- ***Potential of alternatives for ozne depletion and global warming.*** Each potential alternative must be evaluated for its contribution to ozone depletion as well as global warming. In most cases, it will be considered unacceptable to replace a high ozone depletor with a nonozone-depleting substance that has a high global warming potential. The focus during the phaseout of ozone-depleting substances should be on finding substitutes which do not contribute significantly to other environmental problems.

- ***Energy efficiency.*** The energy efficiency of an alternative cleaning process will have direct impacts on both the cost of maintaining a process as well as on the environment via global warming concerns.

- ***Energy on waste stream.*** Some alternative cleaning processes will result in an increase in the amount of waste generated, while others will either decrease waste or produce a different type of waste. In any case, the phaseout of CFC-113 and MCF in cleaning operations will reduce or eliminate the need to dispose of spent solvent. However, processes such as aqueous cleaning, which are likely to be widely used in aircraft maintenance, will result in large amounts of wastewater which may need to be treated before being discharged to a POW.

- ***Toxicity and Worker Safety.*** Alternatives should minimize occupational exposure to hazardous chemicals where possible. Personal Exposure Limits (PELs) such as those determined by the Occupational Safety and Health Administration (OSHA) in the U.S. should be considered before selecting alternatives. Personal protective equipment, such as gloves, safety glasses, and shop aprons, should be reviewed for compatibility with alternative cleaners. Work procedures and practices should be reviewed and modified to accommodate the properties of the alternative cleaner. A toxicologist should also be consulted if the cleaner or cleaning process is new to the facility.

- ***Flamability.*** Fire and explosion hazards are very important considerations. In some instances, changes in a material or process will require the review of fire protection engineers and insurance carriers. Flammability should be evaluated and adequate fire control measures should be implemented before switching to a cleaning process which involves potentially flammable substances.

* * * * *

In order to speed the process of evaluating potential alternatives, several large airlines in the United States have developed standardized forms to gather information on alternatives. On these forms, vendors of alternatives provide information including the following:

- chemical type
- chemical composition
- physical properties
- usage instructions
- customer approvals
- results of standard industry tests (ASTM, Douglas, Boeing)
- effects on aircraft materials
- 'health impacts
- safety procedures, and
- regulated contents.

For at least one of the airlines, an alternative will not be considered if the chemical data sheet is not completed in its entirety. At Continental Airlines, the completed datasheet is reviewed by representatives from engineering, safety, and environmental programs. If all approve the use of the product, it is then brought in for testing. The full "Chemical Qualification Sheet" used by Continental is presented in Appendix D.

QUALIFICATION TESTING OF ALTERNATIVE CLEANING PROCESSES AND MATERIALS

As mentioned in the previous section, there are a number of important items to consider in evaluating the acceptability of an alternative chemical or process. Perhaps the most important criteria in selecting an alternative is the qualification testing required by the aircraft manufacturers. This testing is vital to insure the safety of the aircraft and to avoid the possibility of future warranty and/or liability problems.

In many cases, the maintenance manuals for an aircraft will specify the exact type of cleaner to be used in a specific process. For instance, the Boeing 747 Maintenance Manual calls for the use of a mild alkaline cleaner in order to clean the exterior surface of the aircraft. While this does indicate that the specified cleaner or cleaning method is approved for use on the aircraft, it does not mean that the specified cleaner is the only acceptable product. Herein lies the opportunity for airlines to begin using alternative materials and processes.

In general, initiating a program to select alternatives, as well as the actual evaluation and selection process, is entirely the responsibility of each individual airline. While the aircraft and engine manufacturers do provide some guidance for performing product evaluations, most do not actively test and approve new cleaning materials and process. Both Douglas Aircraft and the Boeing Corporation have stated this policy clearly in guidance documents distributed to all customers.

The Douglas Aircraft Company's Customer Service Document (CSD) #1 states that "Douglas will not test and approve maintenance chemicals for use on operational jet aircraft, as was done originally. The responsibility for approval of aircraft maintenance chemicals for use on Douglas manufactured aircraft is with the operator." Similarly, the Boeing Company's document D6-17487, which contains testing guideline for alternatives, states that "the Boeing Company will not perform the tests described [in this document] for the airlines nor will the Boeing Company act as an intermediary between vendors and airlines. . . . The final selection of materials rests with the user." The full text of the Douglas and Boeing documents can be found in Appendices E and F, respectively.

In these documents, Boeing and Douglas have specified the testing procedures to be carried out in approving alternative cleaning chemicals and processes. For each manufacturer, a specific set of tests are required for each alternative chemical or process. The tests to be performed are dependent on the type of cleaner being evaluated, as summarized in Exhibits 7a and 7b.

Boeing gives step-by-step instructions for carrying out each of the required tests, while Douglas cites standard test methods approved by the American Society for Testing and Materials (ASTM). Both manufacturers give explicit details identifying materials to be used in the tests.

Both Boeing and Douglas stress that the selection of a substitute is the decision of the individual airline. Test results need not be submitted to the aircraft manufacturer for formal approval.

Exhibit 7a

QUALIFICATION TESTS RECOMMENDED BY BOEING

Certification Tests	Manual, Alkaline and Emulsion Cleaners and Liquid Waxes	Acid Brighteners and Corrosion Removers	Paint Strippers	Carbon Removers	Airplane and Facility Deicers	Toilet Flushing Fluids
Sandwich Corrosion Test	X		X[1]	X	X	X
Immersion Corrosion Test			X[1]	X		
Acrylic Crazing Test	X	X		X	X	
Polycarbonate Crazing Test						X
Elastomer Degradation Tests						X
Tape Adhesion Tests						X
Paint Softening Tests	X	X		X	X	X
Hydrogen Embrittlement Test	X		X	X	X	

[1] Materials meeting MIL-R-25134 need not be tested for corrosion.

Exhibit 7b

QUALIFICATION TESTS RECOMMENDED BY DOUGLAS

Qualification Test	I General Purpose Cleaner	II Carbon Exhaust Remover	III Paint Remover	IV Deoxidizer/ Brightener	V Polishes	VI Deicing Compounds
Effects on Painted Surface	X	X	-	-	-	X
Residue	X	X	-	-	X	X
Sandwich Corrosion	X	X	X	X[1]	X	X
Stress Crazing of Acrylic Plastic	X	-	-	X	X	X
Immersion Corrosion, Aluminum	X	X	X	X	X	X
Hydrogen Embrittlement	X	X	X	-	X	X
Cadmium Removal	X	X	X	-	-	X

[1] Test chemical conversion coated aluminum only (P/W 7452876-7, -11, -15), slight etching of the aluminum surface is acceptable.

REVIEW OF EXISTING PROGRAM

The following sequence of activities should be performed to develop a maintenance cleaning program that eliminates the use of CFC-113 and MCF

- Determine where and why CFC-113 and methyl chloroform are consumed in aircraft maintenance cleaning operations;
- Characterize existing cleaning processes. This activity will help reveal how cleaning integrates with other manufacturing processes and determine whether cleaning is necessary;
- Characterize current solvent material and process control methods, operating procedures and disposal practices and determine the sources of any solvent losses. This step will help identify "housekeeping" measures to reduce solvent consumption at little or no net cost to the facility;
- Characterize the substrate materials being cleaned. This step includes identifying the type and geometry of materials being cleaned;
- Characterize the soils and their sources;
- Establish criteria that must be considered before selecting an alternative cleaning process. These criteria include organizational, policy, technical, economic, environment, health, and safety issues; and
- Evaluate and perform qualification testing of alternative chemicals and processes. These tests will be required to gain aircraft and engine manufacturers' approval of the alternatives.

These steps will, provide a better understanding of cleaning needs, allow for the elimination and/or consolidation of certain cleaning operations, and develop a systematic procedure for selecting an alternative cleaning process. With this understanding, the next section describes some major alternative processes to solvent cleaning using CFC-113 and methyl chloroform.

ALTERNATIVE MATERIALS AND PROCESSES

Alternative cleaning materials and processes and alternative solvents to eliminate CFC-113 and MCF are now available for standard aircraft maintenance practices. The choice of an alternative depends on a variety of factors, including the cleanliness required and economic, technical, health, safety, and environmental issues.

It may also be possible to reduce and/or eliminate deposition of soils which require cleaning, allowing the use of a less aggressive cleaning method. Therefore, the conversion to an alternative cleaning process may be made simpler by evaluating the ability to reduce contamination.

The following sections describe the major advantages, disadvantages, and key process details associated with the most promising alternatives.

These technologies should be evaluated on a case-by-case basis. A list of vendors and references at the end of this manual may be a useful source of additional information. The following alternatives are addressed in this manual:

"Good Housekeeping" Practices

Alternative Cleaning Processes:

- Aqueous
- Semi-Aqueous

Alternative Solvents:

- Aliphatic Hydrocarbons
- Chlorinated Solvents
- Organic Solvents
- Hydrochlorofluorocarbons (for essential applications)

Other Cleaning Techniques:

- Perfluorocarbons
- Supercritical Carbon Dioxide
- Media Blasting

"GOOD HOUSEKEEPING" PRACTICES

As previously mentioned, one of the primary components of a successful phaseout strategy is the identification of uses of the solvent to be eliminated. An accurate picture of solvent usage will allow the phaseout team to focus its efforts on those areas where large quantities of solvent are used and where alternatives are readily available. This solvent use characterization can also be used to decrease consumption immediately through the classification of uses as either legitimate and improper uses.

Many of the aircraft maintenance applications in which CFC-113 and MCF are being used in a facility are neither necessary nor intended uses. When these substances were introduced to the facility years ago, they were intended for specific applications. However, their excellent cleaning ability, coupled with the availability of these solvents, has often resulted in their abuse.

One method of significantly reducing a facility's usage of CFC-113, and especially MCF, is the implementation of "good housekeeping" measures. These measures should be designed to limit use of these substances to applications for which they are intended, and to eliminate their use in other convenience applications. The first step in this "good housekeeping" procedure is the identification of all uses of the solvents.

Use of CFC-113 and MCF should be evaluated using surveys, shop inspections, and whatever additional means are necessary. The resulting data should be cataloged so that it can be compared with future data. Computerizing the cataloging system may make tracking usage patterns easier in the long run.

Once the survey of current uses is completed, the solvent substitution team should evaluate each of the uses to determine whether or not the solvent being used was intended for use in that application. In cases where it is decided that the solvent was not meant to be used in a specific application, this usage should be eliminated immediately and replaced with the originally intended solvent or cleaning process. Investigations should also be conducted to learn how CFC-113 or MCF came to be used for the unintended application. The results of this investigation should help to prevent the same problem from occurring in other applications or with other chemicals.

After the cataloging system is in place, arrangements can be made to monitor and log all future purchases and dispersements of CFC-113, MCF, and all other solvents. Airlines using an approach such as this have had substantial success in controlling their consumption not only. of ozone-depleting solvents, but of other solvents as well, thereby experiencing significant cost savings. One major airline in Europe has reported a reduction in CFC-113 and MCF usage of more than 50 percent .through "good housekeeping" measures alone.

AQUEOUS CLEANING

Aqueous cleaners use water as the primary solvent. They often incorporate surfactants and builders with special additives such as pH buffers, corrosion inhibitors, saponifiers,. emulsifiers, deflocculants, complexing agents, antifoaming agents, and other materials. These ingredients can be formulated, blended, and concentrated in varying degrees to accommodate the user's cleaning needs. Exhibit 8 presents an overview of the advantages and disadvantages of aqueous cleaning.

Since the discovery that CFC-113 and MCF were contributing to depletion of ozone in the stratosphere, many aircraft maintenance facilities have switched to alternative cleaning processes. Many of the cleaning procedures which previously used CFC-113 and methyl chloroform can and have been satisfactorily converted. to aqueous cleaning.

In order to implement an aqueous cleaning process, there are several factors to consider. These include the cleaning ability of the cleaning solution, the compatibility with aircraft materials, the equipment needed to conduct the cleaning operations, and worker safety. The optimum selection of chemistry and equipment will dictate the efficiency of the overall cleaning process.

Process Chemistry

Aqueous cleaners. are made up of three basic components: (1) the builders which make up the largest portion of the cleaner and create stable soil emulsions once soils are removed from a surface, (2) the organic and inorganic additives which promote cleaning and cleaner stability, and (3) the surfactants and wetting agents which are the key constituents and remove or displace soils from surfaces and initiate the emulsification process. As noted earlier, aqueous cleaners can be tailored to meet specialized cleaning needs.

Builders are the alkaline salts in aqueous cleaners. They are usually a blend selected from the following groups: alkali metal orthophosphates and condensed phosphates, alkali metal hydroxides, silicates, carbonates, bicarbonates, and borates. A blend of two or more of these builders is typical in most aqueous cleaners.

Although phosphates are the best overall builders, discharge of cleaning solutions containing phosphates is often subject to environmental regulations, thereby limiting their use. Chelating agents such as the sodium salt of ethylenediamine tetra acetic acid (EDTA) and gluconates can be used instead of phosphates. Silicates are sometimes difficult to rinse and may cause trouble in subsequent plating operations if not completely removed. They may also cause fouling in process equipment such as filters and pumps. Hydroxides are effective on difficult soils. They saponify effectively because of their high pH. Carbonates are an inexpensive alkaline source but are less effective builders than the phosphates.

Additives can be either organic or inorganic compounds and provide additional cleaning or surface modifications. Glycols, glycol ethers, chelating agents, and polyvalent metal salts, are common additives.

Surfactants are organic compounds that provide detergency, emulsification, and wetting in alkaline cleaners. Surfactants are unique because of their characteristic chemical structure. They have two distinct structural components attached together as a single molecule. The hydrophobic half has-little attraction for the solvent (water) and is insoluble. The other half is hydrophilic and is polar, having a strong attraction for the solvent (water) which carries the molecule into solution. Their unique chemical structure provides high affinity for surface adsorption. Surfactants are classified as anionic, cationic, nonionic, and zwitterionic (amphoteric). Their use reduces the surface tension of water,

Exhibit 8

AQUEOUS CLEANING

ADVANTAGES

Aqueous cleaning has several advantages over organic solvent cleaning.

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

DISADVANTAGES

Depending upon the specific cleaning application there are also disadvantages.

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

allowing it to penetrate into tightly spaced areas where water could not otherwise reach.

The use of a nonfoaming cleaner is extremely important in alkaline cleaning applications performed using a spray technique.

Nonionic surfactant is generally the only type of surfactant that results in minimum foaming and provides good detergency. Therefore, it is often used in spray applications. All types of surfactants can be used for immersion cleaning,. although cationic surfactants are rarely used.

Process Equipment

Typical aqueous cleaning equipment can be classified in two general categories: in-line and batch. In-line equipment is generally highly automated and allows for continuous processing of the product being cleaned. Batch cleaning requires that operators load and unload the cleaning equipment after each cycle is completed. Given equal cleaning cycle times, in-line cleaners allow for a significantly higher throughput than batch cleaners.

The in-line and batch equipment can be further classified according to the method by which the cleaner is applied to the part to be cleaned. The three basic methods of aqueous cleaning are immersion, spray, and ultrasonic. Exhibit 9 presents an overview of the advantages and disadvantages of these three types of equipment.

Immersion equipment cleans by immersing parts in an aqueous solution and using agitation or heat to displace and float away contaminants. Agitation can be either mechanical or ultrasonic.

Spray equipment cleans parts with a solution sprayed at medium-to-high pressure. Spray pressure can vary from as low as 2 psi to 400 psi or more. In general, higher spray pressure is more effective in removing soil from metal surfaces. Aqueous cleaners which are specifically designed for spray application are prepared with low foaming detergents.

The spray design should be able to reach all part surfaces by mechanically manipulating the part or the spray nozzles. Although spray cleaning is effective on a wide variety of parts, some part configurations may be difficult to clean using currently available spray technology.

A high pressure spray is an effective final rinse step. Pressures may range from 100 psi in noncritical applications to 500 - 2000 psi in critical applications. Optimization of nozzle design such as spray pattern, drop size and formation, pressure/velocity, and volume have a major impact on effectiveness. A final spray is much cleaner than an immersion rinse, since the water spray contacting the part can be highly pure and filtered.

Ultrasonic cleaning equipment works well with water-based processes. Because the cavitation efficiency is higher for water than for CFC-113 and MCF, the removal of particles from surfaces is usually more effective in aqueous versus organic solvent media. Process design requires caution to insure that cavitation erosion of part surfaces is not a problem. Certain part geometries are also sensitive to ultrasonic agitation.

It is important to optimize system operations when using ultrasonic systems. Since good ultrasonic cleaners have few standing waves, reflection from the surface and the walls is an important consideration. The number of parts and their orientation to walls, fixtures, and other parts will impact cleaning performance. The fixturing should be low mass, low surface energy, and nonabsorbing cavitation resistant material such as a stainless steel wire frame. Avoid using plastics for fixtures because of leaching and absorption of sonic energy.

Both ultrasonic and spray equipment can be used together to great advantage, especially in rinsing. Low pressure (40-80 psi) spray at relatively high volumes is good for initial rinsing. It is critical to keep the part wet at all times prior to final drying. A secondary immersion-ultrasonic rinse is especially useful for parts with complex geometry or blind holes.

In some instances final rinsing with DI water or an alcohol, such as isopropanol, can remove residues and prevent water spots.

Exhibit 9

AQUEOUS CLEANING PROCESS EQUIPMENT

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

Process Details

Aqueous cleaning in aircraft maintenance procedures is currently performed using both large- and small-scale immersion and spray cleaning techniques. Many products are cleaned individually due to their large size, although some batch cleaning does take place. In addition to immersion and spray equipment, aqueous cleaning in aircraft maintenance is performed by manual wiping or scrubbing.

The aqueous cleaning procedure used in aircraft maintenance consists of three general process steps:

- Wash Stage
- Rinse Stage
- Dry Stage

The following is a description of the stages which make up the aqueous cleaning process.

Wash Stage. The wash stage in an aqueous cleaning process refers to the application of a water-based cleaner, often mixed with detergents and surfactants. In aircraft maintenance procedures, the method of cleaner application is primarily dependent on the part or surface being cleaned.

Relatively small assemblies which have been removed from the aircraft can be immersed in a tank which contains the cleaning agent. Often this solution will be heated to improve cleaning. Parts which are too large for immersion tanks may be cleaned using a spray washer. If immersion tanks are used, contamination build-up in the cleaning solution must be monitored. When the level of contarnination becomes too high, the cleaner should be treated and reused or disposed of.

Surfaces which are cleaned without removal from the aircraft include the fuselage and flight control surfaces. These are usually cleaned manually by wiping, brushing, or low-pressure spray.

In the manual wipe process, the cleaner is applied to the surface using a cloth wipe or a small mop which has been soaked in the cleaner. In the low-pressure spray technique, the cleaner is applied with a small, portable spray gun. In most cases, manual wiping is substantially more time consuming than immersion and spray washing techniques.

Rinse Stage The rinse stage of aqueous cleaning removes all of the cleaning solution applied during the wash stage from the part being cleaned. As the cleaner is removed, all of the contaminants which have been displaced and/or solubilized are also removed from the part. The rinse is often performed using water with no additives or, in some cases, deionized water. However, rinse aids are sometimes added to water to cause the water to form a sheet rather than "bead up." This sheeting action reduces water spots and aids in quicker, more uniform drying.

The rinse processes in aircraft maintenance are identical to those employed in the wash stage - immersion, spray, or wipe. In any case, the result should be a clean surface. In some cases, several rinse stages are required.

Dry Stage. The dry stage is a vital part of any aqueous cleaning process. In aircraft maintenance cleaning, special attention must be paid to ensure that all water is removed from parts before reassembly. A failure to remove water can result in the water freezing when the aircraft reaches high altitudes. This freezing can in turn cause excessive stress on the aircraft, possibly resulting in cracking.

There are five drying methods currently employed with aqueous cleaning in the aircraft industry. The first is the use of a drying oven. These units evaporate excess water through the application of heat and can accommodate a wide variety of parts. Ovens can only be used for parts which have been removed from the body of the aircraft. The second drying option is a manual wipe with a dry cloth or mop to absorb the excess water from the 'clean part. This method will not be adequate for parts with small crevices and/or closely spaced components since a cloth or mop may not be able to fit within the small spaces in which water may be trapped. A third method for the removal of excess water is forced air drying. In this method, hot air is blown onto the cleaned part to force water off the part. Applications where the air is blown at an angle of approximately 45° are known as air knives. A fourth method for drying parts after cleaning is the use of dewatering oils. These oils, when placed on a cleaned surface, displace moisture and provide a thin film preservative on the part. As an alternative to these four drying methods, some aircraft maintenance facilities choose to let the cleaned parts dry in air. Given enough drying time, all residual water should evaporate, leaving a clean, dry part. This time, however, can be quite lengthy and may 'slow the repair or overhaul process. In addition, air drying increases the risk of corrosion and may leave residual salts from evaporation on the component.

Other Process Details

There are at least three additional process details which will influence a facility's decision regarding the feasibility of aqueous cleaning.

Removal of Cleaning Fluids. Care should be taken to prevent cleaning fluids from becoming trapped in holes and capillary spaces. Low surface tension cleaners sometimes penetrate spaces and are not easily displaced by a higher surface tension, pure water rinse. Penetration into small spaces is a function of both surface tension and capillary forces.

Wastewater Issues. One of the major drawbacks associated with the use of aqueous cleaning is the fact that wastewater treatment may be required prior to discharging spent cleaner and rinse water. In some applications the cleaning bath is changed infrequently and a relatively low volume. of wastewater is discharged. In others, the water can be evaporated to leave only a small volume of concentrated waste for recycling. Due to the size of most maintenance facilities, and the large number of parts to be cleaned, extensive use of aqueous cleaning could result in substantial wastewater treatment needs. The wastewater treatment process must also account for the wide variety of soils cleaned from aircraft surfaces and assemblies. Facilities considering a switch to aqueous cleaning should consult with their local water authorities to determine the need for pre-treatment of wastewater prior to discharge.

Water Recycling. Recycling or regeneration of the cleaner/detergent solution is feasible and should be considered. This can be accomplished using a combination of oil skimming techniques, coalescing separators, and ultrafiltration (e.g., ceramic membranes). Vendors of aqueous cleaners sometimes pick-up spent cleaner from customers, recycle it, and re-sell it.

SEMI-AQUEOUS CLEANING

Semi-aqueous cleaning involves the use of a nonwater-based cleaner with a water rinse. It is applicable to electronics, metal, and precision cleaning processes, although it is most frequently used in metal cleaning, Semi-aqueous cleaners can consist of a wide variety of chemical constituents. Examples of semi-aqueous cleaning formulations are hydrocarbon/surfactant mixtures, alcohol blends, terpenes, and petroleum distillates. Semi-aqueous cleaning is used in many aircraft maintenance facilities, though not to the extent of aqueous cleaning.

The advantages of semi-aqueous cleaning solutions include the following:

- Good cleaning ability; typically superior to aqueous cleaning for heavy grease, tar, waxes, and hard-to-remove soils;
- Compatible with most metals and plastics;
- Suppressed vapor pressure (especially if used in emulsified form);
- Non-alkalinity of process prevents etching of metals, thus helping to keep metals out of the waste stream and minimizing potential adverse impact to the substrate;
- Reduced evaporative loss;
- Potential decrease in solvent purchase cost;
- A rust inhibitor can be included in the formulation to protect parts from rusting.

Drawbacks associated with the use of semi-aqueous cleaning processes include:

- Rinsability problems; thus residues may remain on the part;
- Disposal of spent solvent after water recycling may increase costs;
- Flammability concerns, particularly if a concentrated cleaner is used in a spray application. However, the flammability issue can be solved with proper equipment design;
- Some cleaners' have objectionable odors;
- Some of the cleaners are VOCs;
- Drying equipment may be required in some applications;
- Some cleaners can auto-oxidize in the presence of air. One example of such a cleaner is d-limonene (a terpene hydrocarbon isomer). This can be reduced using an antioxidant additive;
- Some constituents pose potential exposure risks to workers. For example, ethylene glycol methyl ether has displayed evidence of potential risk in laboratory animals.

Process Equipment

The equipment normally used in a typical semi-aqueous cleaning process is similar to that used in aqueous applications: immersion equipment, spray equipment, and cloths/mops for manual cleaning. Manual cleaning, however, is not extensively practiced in the aircraft maintenance industry using semi-aqueous cleaners.

While equipment which has been designed specifically for use with concentrated semi-aqueous cleaners is available, some vapor degreasing units can be modified to become an immersion wash tank. However, a rinse tank will also usually be required.

Immersion equipment is still the simplest method of cleaning parts and/or assemblies which can be removed from the aircraft. The primary distinction from aqueous immersion cleaning is that, due to the high solvency of hydrocarbon/surfactant blends, less mechanical energy may be required to achieve a satisfactory level of cleanliness. However, to achieve a higher level of cleanliness, agitation must be added to the process, either mechanically or with ultrasonics, or the cleaning solution must be heated.

As with aqueous cleaning, a mechanical spray can improve the cleaning performance of the semi-aqueous cleaning solution. It is important to note that,, if a spray is used with a concentrated hydrocarbon/surfactant blend, the atomized solution is prone to combustion and special care must be taken to prevent fire risks. One such prevention measure is the use of a nitrogen blanket which displaces oxygen from the spray chamber, thereby reducing fire risk.

One semi-aqueous cleaning option, called "spray-under immersion," combines both immersion and spray cleaning techniques. In this equipment, high pressure spray nozzles are placed below the surface of the liquid. This prevents the formation of atomized solution and decreases flammability. Mechanical agitation, workpiece movement, and at properly designed ultrasonic agitation may also be used.

Process Details

Just as the equipment used in semi-aqueous cleaning processes is similar to that used in aqueous cleaning, so too are the cleaning stages. The semi-aqueous cleaning process consists of a, wash stage, a rinse stage, and a dry stage.

There are two primary differences between the aqueous and semi-aqueous cleaning processes. The first is the cleaner which is used in the wash stage. As mentioned, rather than the simple detergent and water mixture used in aqueous cleaning, semi-aqueous processes make use of any one of a number of cleaning agents, including hydrocarbons, alcohols, and terpenes.

The second difference lies in the addition of a second wash stage after the initial wash in the cleaner. In many cases, the initial cleaning stage may be followed by an emulsion wash stage.

In the wash step, the cleaner is applied to the part being cleaned with some form of mechanical energy. However, due to the fact that semi-aqueous cleaners generally have higher solvency power than aqueous cleaners, less mechanical energy is usually needed to achieve an acceptable level of cleanliness.

Low flash point hydrocarbon/surfactant cleaners are generally not heated; however, some are slightly warmed when the cleaner is used in a diluted form. High flash point hydrocarbon surfactant cleaners may be heated to within 20-30°F (-7 - -l°C) of their flash point to remove. difficult soils. Cleaners that are ignitable should not be used in vapor or spray cleaning without an inert atmosphere or other protective equipment. In addition, application methods that avoid misting, such as spray-under immersion or ultrasonics, should be used.

Many semi-aqueous processes include an emulsion stage after the initial wash and before the rinse stage. In this stage, the part is immersed in an emulsion which further cleans the part and helps to remove soils from the part's surface. This step results in less contamination of the rinsewater, making recycling of the rinsewater easier than it would be otherwise. The emulsion cleaner is sent to a decanter where the soils are removed from the cleaner. The cleaner can then be reused in the emulsion wash.

A rinse with clean water removes the residues left by the wash step(s). The rinse step is necessary when concentrated cleaners are used because of their low volatility (which prevent them from evaporating from the parts cleaned in the wash stage). However, the rinse step may not be necessary when a dilute hydrocarbon emulsion is used, provided the level of cleanliness needed does not require removal of the residue from the wash stage. In some instances, a fast evaporating alcohol is used as a final rinse step. The rinse step may also serve as a finishing process and, in some instances, is used to apply rust inhibitors to the parts.

The drying step serves the same function as in aqueous cleaning. The removal of excess water from the part prepares it for further processing,. prevents it from rusting, and reduces the possibility of cracks forming in the aircraft due to frozen water. The same types of drying methods used in aqueous cleaning -- heat, forced air, manual wipe, dewatering oils, ambient air drying - are also used in semi-aqueous processes.

Another similarity between aqueous and semi-aqueous processes is the possible . need for wastewater treatment. In order to avoid processing excessive quantities of wastewater, .some maintenance facilities may choose to recycle their spent cleaners. Some currently available semi-aqueous cleaners can be easily separated from the rinse water. This allows the rinse water to be recycled or reused. The waste cleaner can then be burned as fuel.

ALIPHATIC HYDROCARBONS

There is a wide range of aliphatic hydrocarbon solvents that can be used in aircraft maintenance cleaning (see Exhibit 10). At the present time, many aircraft manufacturers recomnmend the use of several of these solvents in cleaning applications detailed in maintenance manuals. The current use of these solvents in routine aircraft maintenance is widespread.

Petroleum fractions, commonly known as mineral spirits or kerosene, are used extensively in maintenance cleaning (e.g., auto repair). These substances are derived from the distillation of petroleum. They are used in single-stage cleaning operations in open-top equipment using ambient air drying. Synthetic aliphatic hydrocarbons, which offer closer control of composition, odor, boiling range, evaporation rate, etc, are employed in OEM cleaning processes as well as in maintenance operations.

The advantages of aliphatic hydrocarbon cleaners include:

- Superior cleaning ability for a wide variety of soils, especially heavy grease, tar, waxes and hard to remove soils. This makes them especially useful in aircraft cleaning where a variety of lubricants and grime are removed from surfaces. Low surface tension allows good penetration into areas with closely spaced parts or components.
- Compatible (non-corrosive) with most rubbers, plastics and metals.
- They employ no water and can therefore clean water-sensitive parts.
- Low odor and low toxicity grades are available.

Exhibit 70

PROPERTIES OF ALIPHATIC SOLVENTS

PRODUCT	Lb./Gal. 60°F	Sp. Gr. 60°/60°F	Boiling Range °F	Fl. Pt. °F TCC	Evap. Rate[1]
Mineral Spirits	6.37	0.764	305-395	105	0.1
Odorless Mineral Spirits	6.33	0.760	350-395	128	0.1
Stoddard Solvent	6.47	0.796	320-369	107	0.2
140 Solvent	6.54	0.786	360-410	140	0.1
C10/C11 Isoparaffin	6.25	0.750	320-340	107	0.3
C13 N-Paraffin	6.35	0.760	320-340	200	0.1
C10 Cycloparaffin	6.75	0.810	330-360	105	0.2
Kerosene	6.60	0.790	330-495	130	-

[1] **n-Butyl Acetate=1**

Note: Fl. Pt. = Flash Point; Sp. Gr. = Specific Gravity

- Some products are available with flash points greater than 200°F.
- Reduced evaporative loss.
- No wastewater is produced.
- Waste streams from those products with flash points greater than 140°F may be classified as nonhazardous.
- Synthetic aliphatic hydrocarbons . are not regulated as hazardous air pollutants under the Clean Air Act.
- Recyclable by distillation. High stability and recovery.

The disadvantages include:

- Flammability concerns. However, these concerns can be mitigated with proper equipment design.
- Slower drying times than CFC-113 and MCF.
- VOC control may be required.
- Some grades have low Occupational Exposure Limits.
- Odors may cause some worker discomfort.

The steps in a typical aliphatic hydrocarbon cleaning process are analogous to those for aqueous or semi-aqueous processes. Equipment designs for use with aliphatic hydrocarbons are modified aqueous equipment designs, primarily to account for flammability and VOC concerns.

The major steps in the cleaning process are typically:

- Wash steps (1 to 3 stages depending on degree of cleaning needed) with an aliphatic hydrocarbon cleaner;
- Drying step, often using forced air;
- VOC emission control by destruction or recovery from solvent laden air, if required; and
- Waste solvent recovery and/or disposal.

The wash steps involve liquid-phase cleaning at temperatures sufficiently below the flash point of the fluid. Ultrasonics or other agitation processes such as immersion spraying can be used to augment cleaning action. Spraying or misting processes, where fine droplets are formed, should be employed only in an inert environment or with equipment with other protection against ignition conditions. This protection is required because line droplets can ignite at temperatures below bulk fluid flash point.

Fluids with flash points near 104°F (40°C) should be operated in unheated equipment, at ambient temperatures. For higher flash points, hot cleaning can be employed to boost cleaning action. For systems with good temperature control (independent temperature sensors, cutouts, level indicators, etc), a safety margin of 59°F (15°C) between the fluid flash point and the cleaning temperature is recommended. Obviously, use of a high flash point solvent will greatly reduce the risk of fire. For systems with poor temperature control, a larger margin should be employed.

Each wash step should be followed by a drain period, preferably with parts rotation, to minimize solvent dragout from stage to stage.

In multistage processes, fluid from one bath is periodically transferred to the preceding bath as its soil level builds up. Fresh solvent is added only to the final bath to ensure the highest cleanliness of parts, and spent solvent is removed only from the first stage.

The drying step normally uses forced air, which may be heated. If the dryer is not operating. at 59°F (15°C) below the flash point of the fluid, sufficient air flow should be provided so that the effluent air composition is well below the Lower Explosive Limit of the system.

Where required, the VOC recovery step is an important part of the cleaning process. Depending on the solvent chosen, either carbon adsorption or condensation are the best technologies for capturing solvent vapors from spent drying air. Numerous vendors market this type of recovery equipment. In some cases, however, the VOC concentration in the air may be too low to facilitate recovery and catalytic incineration may be required to destroy the VOCs.

In the waste recovery area, the best reclamation technology for these products is usually filtration and distillation. One of the advantages of some of the aliphatic hydrocarbon solvents with few impurities and narrow distillation range is that the recovery in distillation is high. Should some disposal of residual solvent be necessary, fuel substitution or incineration are good routes.

OTHER CHLORINATED SOLVENTS

One of the most appealing substitutes for CFC-113 and MCF in terms of process details is the use of another chlorinated solvent which does not contribute to ozone-depletion. The solvents normally used in cleaning applications are trichloroethylene, perchloroethylene, and methylene chloride. While these substances are ideal due to the fact that they are used in vapor degreasing applications, as are CFC-113 and MCF, they may have significant health and environmental impacts which, if not properly addressed, make their use less attractive.

These three cleaning solvents have undergone extensive testing in recent years for safety, health, and environmental impacts. As a result of this testing, two of the solvents -- trichloroethylene and perchloroethylene -- have been classified as VOCs and hazardous air pollutants in the U.S. (although the U.S. EPA has recently proposed that perchloroethylene be exempted from regulation as a VOC). This classification has significant implications for their use in the U.S. since it requires that emissions control measures be employed. and extensive records be kept when using these solvents.

In addition to these environmental impacts, two of the nonozone-depleting chlorinated solvents have been shown to be carcinogenic to animals in extensive toxicity testing. This discovery has prompted the International Agency for Research on Cancer to classify both perchloroethylene and methylene chloride as "possibly carcinogenic to humans." In addition, many governments have set very low permissible worker exposure limits for all three chlorinated solvents. The U.S. Occupational Safety and Health Administration (OSHA) has set worker exposure limits at 100 parts per million (ppm) for perchloroethylene and trichloroethylene, and 500 ppm for methylene chloride. A proposal has been submitted to lower the permissible exposure limit (PEL) for methylene chloride to 25 ppm.

Chlorinated solvents are subject to hazardous waste regulations in some areas, including the U.S. where they are covered under the Resource Conservation and Recovery Act (RCRA). Users of these solvents must be aware of and comply with all regulations governing use, storage, and disposal of these materials.

Despite the many possible environmental and safety effects associated with the use of chlorinated solvents, they are feasible substitutes for CFC-113 and methyl chloroform in aircraft maintenance cleaning provided adequate control measures are used. These controls must include use in a tight vapor degreaser which is equipped with a cover, increased freeboard, and freeboard chillers. The controls will help to limit emissions of the solvent vapor. These controls are similar to those described and diagramed in the discussion of HCFCs. Exhibit 11 summarizes the solvent properties of these other chlorinated solvents.

Dry cleaning operations are one application in which chlorinated solvents are being widely substituted for CFC-113. Perchloroethylene has been used for years in commercial dry cleaning operations and is now being adopted by airlines for use on seat covers and draperies. New state-of-the-art cleaning equipment has been developed which limits emissions while recovering and reusing the perchloroethylene cleaner. One major airline in the United States has moved away from synthetic materials to more wool and leather in order to be able to use perchloroethylene for dry cleaning. However, perchloroethylene does not clean leather very well and CFC-113 is still needed in some cases. Due to the significant difference between the cost of perchloroethylene and CFC-113, this airline has experienced a large savings by switching to perchloroethylene. After an initial capital investment of $860,000 for new equipment and facilities work, the airline's average monthly solvent cost dropped from $90,000 to $9,000. Thus, the equipment paid for itself in just under 11 months. This savings was realized while processing over 160,000 lbs. of dry cleaning per month.

Exhibit 11

PROPERTIES OF CHLORINATED SOLVENTS

Physical Properties	CFC-113	MCF	Trichloro-ethylene	Perchloro-ethylene	Methylene Chloride
Ozone Depleting Potential	0.8	0.12	0	0	0
Chemical Formula	CCl_2FCClF_2	CH_3CCl_3	$CHClCCl_2$	CCl_2CCl_2	CH_2Cl_2
Molecular Weight	187.38	133.5	131.4	165.9	84.9
Boiling Point (°C)	47.6	73.8	87	121	4.0
Density (g/cm^3)	1.56	1.34	1.46	1.62	1.33
Surface Tension (dyne/cm)	17.3	25.4	29.3	31.3	N/A
Kauri Butanol Value	31	124	130	91	132
U.S. OSHA PEL 8 hr. TWA (ppm)	1000	350[a]	100	100	500
Flash Point (°C)	None	None	None	None	None

[a] Obtained from HSIA White Paper 1989.

Source: UNEP 1991.

OTHER ORGANIC SOLVENTS

The solvent cleaning industry has used a wide range of other organic solvents for electronics, metal, and precision cleaning. Some of the solvents commonly used, include ketones, alcohols, ethers, and esters. These solvents can be used in either a heated state or at room temperature in a dip tank, or in hand-wipe operations. Due to the fact that most are flammable, these types of organic solvents are most often used at room temperature in a process commonly known as cold cleaning. In aircraft maintenance procedures, organic solvents are often excellent candidates for use as a wipe solvent in manual cleaning.

The ketones form a group of very powerful solvents (see Exhibit 12). In particular, acetone (dimethyl ketone) and methyl ethyl ketone (MEK) are good solvents for polymers and adhesives. Both are recommended extensively in aircraft manufacturer maintenance manuals. In addition, acetone is an efficient dewatering agent. However, their flammability (note that acetone has a flash point of 0°F) and incompatibility with many structural polymers (e.g., stress cracking of polyether sulphone, polyether ketone, and polycarbonate) means that they should only be used with care and in small quantities. It is important to note that MEK is often classified as a hazardous air pollutant, as it is in the U.S. Even so, it is the single most widely used hazardous air pollutant in aerospace applications, with a consumption in the U.S. of approximately 3,965,000 pounds per year.

Alcohols such as ethanol and isopropanol, and several glycol ethers are used alone and in blends in a number of applications. These solvents are chosen for their high polarity and for their effective solvent power. The alcohols have a range of flash points and extreme care must be exercised while using the lower flash point alcohols (see Exhibit 13).

A relatively new type of organic solvent cleaning used in the aircraft maintenance industry employs a special vapor degreaser designed for use with alcohols. . One class of such equipment uses an alcohol vapor zone to clean the parts, and has a perfluorocarbon vapor blanket above the alcohol. This blanket effectively reduces the flammability risk associated with the heated alcohol. Perfluorocarbons are discussed later in this section. The second class of alcohol vapor degreasing equipment does not make use of an inerting agent such as perfluorocarbons. In these systems, there are numerous safety devices built into the equipment, including air monitors, automatic sprinkler systems, and automatic shutoff capabilities. Nevertheless, when using this equipment, workers must exercise extreme caution to reduce the risk of explosion.

Esters, such as dibasic esters and aliphatic mono esters, have good solvent properties. They offer good cleaning for a variety of grimes and soils. Most of these materials are readily soluble in alcohols, ketones, ethers, and hydrocarbons, but are only slightly soluble in water. Dibasic esters generally have a high flash point and low vapor pressure. They are only slightly soluble 'in high paraffinic hydrocarbons. Dibasic esters are so low in vapor pressure that a residual film may remain on a surface after application, thereby necessitating a water rinse stage. Aliphatic esters, generally acetates, range in formula from ethyl acetate to tridecyl acetate. The higher grades (hexyl acetate and heavier) are commonly used in degreasing. They fall into the combustible or non-combustible flash point range. They have acceptable compatibility with most polymers. These esters can be dried from a surface by forced air drying with no residual film.

As with chlorinated solvents, many of the organic solvents are toxic and have low worker exposure

Exhibit 12

PROPERTIES OF KETONES

KETONES	Formula	Mol. Wt.	lbs per gal	B.P. °F	F.P. °F	Evap Rate CCl_4 =100	Coefficient of Expansion Per °F	Surface Tension @ 68°F Dynes/cm
ACETONE	CH_3COCH_3	58.08	6.58	132-134	-138.6	139	0.00080	23.7
METHYL ETHYL KETONE	$CH_3COC_2H_5$	72.10	6.71	174-177	-123.5	97	0.00076	24.6
DIETHYL KETONE	$C_2H_5COC_2H_5$	86.13	6.80	212-219	-43.5	-	0.00069	24.8
METHYL n-PROPYL KETONE	$CH_3COC_3H_7$	86.13	6.72	214-225	-108.0	66	0.00062	25.2
CYCLOHEXANONE	$(CH_2)_5CO$	98.14	7.88	266-343	-49.0	12	0.00051	-
METHYL ISOBUTYL KETONE	$(CH_3)_2CHCH_2COCH_3$	100.16	6.68	234-244	-120.5	47	0.00063	22.7
METHYL n-BUTYL KETONE	$CH_3COC_4H_9$	100.16	6.83	237-279	-70.4	32	0.00055	25.5
METHYL CYCLOHEXANONE (Mixed Isomers)	$(CH_3)C_5H_9CO$	112.17	7.67	237-343	-	7	0.00042	-
ACETONYL ACETONE	$CH_3COC_2H_4COCH_3$	114.14	8.10	365-383	15.8	-	0.00052	39.6
DIISOPROPYL KETONE	$(CH_3)_2CHCOCH(CH_3)_2$	114.18	6.73	237-261	-	-	-	-
METHYL n-AMYL KETONE	$CH_3(CH_2)_4COCH_3$	114.18	6.81	297-309	-31.9	15	0.00057	-
DIACETONE	$(CH_3)_2C(OH)CH_2COCH_3$	116.16	7.82	266-356	-65.2	4	0.00055	29.8

KETONES	Formula	Sol % by Wt. @ 68°F		Flash Pt (TCC) °F	Flammable Limits % by Volume in Air		Toxicity MAC in ppm	Spec. Heat Liq. @ 68°F Btu/(lb)(°F)	Latent Heat @ B.P. Btu/lb
		In Water	O' Water		Lower	Upper			
ACETONE	CH_3COCH_3	∞	∞	0	2.6	12.8	1000	0.51	224
METHYL ETHYL KETONE	$CH_3COC_2H_5$	26.8	11.8	28	1.8	11.5	250	0.53	191
DIETHYL KETONE	$C_2H_5COC_2H_5$	$3.4^{104°F}$	4.6	55	-	-	250	0.56	163
METHYL n-PROPYL KETONE	$CH_3COC_3H_7$	4.3	3.3	45	1.6	8.2	200	-	180
CYCLOHEXANONE	$(CH_2)_5CO$	2.3	8.0	145	1.1	-	100	0.49	-
METHYL ISOBUTYL KETONE	$(CH_3)_2CHCH_2COCH_3$	2.0	1.8	64	1.4	7.5	100	0.55	148
METHYL n-BUTYL KETONE	$CH_3COC_4H_9$	$3.4^{77°F}$	$3.7^{77°F}$	73	1.2	8.0	100	0.55	148
METHYL CYCLOHEXANONE (Mixed Isomers)	$(CH_3)C_5H_9CO$	0.2	3.0	118	-	-	100	$0.44^{58°F}$	-
ACETONYL ACETONE	$CH_3COC_2H_4COCH_3$	∞	∞	174	-	-	-	-	-
DIISOPROPYL KETONE	$(CH_3)_2CHCOCH(CH_3)_2$	0.6	-	75	-	-	-	-	-
METHYL n-AMYL KETONE	$CH_3(CH_2)_4COCH_3$	0.4	1.5	120	-	-	100	-	149
DIACETONE	$(CH_3)_2C(OH)CH_2COCH_3$	∞	∞	48	-	-	50	$0.50^{58°F}$	200

Source: DuPont Company, Handbook of Standards for Solvents

Exhibit 13

PROPERTIES OF ALCOHOLS

CHEMICAL	Lb./Gal. 60°F	Sp. Gr. 20°/20°C	Boiling Range °F	Fl. Pt. °F TCC	Evap. Rate[1]
Methanol	6.60	0.792	147-149	54	3.5
Ethanol, Prop. Anhydrous	6.65	0.799	165-176	49	1.8
Ethanol, Spec. Industrial Anhydrous	6.65	0.795	167-178	50	1.8
Isopropanol, Anhydrous	6.55	0.786	179-182	53	1.7
n-Propanol	6.71	0.806	205-208	74	1.0
2-Butanol	6.73	0.809	207-215	72	0.9
Isobutanol	6.68	0.803	225-228	85	0.6
n-Butanol	6.75	0.811	241-245	97	0.5
Amyl Alcohol (primary)	6.79	0.815	261-282	120	0.3
Methyl Amyl Alcohol	6.72	0.808	266-271	103	0.3
Cyclohexanol	7.89	0.949	320-325	142	0.05
2-Ethylhexanol	6.94	0.834	360-367	164	0.01
Texanol	7.90	0.950	471-477	248[2]	0.002

1 n-Butyl Acetate = l
2 C.O.C.

Source: Southwest Chemical Company, Solvent Properties Reference Manual limits. Prior to implementing such products, the review of an occupational health professional may be necessary to ensure that the products are being used in a safe manner. All possible efforts should be made to protect workers from prolonged exposure to toxic chemicals.

With many of the organic solvent alternatives to CFC-113 and MCF, there may be problems with odor. Even though volatility and airborne concentrations may be reduced, the relatively 'strong odors of some of these solvents may build. Without adequate ventilation and possibly masks for workers, these odors may reach a level which would cause discomfort for workers. Therefore, care should be taken to reduce the odor build-up in any location.

Other issues to consider in evaluating organic solvents as CFC-113 and MCF substitutes include VOC emissions and waste disposal. In many locations, most of the organic solvents will be considered VOCs and emissions control is likely to be required. In addition, in many cases, the spent solvent will be considered hazardous waste. It may, therefore, require special handling and disposal practices.

HYDROCHLOROFLUOROCARBONS FOR ESSENTIAL APPLICATIONS

Faced with the phaseout of CFC-113 and MCF, some users of these solvents looked toward severa1 HCFCs (e.g., HCFC-225ca, HCFC-225cb, HCFC-141b, and HCFC-123) as possible substitutes. Exhibit 14 presents physical properties of these chemicals. They are highly desirable due to their good cleaning performance, and their similarity in application method to CFC-113 and MCF.

However, due to their environmental and health impacts, the use of these substances in solvent cleaning applications will be severely limited. At the present time, the only HCFCs which could be used in aircraft maintenance procedures are HCFC-141b and HCFC-225cb. This is due to the toxicity concerns associated with HCFC-123 and HCFC-225ca based on testing performed by the Program for Alternative Fluorocarbon Toxicity Testing (PAFT).

Exhibit 14

PHYSICAL PROPERTIES OF HCFCs AND OTHER SOLVENT BLENDS

	CFC-113	MCF	HCFC-225ca	HCFC-225cb	HCFC-141b
Chemical Formula	CCl_2FCClF_2	CH_3CCl_3	$CF_3CF_2CHCl_2$	$CClF_2CF_2CHClF$	CH_3CFCl_2
Ozone Depleting Potential	0.8	0.1	~0.05	~0.05	0.11
Boiling Point (°C)	47.6	73.9	51.1	56.1	32.1
Viscosity (cps) @ 25°C	0.68	0.79	0.59	0.61	0.43
Surface Tension (dyne/cm)	17.3	25.56	16.3	17.7	18.4
Kauri-Butanol Value	31	124	34	30	76
Flash Point °C	None	None	None	None	None
Toxicity	Low	Low	Underway	Underway	Near Completion

Therefore, these substances are no longer being recommended for use in solvent cleaning applications, where workers will be exposed to the chemicals for long periods of time. In addition, two major manufacturers have withdrawn all of their HCFC-123 formulations previously marketed for solvent cleaning applications. HCFG-141b is currently available and is manufactured by a few companies for use in solvent cleaning applications. Previous formulations included mixtures with HCFC-123 and methanol, but current formulations have dropped the use of HCFC-123. The major drawback associated with the use of HCFC-141b is its relatively high ODP of 0.11. This is only slightly below the ODP of MCF (0.12), a product which HCFC-141b is to be replacing. This similarity in ODP has limited the extent to which HCFC-141b can replace CFC-113 and MCF, since it is generally seen as an unacceptable substitute for MCF. In the U.S., for example, the EPA is likely to ban the use of HCFC-141b as a substitute for MCF in solvent cleaning applications. All of these factors make HCFC-141b an unlikely substitute for MCF in aircraft maintenance cleaning operations.

At the present time, it appears HCFC-225 is a good substitute for both CFC-113 and MCF in general metal and precision cleaning. It is similar to CFC-113 in its chemical and physical properties, and can form azeotropes with alcohols. It is also compatible with most plastics, elastomers, and metals. HCFC-225 can be used as a CFC-113 replacement, where other alternatives do not exist, with relatively few changes in equipment or process operations. Its ability to replace MCF, however, will be limited because the solvency of HCFC-225 is low compared with that of MCF. At present, an HCFC-225 plant has been commissioned which will have a capacity to produce 2,000 MT per year of HCFC-225 (as a mixture of 45 percent HCFC-225ca and 55 percent HCFC-225cb). It is expected that this product will be available in significant quantities in 1994.

As a means of addressing the ODP of HCFCs, the Parties to the Montreal Protocol developed a phaseout schedule for HCFCs at their November 1992 meeting in Copenhagen. Under the new amendment, HCFC consumption must be frozen at the base level by 1996; be cut by 90 percent from the base level by 2015; be cut by 99.5 percent by 2020; and be cut by 100 percent by 2030. The base level is equal to 3.1 percent of 1989 CFC consumption plus 100 percent of 1989 HCFC consumption. This phaseout is prompting many potential users of HCFCs to switch directly to other alternatives.

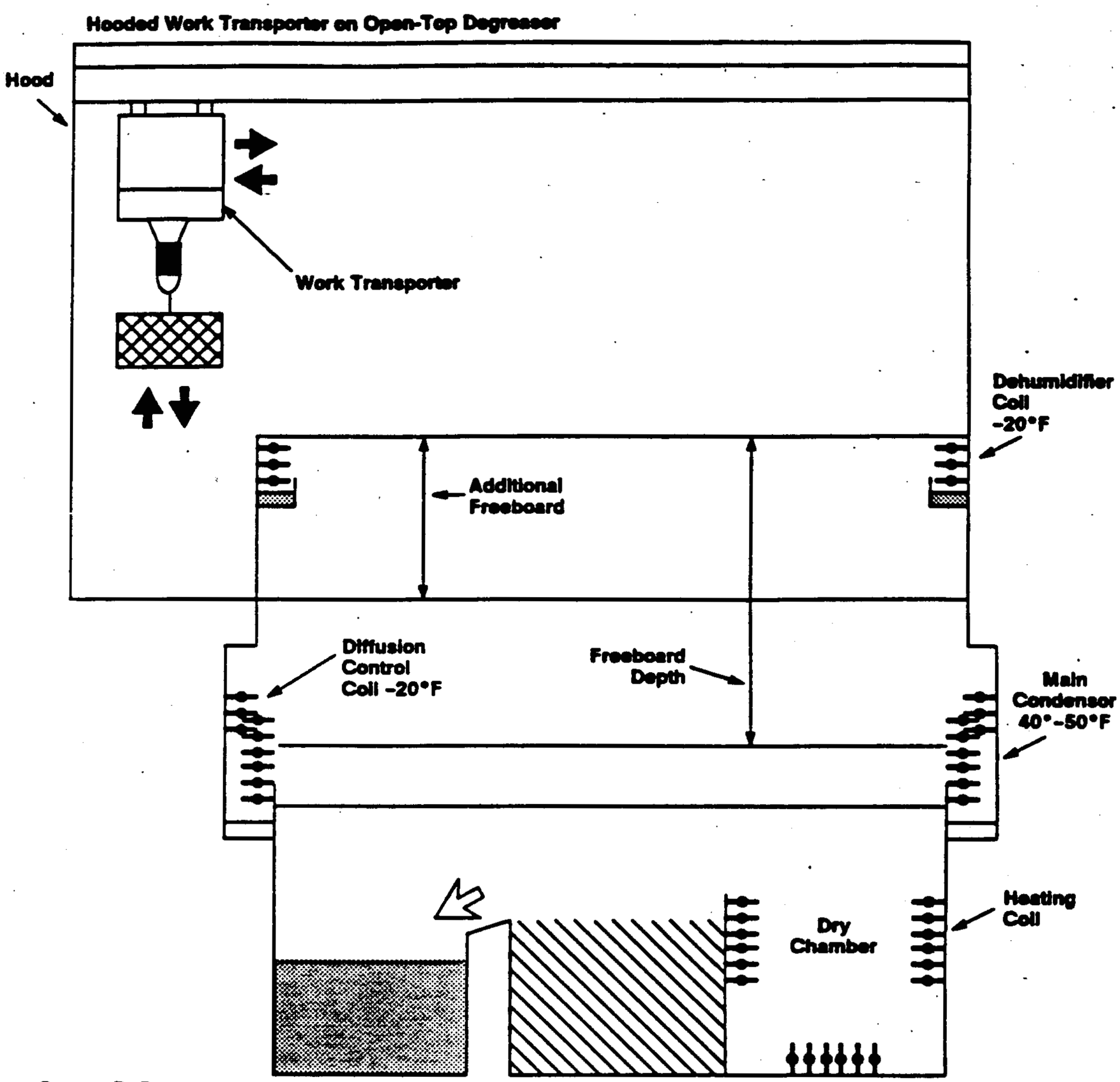
If HCFCs must be used, it is important to consider the process design changes which may be required in order to reduce emissions. For example, conventional degreasers require modification to extend freeboards and lower condenser temperatures. In addition, provisions 'such as superheated-vapor drying or increased dwell times in freeboard are desirable to reduce dragout losses and can be incorporated into the design.

The high volatility of HCFC cleaning solutions require special equipment design criteria. In addition, the economic use of HCFCs may require special emission control features for vapor degreasers (see Exhibit 15, 16, and 17). These include:

- Automated work transport facilities;
- Hoods and/or automated covers on top entry machines;
- Facilities for work handling that minimize solvent entrapment;
- Facilities for superheated vapor drying;
- Freeboard deepened to width ratios of 1.0 to 2.0;
- Main condenser operating at 45" to 55°F (7° to 13°C);
- Secondary condenser operating at -30° to -20°F (-34° to -29°C);
- Dehumidification condenser operating at -30 to -20°F (-34° to -29°C)(optional);
- Seals and gaskets of chemically compatible materials;
- Stainless steel construction;

Exhibit 15

ADVANCED DESIGN DEGREASER FOR USE WITH LOW BOILING POINT SOLVENTS

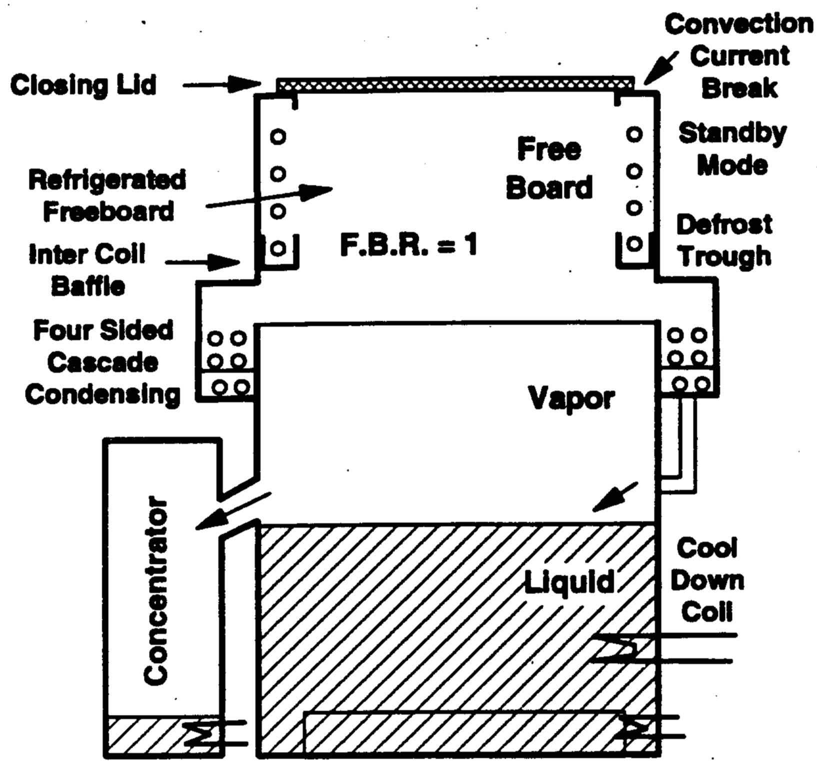


Source: DuPont

S15131(a)-13

Exhibit 16

STACKED LOW EMISSION DEGREASER WITH SOLVENT SAVING FEATURES



Solvent Saving Features
(not shown)

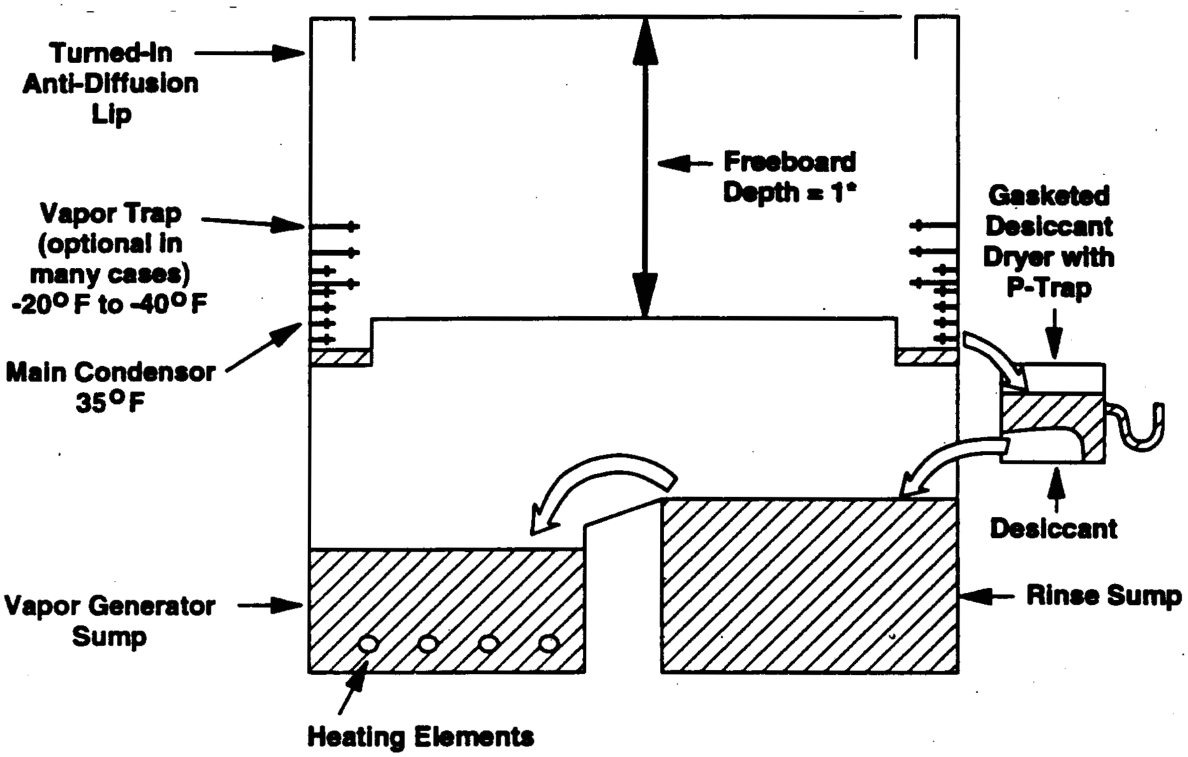
Screwed pipe joints
Correct sealing material
Correct pump seals
Minimum number of pipe joints
Degreaser enclosure
Mechanical handling with optional rotation
Correct size basket

Source: ICI

f38072-1

Exhibit 17

ADVANCED DESIGN DEGREASER FOR USE WITH LOW BOILING POINT SOLVENTS



*Machine Width = w; w = 1 indicates 100% [illegible]board

Source: Allied-Signal

f38072-2

- Welded piping containing a minimum of flanged joints;

- A gasketed water separator or refrigerated desiccant dryer for methanol blends,

- A cool room to work in is recommended;

- Controlled exhaust from refrigeration unit to prevent excessive heat from reaching the separator chambers.

Material compatibility is another important consideration. Certain blends may require compatibility testing with titanium, magnesium, zinc and other metals. In addition, the solvent blends have shown some adverse effects with plastics such as ABS, acrylic, and Hi-Impact Styrene. Like metals, plastics need to be tested on an individual basis.

Other Cleaning Techniques

In addition to the more common alternative cleaning procedures described in the previous sections, there are several additional processes which can be used to a lesser extent in aircraft maintenance cleaning. These techniques include the following:

- Perfluorocarbons
- Supercritical carbon dioxide
- Media blasting techniques

Each of these procedures has strict limitations associated with its use.

Perfluorocarbons

Perfluorocarbons (PFCs) are a group of compounds in which all of the hydrogen atoms of a hydrocarbon are replaced with fluorine atoms. They are characterized by extreme stability, low toxicity, nonflammability, and zero ozone-depletion potential. The wide range of boiling points available for PFCs makes them very versatile. One manufacturer notes that six PFC compounds have boiling points ranging from 84° to 320°F (29" to 160°C).

A major disadvantage associated with the use of PFCs is their extremely high global warming potential. Due to their stability, atmospheric lifetimes for some PFCs have been estimated to be greater than 500 years, perhaps reaching as high as 3,000 years. Thus, it is possible that by widely substituting PFCs for CFC-113 and MCF, users might be trading one environmental problem for another. This tradeoff has prompted the governments of several developed countries to severely restrict, or consider restricting, the use of PFCs in solvent cleaning. Both the U.S. and Sweden have indicated that they intend to limit use of PFCs to essential uses only, or ban their use altogether in some applications.

A second major disadvantage associated with the use of PFCs is their extremely high cost. The high cost is due to the complex manufacturing processes which are carried out to produce these synthetic compounds. In late 1990, a typical low- to mid-range boiling point PFC cost US$90 per kilogram:

PFCs have proven to be effective in precision cleaning applications such as the cleaning of high accuracy gyroscopes. All current high density flotation fluids are soluble in PFCs and can therefore. be used for flushing filled assemblies. In addition, high pressure spraying with PFCs is an extremely effective method of particle removal. The excellent stability of PFCs makes them compatible with all gyroscope construction materials, including beryllium. Due to their global warming potential and extremely high cost, any equipment in which PFCs are used will need to be tightly sealed to avoid large losses of the compounds.

Suprecritical Carbon Dioxide

The use of supercritical carbon dioxide in precision cleaning applications is a relatively new alternative to CFC-113 and MCF cleaning. It has been proven effective in removing a wide variety of oils, including silicones, damping fluids, machining oils, and lubricating oils, from assemblies in aircraft maintenance. Supercritical carbon dioxide is especially useful in applications where aqueous and semi-aqueous cleaners are unable to penetrate small crevices and pores in assemblies. Eexcessive cleaning may result in damage to plastic parts. Therefore, time, pressure, and temperature must be monitored during the cleaning process.

The supercritical carbon dioxide cleaning process was tested by a major manufacturer on inertial guidance systems in 1981, and is currently being further developed through a U.S. Air Force program. Testing has shown that the process is as effective as CFC-113 in removing fill fluids from gyroscope housings prior to rebuild. The supercritical carbon dioxide cleaning process is being developed to focus on small parts as well as low-throughput of high value parts, and equipment costs will range from US$50,000 to US$250,000 depending on the application.

Media Blasting Techniques

The technique of blasting a surface with a given media in order to dislodge contaminants is fairly common in aircraft maintenance procedures. This technique is generally applicable only to smooth surfaces, and is used primarily to remove scale, corrosion, oxidation, and carbon deposits. It relies on the use of very high-pressure spray of a given media which, when it contacts the surface to be cleaned, dislodges the soils on the surface, resulting in a clean product. Blasting is most often used-on aircraft engine parts, and can be divided into two general types of processes -- dry abrasive blasting, and wet abrasive blasting.

The media used in the blasting procedures is dependent upon the product being cleaned and the blasting technique employed. For dry abrasive blasting, there are a large number of media which are recommended and/or currently used by aircraft maintenance engineers. These include:

- Sand
- Plastic beads
- Glass beads
- Nut shells and rice hulls
- Fruit pits
- Wheat starch

Dry abrasive blasting using wheat starch as the media is currently undergoing testing at two large airlines in the United States. Regardless of the media used in dry abrasive blasting, the material being cleaned must be able to withstand extreme pressures and should have a breaking strength of at least 210,000 pounds per square inch (1450 MPa). In addition, care must be taken to prevent explosions.

Another consideration associated with most dry abrasive blasting is the amount of waste generated by the procedure. The overall quantity and type of waste will depend on the size of the parts. being cleaned and the media being used in the blasting process. One large military facility in the United States reports producing approximately 600,000 lbs. of waste in a single year.

Wet abrasive blasting is used primarily for surface cleaning prior to painting and is similar to dry abrasive blasting with the exception that a liquid is used in a high-pressure spray in the place of one of the dry media previously mentioned. There are two 'types of wet abrasive blasting, fine and medium. This classification refers to the spray which is applied, determining whether a fine atomized spray is delivered, or a less fine spray is used. Surfaces to be cleaned using wet abrasive blasting must be able to withstand the same pressures as those cleaned with dry abrasive blasting. Typica1 media used in wet abrasive blasting are water and sodium bicarbonate/water mixtures. Care must be taken to ensure that wet abrasive blasting is not used on parts which may be vulnerable to corrosion.

For small-scale operations, the blasting operation is carried out in a blasting booth which is equipped with a number of safety devices including air-extraction systems, soundproofing, and dust catchers. In addition, operators inside the booth wear safety gear, gloves, breathing masks, and protective clothes. . While some blasting procedures are carried out with the operator inside the booth, others have the operator standing outside and using gloves which are built into the side of the booth.

Wet abrasive blasting is also being used successfully in large-scale applications, although the use in these cases is primarily for stripping paint. One military facility in the U.S. has recently constructed a new facility in which it can strip paint from an entire aircraft using a sodium bicarbonate/water slurry. A similar facility has recently been built in Germany, where paint is removed from aircraft using a water/alcohol spray.

Several precautions must be taken when using any type of blasting. Blasting should not be used as a cleaning method for parts which will later be subject to fluorescent dye testing, as the blast residue may cover small cracks in the surface. Another issue is recontamination of clean surfaces.

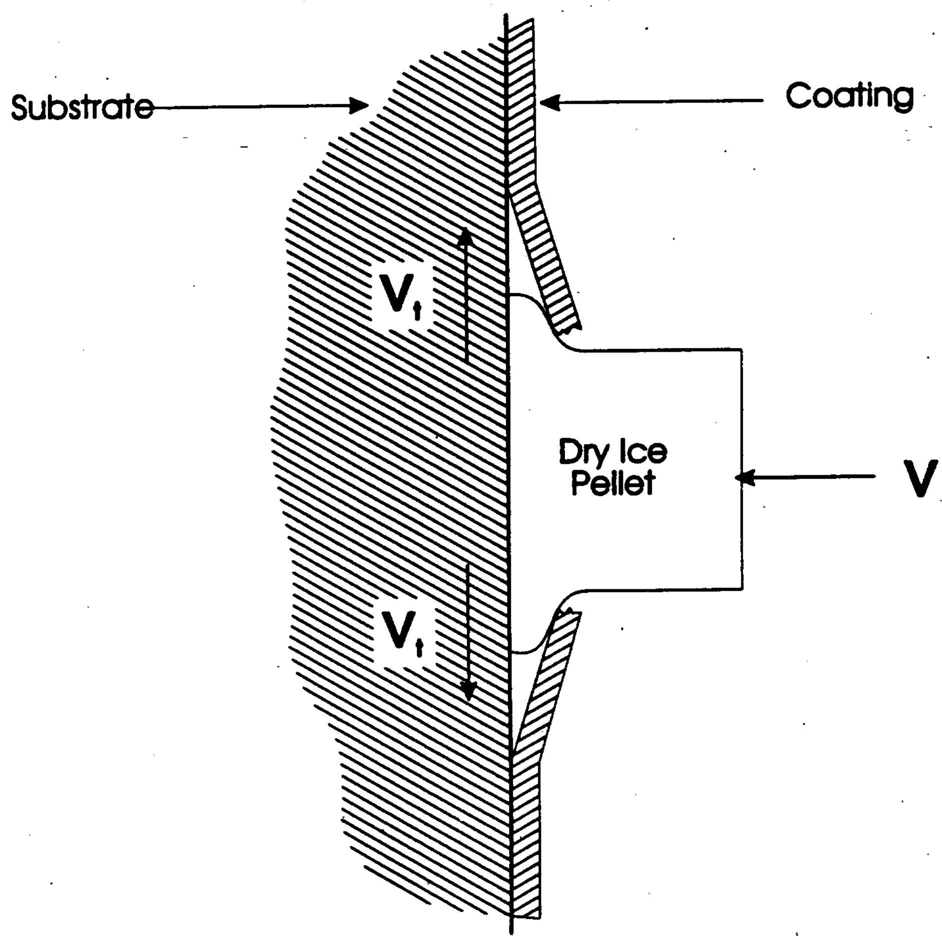
Whenever possible, a different booth and spray device should be used for each material being cleaned (e.g., alloyed steel, titanium parts, etc.). This will ensure that no cross-contamination of parts will occur. In addition, when cleaning titanium surfaces using dry abrasive blasting, booths should be cleaned frequently. This will reduce the risk of fire which could come with the accumulation of fine particles of titanium or its alloys.

Recently, a new form of blasting has been developed for use in a variety of applications, including aircraft cleaning procedures. It is similar to the dry abrasive blasting techniques previously described, but uses carbon dioxide ($C0_2$) pellets as the blasting media. While the cleaning technique -- use of a high pressure blasting gun -- is the same, the process itself is not abrasive.

The CO_2 pellet blasting system converts liquid CO_2 into dry ice pellets. These pellets are then propelled through a blast nozzle by high velocity air and the hard pellets strike the surface to be cleaned. When the pellets first reach the surface, they penetrate the contaminant and hit the surface itself. At this point the pellet "ruptures" and the kinetic energv forces the CO_2 to be released along the surface being cleaned. This force then dislodges the contaminant from behind, removing it from the surface. Exhibit 18 illustrates this process.

Exhibit 18

CLEANING DYNAMICS of CO_2 PELLETS



Source: Alpheus Cleaning Technologies Corporation.

ALTERNATIVE CLEANING PRACTICES

The previous section presented a brief description of many of the currently available alternative chemicals and processes that can be used to replace CFC-113 and methyl chloroform. This section presents process-specific information on many of the alternative methods that are currently used in aircraft maintenance cleaning applications. The methods are presented in summary sheet format, with each sheet describing a single alternative to a specific cleaning application. Issues that are addressed on each sheet include:

- soils removed and substrates cleaned;
- steps in the cleaning process;
- equipment required when using the alternative method;
- environment, health, and safety considerations;
- relevant federal, military, and other industry specifications; and
- source(s) of information.

A number of the alternatives detailed in the summary sheets are specified in aircraft manufacturer maintenance or overhaul manuals. In addition, many of the alternative processes are currently being used by several major airlines.

The first three pages of this section are a guide to the cleaning applications addressed and the alternatives discussed in the individual summary sheets. It is important to note that this is not a comprehensive list of cleaning applications that currently use CFC-113 or methyl chloroform, but rather a selection of the applications for which acceptable alternatives are currently available.

A wide variety of alternative chemicals and processes are presented in the summary sheets. These sometimes include the use of substances which may be considered potentially hazardous to human health and/or the environment. The use of these substances may be regulated under national or local law in some countries, while it may not be controlled in others. It is important to consider regulations pertinent to maintenance operations when evaluating each alternative chemical or process.

SUMMARY CHART OF AIRCRAFT MAINTENANCE CLEANING APPLICATIONS AND FEASIBLE ALTERNATIVE CLEANING METHODS

Cleaning Application	Current Cleaning Method with CFC-113 or MCF	Alternative Cleaning Method	Page
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		Semi-Aqueous Cleaning -- Alkaline & Aliphatic Naphtha (Moderately Heavy Soil Removal)	79
		Semi-Aqueous Cleaning -- Alkaline & Aliphatic Naphtha (Heavy Soil Removal)	81
		Semi-aqueous Cleaning -- Terpene	83
		Aliphatic Hydrocarbon Cleaning -- Mineral Spirits	85
Landing Gear	In-Shop Overhaul: Vapor Degreasing or Aerosol Spray	Aqueous Cleaning -- Alkaline	87
		Semi-Aqueous Cleaning -- Mineral Spirits	89
	On-the-Aircraft Maintenance: Aerosol Spray	Aqueous Cleaning -- Alkaline	91
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Engine or Engine Modules	Vapor Degreasing	Aqueous Cleaning -- Hot Tank	95
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	Immersion	Aqueous Cleaning -- Alkaline, Hot Tank	99
	Vapor Degreasing	Aqueous Cleaning - Alkaline, Hot Tank	101
	Vapor Degreasing or Hand-Wipe	Aqueous Cleaning -- One Step Heavy-Duty Alkaline	103
	Immersion	Aqueous Cleaning -- Four Step Heavy-Duty Alkaline	105
	Vapor Degreasing or Hand-Wipe	Aqueous Cleaning -- Alkaline	107
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Cleaning Application	Current Cleaning Method with CFC-113 or MCF	Alternative Cleaning Method	Page
Engine or Engine Modules: Assembled and Semi-Assembled Parts	Aerosol Spray or Hand-Wipe	Aqueous Cleaning -- Alkaline	113
Flight Control Surfaces	Aerosol Spray or Hand-Wipe	Aqueous Cleaning -- Alkaline	115
		Aliphatic Hydrocarbon Cleaning -- Mineral Spirits	117
		Organic Solvent Cleaning -- Methyl Ethyl Ketone or Acetone	119
Electrical Equipment	Aerosol Spray	Aqueous Cleaning -- Alkaline, Ultrasonic	121
		Organic Solvent Cleaning -- Isopropyl Alcohol	123
Hydraulic Lines	Hand-Wipe or Vapor Degreasing	Aqueous Cleaning -- Water-Base Soap Solution	124
Aircraft Seat Covers and Curtains/Draperies	Dry Cleaning	Chlorinated Solvent Cleaning -- Perchloroethylene	125
Prior to Coating: **Polyurethane**	Hand-Wipe	Organic Solvent Cleaning -- Methyl Ethyl Ketone or Blends	126
Chromate Conversion	Hand-Wipe	Organic Solvent Cleaning -- Methyl Ethyl Ketone or Blends	128
		Semi-Aqueous Cleaning -- Alkaline and Aliphatic Naphtha	130
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Prior to Adhesive Bonding	Spray or Hand-Wipe	Organic Solvent Cleaning -- Isopropyl Alcohol	134
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		Organic Solvent Cleaning -- Methyl Ethyl Ketone	139
During Fluorescent Penetrant Inspection	Aerosol Spray or Hand-Wipe	Organic Solvent Cleaning -- Isopropyl Alcohol, Methyl Ethyl Ketone, or Acetone	141
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Cleaning Application	Current Cleaning Method with CFC-113 or MCF	Alternative Cleaning Method	Page
Prior to Welding	Hand-Wipe or Immersion	Organic Solvent Cleaning -- Methyl Ethyl Ketone or Acetone	144
Prior to Painting	Aerosol Spray or Hand-Wipe	Organic Solvent Cleaning -- Methyl Ethyl Ketone and Toluene	146

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Aircraft Exterior Surface - Light Soil Removal

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Aqueous cleaning -- alkaline

Special Notes on Alternative Process:

- Soils removed - Dust and dirt.
- Substrates cleaned - Most smooth metal surfaces.
- Do not use this process to clean mechanical, electrical, or hydraulic components. Refer instead to procedures for cleaning flight control surfaces and landing gear.
- When removing moderately heavy or heavy soils, remove the heavier material first. Then clean the surface using the procedure for light soil removal. Or, use the method for moderately heavy or heavy soils.
- To clean large areas, use non-atomizing spray equipment, swabs, and brushes. When cleaning small areas, use rags, brushes, and sponges. Do not clean an area so large that the cleaner dries on the surface before the surface is flushed with water.
- Mer applying the cleaner, flush the surface with clean water three or more times. In areas where water can get caught, use a clean wet rag or sponge to remove the cleaner. Flush with water from the upper surfaces to the lower surfaces.
- Do not use water hotter than 160°F (71°C).

Alternative Cleaning Process:

1. Dilute cleaner as instructed for light soil removal..
2. Apply water to area, being cleaned.
3. Apply cleaner to surface with non-atomizing spray equipment, swabs, or brushes.
4. Let cleaner stand for approximately 5 minutes. Reapply cleaner as necessary to keep surface wet.
5. Rub surface with a brush for better soil removal.
6. Flush surface with clean, warm water.

7. Dry surface with air or towels.

Materials and Equipment Required:

- Water-base mild alkaline cleaner.
- Non-atomizing spray equipment, brushes.
- Sponges, swabs, or rags.
- Towels.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling alkaline cleaner concentrate.
- Wastewater may require treatment on-site before it is sent to a public wastewater facility.
- Brushes, swabs, sponges, and rags saturated with cleaner should be disposed of properly.

Relevant Speclfications Which May Need to Be Considered:

- AMS-1533, Type I cleaner for aircraft exterior surfaces.

Additional specifications may exist.

Sources: (1) Boeing 747 Maintenance Manual, Cleaning and Washing - Maintenance practices (12-25-01, pp. 301-9) rev. 4/25/90.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Aircraft Exterior Surface -- Moderately Heavy Soil Removal

Chemical(s Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Semi-aqueous cleaning -- water-base alkaline and aliphatic naphtha

Special Notes on Alternative Process:

- Soils removed - Oil and mud.
- Substrates cleaned - Most smooth metal surfaces.
- Do not use this process to clean mechanical, electrical, or hydraulic components. Refer instead to procedures for cleaning flight control surfaces and landing gear.
- To clean large areas, use non-atomizing spray equipment, swabs, and brushes. When cleaning small areas, use rags, brushes, and sponges. Do not clean an area so large that the cleaner dries on the surface before the surface is flushed with water.
- After applying the cleaner, flush the surface with clean water three or more times. In areas where water can get caught, use a clean wet rag or sponge to remove the cleaner. Flush with water from the upper surfaces to the lower surfaces.
- Do not use water hotter than 160°F (71°C).

Alternative Cleaning Process:

1. Prepare cleaning solution by mixing alkaline cleaner, water, and aliphatic naphtha as instructed for moderately heavy soil removal. Cleaner should be thick and creamy.
2. Apply a heavy layer of cleaner to surface with non-atomizing spray equipment, mops, or brushes.
3. Let cleaner stand for 5-10 minutes. Reapply cleaner as necessary to keep surface wet.
4. Rub surface with a brush for better soil removal.
5. Flush surface with clean, warm water.
6. Dry surface with air or towels.

Materials and Equipment Required:

- Water-base alkaline cleaner.
- Aliphatic naphtha cleaning solvent.
- Non-atomizing .spray equipment, mops, and/or brushes.
- Towels.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling alkaline cleaner concentrate.
- Wastewater may require treatment on-site before it is sent to a public wastewater treatment facility.
- Aliphatic naphtha is flammable. Workers should observe normal fire Safety precautions when handling the material.
- VOC recovery may be required when using aliphatic naphtha. Check national and local regulations.
- Brushes and mops containing cleaning solution should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- AMs-1533, Type I cleaner for aircraft exterior surfaces.
- AMs-1528, Type II cleaner for exterior surfaces, emulsion, pressure spraying.
- AMs-1530, Type II cleaner for aircraft exterior surfaces, wipe-on, wipe-off, water miscible.

Additional specifications may exist.

Sources: (1) Boeing, 747 Maintenance Manual, Cleaning and Washing - Maintenance Practices (12-25-01, pp. 301-9), rev. 4/25/90.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Aircraft Exterior Surface -- Heavy Soil Removal

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Semi-aqueous cleaning -- heavy-duty alkaline and aliphatic naphtha

Special Notes on Alternative Process:

- Soils removed - Grease and exhaust particles.
- Substrates cleaned —Most smooth metal surfaces.
- Do not use this process to clean mechanical, electrical, or hydraulic components. Refer instead to procedures for cleaning flight control surfaces and landing gear.
- To clean large areas, use non-atomizing spray equipment, swabs, and brushes. When cleaning small areas, use rags, brushes, and sponges. Do not clean an area so large that the cleaner dries on the surface before the surface is flushed with water.
- After applying the cleaner, flush the surface with clean water three or more times. In areas where water can get caught, use a clean wet rag or sponge to remove the cleaner. Flush with water from the upper surfaces to the lower surfaces.
- Do not use water hotter than 160°F (71°C).

Alternative Cleaning Process:

1. Prepare cleaning solution by mixing alkaline cleaner, water, and aliphatic naphtha as instructed for heavy soil removal.
2. Apply a heavy layer of cleaner to surface with non-atomizing spray equipment, mops, or brushes.
3. Let cleaner stand for 15 minutes maximum. Reapply cleaner as necessary to keep surface wet.
4. Rub surface with a brush for better soil removal.
5. Flush surface with clean, warm water.
6. Dry surface with air or towels.

Materials and Equipment Required:

- Heavy-duty alkaline cleaner.
- Aliphatic naphtha cleaning solvent.
- Non-atomizing spray equipment, mops, and/or brushes.
- Towels.
- Fire protection equipment.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling alkaline cleaner.
- Wastewater may require treatment on-site before it is sent to a public wastewater treatment facility.
- Aliphatic naphtha is flammable. Workers should observe normal fire safety precautions when handling the material.
- VOC recovery may be required when using aliphatic naphtha. Check federal and local regulations.
- Brushes and mops containing cleaning solution should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- AMs-1533, Type I cleaner for aircraft exterior surfaces.
- AMs-1528, Type II cleaner for exterior surfaces, emulsion, pressure spraying.
- AMs-1530, Type II cleaner for aircraft exterior surfaces, wipe-on, wipe-off, water miscible.

Additional specifications may exist.

Sources: (1) Boeing, 747 Maintenance Manual, Cleaning and Washing - Maintenance Practices (12-25-01, pp. 301-91, rev. 4/25/90.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Aircraft Exterior Surface

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Semi-aqueous cleaning -- terpene

Special Notes on Alternative Process:

- **Soils removed -** Exhaust hydraulic oils, grease, and carbon, and dirt.
- **Substrates cleaned -** Most metal surfaces.

Alternative Cleaning Process:

Light exterior cleaning -

1. Spray or foam terpene cleaner on surface
2. Rinse cleaner off with water
3. Allow surface to dry or dry with rags or forced air

Grease and carbon removal -

1. Immerse part in terpent cleaner tank at ambient temperature.
2. Let part soak for 0.5-4 hours, as necessary
3. Remove part from cleaner.
4. Allow surface to dry or dry with rags of forced air.

Materials and Equipment Required:

- Terpene cleaner -- d-limonene based.
- Spray equipment or immersion tank.
- Fire protection and prevention equipment may be required.

Environment, Health, and Safety Considerations:

- Terpene cleaner is flammable. Workers should observe normal fire safety precautions.
- Prolonged skin contact with terpene cleaner may cause dryness and burns. Workers inhaling highly concentrated cleaner may experience headaches and nausea.
- Workers should wear protective eyewear and clothing when handling terpene cleaner.
- Wastewater may require treatment .on-site before .being sent to public wastewater treatment facility.
- Rags and cloths containing spent cleaner should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- MIL-C-85704.

Additional specifications may exist.

Sources: (1) Citrikleen Product Description and Material Safety Data Sheet, Pentone Corporation.
(2) Rillings Jr., Kenneth W. "Replacement of Hazardous Solvents with a Citrus Based Cleaner for Hand Cleaning Prior to Painting and Structural Bonding." Boeing Waste Reduction. 1991.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Aircraft Exterior Surface

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Aliphatic hydrocarbon cleaning -- mineral spirits

Special Notes on Alternative Process:

- **Soils removed -** Oil, grease, carbon, and dirt.
- **Substrates cleaned -** Safe for most metals. May be unsafe for titanium alloys.
- Do not apply mineral spirits to hot engine surfaces, hot aircraft brakes, hot electrical units, and other surfaces which generate heat greater than 100°F (38°C). Higher flash point synthetic hydrocarbons may be acceptable if the flash point is at least 59°F (15°C) above the temperature of the surface.
- Do not allow cleaner to come in contact with lubricated parts.
- Do not allow cleaner to dry on surface being cleaned before removal.

Alternative Cleaning Process:

1. Cover areas which should not come into contact with mineral spirits.
2. Apply mineral spirits to surface sparingly using a clean mop, non-metallic brush, or spray at 40-50 psi.
3. Wipe the surface dry using clean, lint-free cloth as needed to remove cleaner and soils.

Materials and Equipment Required:

- Mineral spirits cleaner.
- Spray equipment, mops, cloths, non-metallic brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Mineral spirits are flammable. Workers should observe normal fire safety precautions when handling the material. Synthetic grades may have flash points significantly higher and are safer to use.

- VOC recovery may be required when using mineral spirits. Check federal and local regulations.

- Mops, brushes, and cloths containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- PD-680, Type I, II, or III Federal Specification (mineral spirits).

- ASTM D484-52, BS 245 (mineral spirits).

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Aircraft Exterior Cleaning (900-1-2-1 No. l), rev. 5/31/91.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Landing Gear (Undercarriage)
In-Shop Overhaul

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing or Aerosol Spray

Feasible Alternative: Aqueous cleaning -- alkaline

Special Notes on Alternative Process:

- **Soils removed -** Oil and grease deposits.
- **Substrates cleaned -** Safe for most metals. May be unsafe for titanium alloys.
- Do not allow cleaner to dry on surface being cleaned.

Alternative Cleaning Process:

1. Apply cleaner using spray, immersion, or wipe-on method, as indicated by vendor instructions. Do not clean assembled parts by immersion unless specified by overhaul or maintenance manual.
2. If using immersion method, allow parts to remain in alkaline cleaner long enough to remove soils, typically 15-30 minutes.
3. Remove heavier soils by rubbing area with mop, cleaning pad, or bristle brush. Use stainless steel bristle brush only on steel parts with tough soils. Use non-metallic bristle brush on other materials.
4. Rinse cleaner off thoroughly using low-pressure water spray and low-pressure steam in inaccessible areas or by immersing in water bath.

Materials and Equipment Required:

- Alkaline cleaner -- modified amine type, non-chromated, non-phenolic, non-flammable.
- Spray equipment or immersion tanks.
- Brush -- stainless steel wire, synthetic or animal bristle.
- Non-abrasive cleaning pads, mops.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling alkaline cleaner.

- Wastewater may require treatment on-site before it is sent to a public wastewater treatment facility.

- Mops, brushes, pads and cloths containing cleaner and soils should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- MLC-87936, Type I or II. (waterbased cleaner - heavy duty solvent emulsion alkaline).

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Landing Gear, Aircraft, and Engine Parrs Cleaning (900-1-1-1 No. 5), rev. 5/31/91.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.
(3) MD-80 Maintenance Manual, Aircraft Cleaning - Description and Operation, rev. 9/1/86.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Landing Gear (Undercarriage)
In-Shop Overhaul

ChemIcal(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing or Aerosol Spray

Feasible Alternative: Semi-aqueous cleaning -- mineral spirits

Special Notes.on Alternative Process:

- **Soils removed -** Oil and grease deposits.
- **Substrates cleaned -** Safe for most metals. May be unsafe for titanium alloys.
- Do not apply mineral spirits to hot engine surfaces, hot aircraft brakes, hot electrical units, and other surfaces which generate heat greater than 100°F (38°C). Higher flash point synthetic hydrocarbons may be acceptable if the flash point is at least 59°F (15°C) above the temperature of the surface.
- Do. not use mineral spirits in areas exposed to open flames or sparks.
- Do not allow solvent to dry on surface being cleaned.

Alternative Cleaning Process:

1. Apply mineral spirits solvents using spray or wipe-on method, as indicated by vendor instructions.
2. Remove heavier soils by rubbing area with mop, cleaning pad, or bristle brush. Use stainless steel bristle brush only on steel parts with tough soils. Use non-metallic bristle brush on other materials.
3. Rinse cleaner off thoroughly using low-pressure water spray and low-pressure steam in inaccessible areas or by immersing in water bath.

Materials and Equipment Required:

- Mineral spirits cleaner.
- Brush -- stainless steel wire, synthetic or animal bristle.
- Non-abrasive cleaning pads, mops.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Wastewater may require treatment on-site before it is sent to a public wastewater treatment facility.
- Mineral spirits are flammable. Workers should observe normal fire safety precautions when handling the material. Synthetic grades may have flash points significantly higher and are safer to use.
- VOC recovery may be required when using mineral spirits. Check federal and local regulations.
- Mops, brushes, and pads containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- PD-680, Type I, II, or III Federal Specification (mineral spirits).
- ASTM D484-52, BS 245 (mineral spirits).

Additional specifications may exist.

Sources:

(1) Delta Airlines Process Standard, Landing Gear, Aircraft, and Engine Parts Cleaning (900-1-1-1 No. 5), rev. 5/31/91.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.
(3) MD-80 Maintenance Manual, Aircraft Cleaning - Description and Operation, rev. 9/1/86.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Landing Gear (Undercarriage)
On-the-Aircraft Maintenance Cleaning

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray

Feasible Alternative: Aqueous cleaning -- alkaline

Special Notes on Alternative Process:

- **Soils removed -** Oil and grease deposits.
- **Substrates cleaned -** Safe for most metals. May be unsafe for titanium alloys.
- Do not allow cleaner to dry on surface being cleaned.

Alternative Cleaning Process:

1. Apply alkaline cleaner with clean mop or cloth.
2. Allow cleaner to remain on surface for 5-10 minutes.
3. Rub heavily soiled surfaces with mop, cleaning pad, or non-metallic bristle brush for better cleaning.
4. Rinse part thoroughly with clean, water-saturated mop or cloth.
5. Dry surface with clean, dry mop or cloth.

Materials and Equipment Required:

- Alkaline cleaner -- modified amine type, non-chromated, non-phenolic, non-flammable; or heavy duty solvent emulsion alkaline, non-chromated, non-phenolic, non-flammable.
- Mops, cloths, non-abrasive cleaning pads, and non-metallic bristle brushes.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling alkaline cleaner.
- Wastewater may require treatment on-site before it is sent to a public wastewater treatment facility.
- Mops, brushes, and pads containing cleaner and soils should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- MIL-G87936, Type I or II (waterbased cleaner - heavy duty solvent emulsion alkaline).

Additional specifications may exist.

Sources:

(1) Delta Airlines Process Standard, Landing Gear, Aircraft and Engine Parts Cleaning (900-1-1-1 No. 9 , rev. 5/31/91.

(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Landing Gear (Undercarriage)
On-the-Aircraft Maintenance Cleaning

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray

Feasible Alternative: Aliphatic hydrocarbon cleaning -- mineral spirits

Special Notes on Alternative Process:

- **Soils removed -** Oil and grease deposits.
- **Substrates cleaned -** Safe for most metals. May be unsafe for titanium alloys.
- Do not apply mineral spirits to hot engine surfaces, hot aircraft brakes, hot electrical units, and other surfaces which generate heat greater than 100°F (38°C). Higher flash point synthetic hydrocarbons may be acceptable if the flash point is at least 59°F (15°C) above the temperature of the surface.
- Do not use mineral spirits in areas exposed to open flames or sparks.
- Do not allow solvent to dry on surface being cleaned.

Alternative Cleaning Process:

1. Apply mineral spirits solvents with clean mop or cloth.
2. Rub heavily soiled surfaces with mop, cleaning pad, or non-metallic bristle brush for better cleaning.
3. Dry surface with clean, dry mop or cloth.

Materials and Equipment Required:

- Mineral spirits cleaner
- Mops, cloths, non-abrasive cleaning pads, and synthetic or animal bristle brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Mineral spirits are flammable. Workers should observe normal fire safety precautions when handling the material. Synthetic grades may have flash points significantly higher and are safer to use.

- VOC recovery may be required when using mineral spirits. Check federal and local regulations.

- Mops, cloths, brushes and. pads containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- PD-680, Type I, II, or III Federal Specification (mineral spirits).

- ASTM DM-52, BS 245 (mineral spirits).

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Landing Gear, Aircraft and Engine Parts Cleaning (900-1-1-1 No. 5), rev. 5/31/91.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-uichloroethane)

Cleaning Methods Employed: Vapor Degreasing

Feasible Alternative: Aqueous cleaning -- hot tank

Special Notes on Alternative Process:

- Soils removed - Removes grease and oil deposits.
- Substrates cleaned - Safe for use on most, metals, including titanium alloys. Some formulations will not be acceptable for cleaning aluminum alloys. Especially suited for cleaning most painted parts.
- Do not exceed the recommended operating temperatures.
- Seven mild non-silicated detergent cleaners are approved for use in this process. Each has its own operating temperature.
- Chloride content of the cleaning solution will attack magnesium parts if the chloride content exceeds 0.15 percent total chloride.
- Total immersion time should not exceed 60 minutes for magnesium parts.
- Low-alloy steels will be particularly vulnerable to corrosion.

Alternative Cleaning Process:

1. Immerse the parts to be cleaned in the cleaning solution for up to 30 minutes at the temperature given in the process manual for the cleaner chosen.
2. Remove the parts and wash immediately in cold water.
3. Pressure wash the parts using an air/water gun.
4. Check for water breaks.
5. Repeat steps 1, 2, 3, and 4 if necessary until parts are clean.
6. If used as a pre-clean for further processing, continue as instructed; otherwise,
7. Immerse the parts in clean water at a minimum temperature of 176°F (80°C).

8. Dry parts using a clean, dry air blast.

Materials and Equipment Required:

- Approved mild non-silicated detergent cleaner.
- Air/water spray equipment and two immersion tanks.

Environment, Health, and Safety Considerations:

- Wastewater may require treatment on-site before being sent to a public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Roll-Royce Engine Overhaul Process Manual, Primary Cleaning -- Aqueous (70-00-00, Process 102), rev. 1/18/90

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing

Feasible Alternative: Aliphatic hydrocarbon cleaning - mineral spirits,

Special Notes on Alternative Process:

- **Soils removed --** Superficial accumulations of grease, oil, gum, and dirt.
- **Substrates cleaned --** Safe for use on all metals,. including titanium alloys.
- Do not apply mineral spirits to hot engine surfaces, hot aircraft brakes, hot electrical units, and other surfaces which generate heat greater than 100°F (38°C). Higher flash point synthetic hydrocarbons may be acceptable if the flash point is at least 59°F (15°C) above the temperature of the surface.
- Do not use mineral spirits in areas exposed to open flames or sparks.
- Not to be used alone before bonding, plating, painting, pIasma/metal spraying, fluorescent penetrant inspection, magnetic particle inspection, and abrasive blasting (unless mineral spirits have evaporated from surface). In these cases, another subsequent cleaning process may be required.

Alternative Cleaning Process:

1. Clean parts by spraying, wiping, or immersing the part in mineral spirits.
2. Spraying should be done in a ventilated spray booth. Use brushes and scrapers to remove hard carbon deposits.
3. If cleaning by immersion, use soft-bristle brush or ultrasonic/mechanical agitation to remove stubborn accumulations. Allow the part to soak for one to three hours.
4. Rinse with high-pressure spray.
5. Apply rust preventative as necessary.

Materials and Equipment Required:

- Mineral spirits cleaner.
- Spray equipment or solvent immersion tank.

- Brushes and scrapers.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Mineral spirits are flammable. Workers should observe nomal fire safety precautions when handling the material. Synthetic grades may have flash pints significantly higher and are safer to use.
- VOC recovery may be required when using mineral spirits. Check federal and, local regulations. .
- Mops and cloths containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- PD-680, Type I, II, or III Federal Specification (mineral spirits).
- ASTM D484-52, BS 245 (mineral spirits).

Additional specifications may exist.

Sources:
(1) Continental Airlines Cleaning Shop Process Chart, Cleaning Procedures - Method 1 Solvent Cleaning.
(2) Delta Airlines Process Standard, Mineral Spirits Cleaning (900-1-1 No. 11), rev. 10/15/90.
(3) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Immersion

Feasible Alternative: Aqueous cleaning -- alkaline, hot tank

Special Notes on Alternative Process:

- Soils removed - Metallic oxides and other products of combustion from engine parts.
- Substrates cleaned - Safe for certain metals. Not safe for use on aluminum and other non-ferrous metals due to the high corrosiveness of the alkaline cleaner. Also may be unsafe on titanium alloys.
- For light cleaning and light paint removal, follow the steps below, but reduce soak time in alkaline baths to 0-10 minutes and skip step 6, the alkaline permanganate bath.
- Immersion tanks should be equipped with mechanical agitation.

Alternative Cleaning Process:

1. Immerse part in 190-200°F (88-93°C) alkaline rust remover for 30 minutes.
2. Rinse part with 140-180°F (60-82°C) water in agitated dip rinse for 5 minutes.
3. Hand spray part with air and water rinse.
4. Immerse part in 245-250°F (118-121°C) alkaline descaler & conditioner for 30 minutes.
5. Water rinse using steps 2 and 3.
6. immerse part in 190-200°F (88-93°C) alkaline permanganate solution for 30 minutes.
7. Water rinse using steps 2 and 3.
8. Immerse again in alkaline rust remover tank for 5 minutes.
9. Water rinse using steps 2 and 3.
10. If part not sufficiently clean, repeat steps 1 through 9. Repeating process will not harm the part.
11. Blow dry part. Apply rust preventive compound as necessary.

Materials and Equipment Required:

- Alkaline cleaner -- rust and scale remover, non-chromated, non-phenolic, non-flammable.
- Alkaline cleaner - descaler and conditioner, non-chromated, non-phenolic, non-flammable.
- Alkaline cleaner -- permanganate, non-chromated, non-phenolic, non-flammable.
- Rust preventive compound, non-chromated, non-phenolic, combustible.
- Immersion tanks with mechanical agitation.
- Air and water spray equipment.

Environment, Health, and Safety Considerations:

- Cleaners used in this process are highly alkaline. Workers should wear protective eyewear and clothing when handling these materials.
- Wastewater may require treatment on-site before being sent to public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional Specifications may exist.

Sources (1) Delta Airlines Process Standard, Hot Tank Alksline Cleaner, Descaler and Rust Remover (900-1-2-3 No. 3), rev. 11/24/86, 11/15/91

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing

Feasible Alternative: Aqueous cleaning -- alkaline, hot tank

Special Notes on Alternative Process:

- Soils removed - Removes oil, grease, and loose carbon deposits.
- Substrates cleaned - Steel, nickel-base alloy, and, titanium. Not for use on aluminum alloys.

Alternative Cleaning Process:

1. Immerse the parts to be cleaned in the alkaline silicate cleaning solution at 194-212°F (90-100°C) for as long as is needed to remove all oil, grease, and loose carbon.
2. Remove the parts and wash immediately under clean, cold, running water.
3. Pressure wash the parts using an air/water gun.
4. Check for water breaks.
5. Repeat steps 1-4 as necessary until clean.
6. If used as a pre-clean for further processing, continue as instructed; otherwise,
7. Immerse the parts in clean water at a minimum temperature of 176°F (80°C).
8. Dry the parts using a clean, dry air blast.

MaterialsandEquipmentRequired:

- Alkaline silicate cleaner.
- Air/water spray equipment and two immersion tanks.

Environment, Health, and Safety Considerations:

- Rubber gloves should be worn when working with alkaline cleaning solutions.
- .Wastewater may require treatment on-site before being sent to a wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist

Sources: (1) Rolls-Royce Engine Overhaul Processes Manual, Hot Aqueous Degreasing (70-00-00, Process 118), rev. 1/18/90.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform and methylene chloride

Cleaning Methods Employed: Vapor Degreasing and Hand-Wipe

Feasible Alternative: Aqueous cleaning -- one step heavyduty alkaline

Special Notes on Alternative Process:

- Soils removed - This process is effective for derusting, paint stripping, and general cleaning.
- Substrates cleaned - Can be used on ferrous and high temperature alloy jet engine parts. Do not use this process on tin, zinc, aluminum, titanium, or their alloys.

Alternative Cleaning Process:

1. Pre-clean part by immersing in hot (180–200°F,82-93°C) alkaline rust and scale remover for 10-20 minutes.
2. Pressure rinse with tap water.
3. Clean part by immersing in hot (180-200°F, 82-93°C) alkaline rust and scale remover for 30-90 minutes.
4. Remove and drain part. Spray rinse until all alkaline residues have been removed.
5. Blow dry with clean shop air.
6. Apply rust inhibitor as necessary.

Materials and Equipment Required:

- Alkaline cleaner -- rust and scale remover.
- Immersion tanks.
- Water and air spray equipment.

Environment, Health, and Safety Considerations:

- Cleaners used in this process are highly alkaline. Workers should wear protective eyewear and clothing when handling these materials.

- Wastewater may require treatment on-site before being sent to public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources (1) Continental Airlines Cleaning Shop Process Chart, Cleaning Procedures - Method 5 One Step Heavy-Duty Alkaline Cleaner.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform

Cleaning Methods Employed: Immersion

Feasible Alternative: Aqueous cleaning -- four step heavyduty alkaline .(with acidic descaler)

Special Notes on Alternative Process:

- Soils removed - Heat scale and oxide formation.
- Substrates cleaned - This process is effective on. hot-section parts of the engine. It is only partially effective on oxidized nickel base alloys. Do not use this cleaning process on aluminum, magnesium, titanium, or their alloys.

Allernative Cleaning Process:

1. Pre-clean pan by immersing in hot (180-200°F, 82-93°C) alkaline rust and scale remover for 10-20 minutes.
2. Spray rinse with tap water.
3. Clean part by immersing in hot (180-200°F, 82-93°C) alkaline rust and Scale remover for 15-30 minutes.
4. Pressure rinse with tap water.
5. Immerse part in hot (175-185°F, 79-85°C) acidic rust and scale remover for 20-30 minutes.
6. Pressure rinse with tap water.
7. Immerse part in hot (203-212°F, 95-100°C) alkaline permanganate for 30-60 minutes.
8. Pressure rinse with tap water.
9. Repeat steps 3 and 4.
10. Blow dry with clean shop air.
11. Apply rust inhibitor as necessary.

Materials and Equipment Required:

- Alkaline cleaner -- rust and scale remover.
- Acidic cleaner -- rust and scale remover.
- Alkaline cleaner -- permanganate.
- Immersion tanks.
- Water and air spray equipment.

Environment, Health, and Safety Considerations:

- Cleaners used in this process are highly alkaline or acidic. Workers should wear protective eyewear and clothing when handling these materials.
- Wastewater may require treatment on-site before being sent to public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Continental Airlines Cleaning Shop Process Chart, Cleaning Procedures - Method 8 Four Step Heavy-Duty Alkaline Cleaning and Acidic Descaling Without Inhibited Phosphoric Acid.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing and Hand-Wipe

Feasible Alternative: Aqueous cleaning -- alkaline

Special Notes on Alternative Process:

- Soils removed -- Jet engine exhaust carbon deposits, engine oil deposits, hydraulic fluids, and other soils on engine and aircraft parts.
- Substrates cleaned -- Safe for all metals, including titanium. Also safe on epoxy and polyurethane paints, plating, elastomers, plastics, and metals.
- This process is primarily used to clean and brighten engine thrust reversers, gear boxes and cowling.
- Do not allow the cleaner to dry on surfaces being cleaned.

Alternative Cleaning Process:

1. Cover areas that should not come into contact with cleaner, including lubricated parts, electrical units, and open systems.
2. Apply cleaner to surface with spray or brush.
3. Let cleaner stand for indicated time:
   a. Steel or titanium surfaces: 15-30 minutes or longer to remove carbon deposits. 30-60 minutes or longer to remove baked-on hydraulic fluid and oil deposits.
   b. Aluminum or magnesium surfaces: 30 minutes maximum to remove carbon deposits, baked-on hydraulic fluid, and oil deposits.
4. Reapply cleaner as necessary to prevent surface from drying.
5. Rub heavy soils with non-metallic bristle brush or cleaning pad, if necessary.
6. Rinse cleaner off thoroughly with hot or warm water. Any cleaner remaining on aluminum or magnesium surface will attack the metal.
7. Remove masking.

8. Reapply permanent corrosion to magnesium surfaces that do not have permanent paint/chemical treatment type corrosion protection.

9. Allow cleaned surface to dry.

Materials and Equipment Required:

- Alkaline cleaner -- engine thrust reverser, non-chromated, non-phenolic, non-flammable.

- Spray equipment, cleaning pads, non-metallic bristle brushes.

Environment, Health, and Safety Considerations:

- Workers should wear protective clothing and eyewear when handling alkaline cleaner.

- Wastewater may may require treatment on-site before being sent to public wastewater treatment facility.

- Brushes and pads containing cleaner and soils should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- AMS-1540, Type II cleaner, thrust reverser water base.

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Carbon Removal Cleaning - Aircraft and Engine Parts (900-1-1 No. 20). rev. 1-30-89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing

Feasible Alternative: Blasting -- high pressure steam/water

Special Notes on Alternative Process:

- **Soils removed --** Removes grease, carbon, and oil deposits.
- **Substrates cleaned --** Safe for use on all metals. Not for use on fragile components or on large areas of thin, unsupported material.
- Use of these processes is prohibited without prior approval.
- process parameters such as temperature, pressure, chemical additive, etc. must be approved by the technical authority.

Alternative Cleaning Process:

1. Mount or anchor the part to be cleaned to prevent movement and subsequent damage during the cleaning process.
2. Set nozzle workpiece at a distance of 50-150 mm for steam cleaning and 150-250 mm for high pressure water cleaning.
3. Wash the part according to the equipment manufacturer's instructions.
4. If a detergent was used in conjunction with the high pressure water or steam cleaning, wash the part a second time using clean water or steam to remove any residual detergent. For titanium parts, deionized water should be used.
5. Dry the part using a dewatering oil or dry compressed air.

Materials and Equipment Required:

- Clean water/stream. Possibly detergent and/or deionized water.
- High pressure cleaning equipment.
- Air spray equipment or dewatering oil for parts drying.

Environment, Health, and Safety Considerations:

- Wastewater may require treatment on-site before being sent to a public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Rolls-Royce Process Specification, High Velocity Steam/Water Cleaning (RPS 693, issue 1), written July 1992.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Vapor Degreasing

Feasible Alternative: Chlorinated solvent cleaning -- trichloroethylene

Special Notes on Alternative Process:

- Soils removed -- Removes grease and oil deposits.
- Substrates cleaned -- Safe for use on most metals, but may not be applicable to titanium.
- Immersion of parts must not exceed 30 minutes for any single cleaning operation.
- Trichloroethylene should be fully stabilized and inhibited.

Alternative Cleaning Process:

1. If heavy grease and dirt are present, remove it with a pressure kerosene wash.
2. Ensure that parts are dry and are at room temperature.
3. Place the parts in a basket or on a sling and immerse them in the trichloroethylene vapor.
4. Withdraw the parts slowly from the vapor when the temperature of the parts has increased to equal the temperature of the heated trichloroethylene vapor and allow the parts to drain while in the freeboard zone of the degreaser.
5. Examine the parts to be sure that all contaminants have been removed. If additional cleaning is required, reload the parts in a different orientation and repeat steps 3 and 4.

Materials and Equipment Required:

- Chlorinated solvent -- trichloroethylene.
- Kerosene.
- Pressure cleaning equipment.
- Vapor degreaser.

Environmental, Health, and Safety Considerations

- Trichloroethylene has been classified as a VOC, hazardous air pollutant, and toxic substance in many countries. Check federal and local regulations for emissions control requirements, worker exposure limits, and VOC recovery requirements.

- Spent solvent may be classified as hazardous waste and should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- MIL-T-27602 (trichloroethylene).

- 0-T-634 (trichloroethylene).

Additional specifications may exist.

Sources: (1) Rolls-Royce Engine Overhaul Processes Manual, Non-Aqueous Vapor and Liquid Degreasing (70-00-00-110-101-002), rev. 1/18/90.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Engine or Engine Modules
Assembled and Semi-Assembled Parts

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Spray or Hand-Wipe

Feasible Alternative: Aqueous cleaning -- alkaline

Special Notes on Alternative Process:

- Soils removed - Baked-on hydraulic fluid and engine oil deposits.
- Substrates cleaned -- Safe for use on paints, elastomers, and most metals. May be unsafe for titanium alloys. This process should be used to clean assembled and semi-assembled parts. Do not use for overhaul cleaning.

Alternative Cleaning Process:

1. Cover engine inlet, all open engine system lines and ducts, and lubricated parts.
2. Spray cleaner onto surface.
3. Let cleaner stand for 10-15 minutes. Reapply cleaner as necessary to prevent surface from drying.
4. Rub heavily soiled surfaces with non-metallic bristle brush. Apply additional cleaner, if necessary.
5. Rinse cleaner off thoroughly with 140-180°F (60-82°C) water spray.
6. If surface has not reached desired cleanliness, repeat process.
7. Allow surface to dry.
8. Remove covers .

Materials and Equipment Required:

- Alkaline cleaner -- modified amine type, non-chromated, non-phenolic, non-flammable.
- Spray equipment, non-metallic bristle brushes.

Environment, Health, and Safety Considerations:

- Workers should wear protective clothing and eyewear when handling alkaline cleaner.
- Wastewater may require treatment on-site before being sent to public wastewater treatment facility.
- Brushes containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Cleaning - Engine Exterior Surfaces - On-the-Washrack (900-1-3-2 No. 5), rev. 3/15/91.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Flight Control Surfaces

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Aqueous cleaning -- alkaline

Special Notes on Alternative Process:

- **Soils removed --** Carbon deposits, burned-on hydraulic fluid deposits, oils, and greases.
- **Substrates cleaned --** Aircraft exterior composite parts made of laminated graphite/epoxy, fiberglass/epoxy, and Kevlar/epoxy materials.
- To avoid water entrapment and heat delamination damage of composite materials, keep cleaner and water temperature below 150F (66°C) and pressure below 80 psi.

Alternative Cleaning Process:

1. Cover vents, ducts, and ports. Mask surfaces with openings and crevices to avoid entrapment of water or cleaning solution.
2. Apply cleaner using spray, brush, or wipe-on method.
3. Rub heavily soiled areas with clean mop or non-metallic bristle brush for better cleaning.
4. Let cleaner stand for 5-10 minutes. If necessary, reapply cleaner to prevent surface from drying.
5. Rinse surface thoroughly with cold or warm, low-pressure water.
6. Allow surface to dry.
7. Remove covers.

Materials and Equipment Required:

- Alkaline cleaner -- modified amine type, non-chromated, non-phenolic, non-flammable; or heavy duty solvent emulsion alkaline, non-chromated, non-phenolic, non-flammable.
- Spray equipment, mops, non-metallic brushes.

Environment, Health, and Safety Considerations:

- Workers should wear protective clothing and equipment when handling alkaline cleaner.
- Wastewater require treatment on-site before being sent to public wastewater treatment facility.
- Mops and brushes containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- MIL-C-87936, Type I or II (waterbased cleaner - heavy duty solvent emulsion alkaline).
- MIL-C-87937, Type II (waterbased cleaner).
- AMS-1528, Type II cleaner for aircraft exterior surfaces, emulsion, pressure spraying.
- AMS-1530, Type II cleaner for aircraft exterior surfaces, wipe-on, wipe-off, water miscible.

Additional specifications may exist.

Sources:
(1) Delta Airlines Process Standard, Cleaning Aircraft Exterior Composite Parts/Surfaces (900-1-1 No. 22), rev. 5/31/92.
(2) MD-80 Maintenance Manual, Aircraft Cleaning - Description and Operation, Equipment and Materials, rev. 9/1/86.
(3) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Flight Control Surfaces

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Aliphatic hydrocarbon cleaning -- mineral spirits

Special Notes on Alternative Process:

- **Soils removed --** Oil, grease, hydraulic fluid, and dried deposits such as dry film lubricants, adhesives, and lacquers.
- **Substrates cleaned --** Aircraft exterior composite parts made of laminated graphite/epoxy, fiberglass/epoxy, and Kevlar/epoxy materials.
- This process is to be used if the deposits being removed are wet. For removal of dry deposits, the Flight Control Surfaces-Organic Solvent Cleaning alternative may be used.

Alternative Cleaning Process:

1. Cover all vents, ducts, and ports. Mask openings and crevices to avoid solvent entrapment.
2. Apply mineral spirits to surface using spray, brush, or wipe-on method.
3. Rub heavier soiled areas with clean mops or non-metallic brushes for better cleaning.
4. Let cleaner remain on surface until soils can be removed. Reapply cleaner as necessary to prevent surface from drying.
5. Dry surface with clean mops or cloths.
6. Remove covers.

Materials and Equipment Required:

- Mineral spirits cleaner.
- Non-atomizing spray, mops, non-metallic brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Mineral spirits are flammable. Workers should observe normal fire safety precautions when handling the material. Synthetic grades may have flash points significantly higher and are safer to use.

- VOC recovery may be required when using mineral spirits. Check federal and local regulations.

- Mops, cloths, and brushes containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- PD-680, Type I, II, or III Federal specification (mineral spirits).

- ASTM D484-52, BS 245 (mineral spirits).

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Cleaning Aircraft Exterior Composite Parts/Surfaces (900-1-1 No. 22), rev. 5/31-91.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Flight Control Surfaces

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Organic solvent cleaning -- methyl ethyl ketone or. acetone

Special Notes on Alternative Process:

- Soils removed - Oil, grease, hydraulic fluid, and dried deposits such as dry film lubricants, adhesives, and lacquers.
- Substrates cleaned -- Aircraft exterior composite parts made of laminated graphite/epoxy, fiberglass/epoxy, and Kevlar/epoxy materials.
- This process is used to remove dry soil deposits. For removal of wet deposits, the Flight Control Surfaces-Aliphatic Hydrocarbon Cleaning alternative may be used.

Alternative Cleaning Process:

1. Cover all vents, ducts, and ports. Mask openings and crevices to avoid solvent entrapment.
3. Apply methyl ethyl ketone or acetone using spray, brush, or wipe-on method.
4. Rub heavier soiled areas with clean mops or non-metallic brushes for better cleaning.
5. Let solvent cleaner remain on surface until soils can be removed. Reapply cleaner as necessary to prevent surface from drying.
6. Dry surface with clean mops or cloths.
7. Remove covers.

Materials and Equipment Required:

- Methyl ethyl ketone or acetone cleaner.
- Non-atomizing spray, mops, cloths, non-metallic brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Methyl ethyl ketone and acetone are toxic and highly flammable. Workers should observe normal fire safety precautions when performing cleaning operations.

- Spent solvent may be classified as a hazardous waste and should be disposed of properly. Check federal and local regulations.

- VOC recovery may be required when using MEK or acetone. Check federal and local regulations.

- Mops, cloths, and brushes containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-M-261, Federal specification (MEK).

- 0-A-51 (acetone).

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard, Cleaning Aircraft Exterior Composite Parts/Surfaces (900-1-1 No. 22). rev. 5/31-91.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Electrical Equipment

Chemical(s) Currently Used: CFC-113

Cleaning Methods Employed: Aerosol Spray

Feasible Alternative: Aqueous cleaning -- alkaline, ultrasonic

Special Notes on Alternative Process:

- Soils removed - Dirt.
- Substrates cleaned - Alkaline cleaners are safe on most metals. Some cleaners may be not be safe on titanium and/or titanium alloys. Consult manufacturer for specifics.
- This process can be used to clean inaccessible or difficult-to-clean areas, such as those in electrical components. Several different cleaning solutions can be used with ultrasonic equipment.

Alternative Cleaning Process:

1. Prepare cleaning solution as directed by manufacturer.
2. Remove heavier soils first manually using organic solvent spray.
3. Immerse in ultrasonic cleaning tank for 5-20 minutes, as required.
4. Rinse in ultrasonic hot water tank (150-17°F, 66-77°C) for 5-20 minutes, according to cleaning solution.
5. Air dry.
6. Additional cleaning steps may be necessary, depending on the cleaner used. Check with manufacturer for details.

Materials and Equipment Required:

- Alkaline cleaner -- hot tank, non-chromated, non-phenolic, non-flammable.
- Ultrasonic cleaning tanks.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling alkaline cleaners.

- Wastewater may require treatment on-site before being sent to public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Delta Airlines Process Standard; Cleaning - Ultrasonic (900-1-1 No. 17), rev. 11/15/91.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Electrical Equipment

Chemical(s) Currently Used: CFC-113

Cleaning Methods Employed: Aerosol Spray

Feasible Alternative: Organic solvent cleaning -- isopropyl alcohol

Special Notes on Alternative Process:

- Soils removed - Dirt.
- Substrates cleaned - Metals and Composites. .

Alternative Cleaning Process:

1. Wipe electrical equipment with cloth dipped in isopropyl alcohol.

Materials and Equipment Required:

- Isopropyl alcohol cleaner.
- Cloths.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Isopropyl alcohol is flammable. Workers should observe normal fire safety precautions when handling the material.
- VOC recovery may be required when using. isopropyl alcohol. Check federal and local regulations.
- Cloths containing spent solvent should be disposed of properly.

Relevant Specifications WhichMay Need to Be Considered:

- 0-A-396.

Additional specifications may exist.

Sources: (1) MD-80 Maintenance Manual, Aircraft Exterior Cleaning, (12-22-01 Pg. 702), rev. 9/1/86.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/89.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Hydraulic Lines

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe or Vapor Degreasing

Feasible Alternative: Aqueous cleaning -- water-base soap solutions

Special Notes on Alternative Process:

- **Soils removed --** Corrosion, salts, and dirt.
- **Substrates cleaned --** Stainless steel hydraulic lines.

Alternative Cleaning Process:

1. Loosen clamps.
2. Wash lines, including area under clamps and inside the clamps with waterbase soap solution.
3. Rinse area thoroughly to remove soap.
4. Dry hydraulic lines under clamps thoroughly using clean, dry compressed air.

Materials and Equipment Required:

- Waterbase soap solution cleaner.

Environment, Health, and Safety Considerations:

- Wastewater may require treatment on-site before being sent to public wastewater treatment facility.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) DC-10 Maintenance Manual, Cleaning and Protecting Hydraulic Lines - Maintenance Practices (20-40-05, pp. 201-2), rev. 4/1/80.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Aircraft Seat Covers and Curtains/Draperies

Chemical(s) Currently Used: CFC-113

Cleaning Methods Employed: Dry Cleaning

Feasible Alternative: Chlorinated solvent cleaning -- perchloroethylene

Special Notes on Alternative Process:

- **Soils removed** -- Dirt.
- **Substrates cleaned** -- Man-made fiber blends.
- This method may not be effective for cleaning leather seat covers.

Alternative Cleaning Process:

1. Clean according to equipment manufacturer's instruction in specialized equipment built for use with perchloroethylene.

Materials and Equipment Required:

- Perchloroethylene cleaner.
- Dry cleaning equipment.
- Fire protection equipment.

Environment, Health, and Safety Considerations:

- Perchloroethylene has been classified as a VOC, hazardous air pollutant, and toxic substance in many countries. Check federal and local regulations for emissions control measures, worker exposure limits, and VOC recovery requirements.
- Spent solvent may be classified as hazardous waste and should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Delta Airlines Standard Operating Practice.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Coating
Polyurethane Coating

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe

Feasible Alternative: Organic solvent cleaning -- methyl ethyl ketone or blends

Special Notes on Alternative Process:

- **Soils removed --** Light oil and grease.
- **Substrates cleaned --** Certain metal surfaces prior to the application of the exterior polyurethane coating system and its primers. Different metals may required slightly different procedures, as noted below.

Alternative Cleaning Process:

All aluminum and steel alloy surfaces -

1. Apply methyl ethyl ketone or organic solvent blend with clean, lint-free white cloth. Wipe cleaner off immediately with clean, dry, lint-free white cloth.

Continue with the following steps only for non-anodized aluminum and titanium alloy surfaces -

2. Abrade surface with very fine, abrasive pads and water.
3. Spray rinse the abraded surface with tap water.
4. Apply phosphoric acid cleaner with clean, lint-free cloths or fiber bristle brush.
5. Scrub surface with fiber bristle brush for 5 minutes.
6. Reapply cleaner, if necessary, to prevent it from drying on surface.
7. Spray rinse surface again with clean water.
8. If "water break free" surface is not attained, repeat cleaning process. There is a water break free surface when the rinse water coalesces into large lenses without sudden flashed.
9. Check the acidity of the surface while it is still wet. The pH should be neutral or slightly acid, at pH 6 or 7. If the surface has a pH below 6, then re-rinse with tap water. Check acidity level and repeat rinse, if necessary.

10. Allow surface to air dry for 2-24 hours at a minimum temperature of 70°F (21°C). Do not apply primer until surface is completely dry.

Materials and Equipment Required:

- Cleaner -- methyl ethyl ketone.
- Organic solvent blend cleaner.
- Aluminum phosphoric acid type cleaner.
- Very fine abrasive pads.
- Line-free cloths or fiber bristle brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Methyl ethyl ketone is toxic and highly flammable. Workers should avoid breathing vapors for prolonged periods of time. Protective clothing should be worn when handling solvent.
- Spent solvent may be classified as a hazardous waste and should be disposed of properly. Check federal and local regulations.
- VOC recovery may be required when using MEK or organic solvent blends. Check federal and local regulations.
- Mops and cloths containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-M-261, Federal specification (MEK).
- MIL-A-9962, Military specification (very fine abrasive pad).
- MIL-C-38736.

Additional specifications may exist.

Sources: (1) Lockheed L-1011 Maintenance Manual, Application of Exterior Coating System for the L-1011 Aircraft (20-51-11), rev. 5/1/92.
(2) Lockheed Fort Worth Company

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Coating
Chromate Conversion Coating

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe

Feasible Alternative: Organic solvent cleaning -- methyl ethyl ketone or blends

Special Notes on Alternative Process:

- **Soils removed** - Light oil and grease.
- **Substrates cleaned** - Aluminum alloys.

Alternative Cleaning Process:

1. Seal holes and joints on aircraft parts containing honeycomb or foam plastic to prevent chrome conversion coating from seeping in.
2. Clean surface using methyl ethyl ketone or organic solvent blend applied with a clean brush or rag.
3. Air dry surface with warm air or rub until dry.
4. Remove organic, inorganic, and hydraulic fluid resistant finishes with abrasive, aluminum pad. Scrub until surface is shiny.
5. Use absorbent cotton cloth to remove loose particles.
6. Wipe surface with methyl ethyl ketone and absorbent cotton cloth until no particles are found on the cloth.
7. Air dry for at least 15 minutes.

Materials and Equipment Required:

- Cleaner -- methyl ethyl ketone (MEK).
- Organic solvent blend cleaner.
- Soft bristle brushes or rags.
- Abrasive aluminum pads.

- Clean, dry, lint-free absorbent cotton cloths.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Methyl ethyl ketone is toxic and highly flammable. Workers should avoid breathing vapors for prolonged periods of time. Protective clothing should be worn when handling the solvent.
- Spent solvent may be classified as a hazardous waste and should be disposed of properly. Check federal and local regulations.
- VOC recovery may be required when using MEK or organic solvent blends. Check federal and local regulations.
- Rags, brushes, pads, and cloths containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-M-261 Federal specification (MEK).
- MIL-C-38736.

Additional specifications may exist.

Sources: (1) Boeing 767 Maintenance Manual, Alodine Coating - Cleaning/Painting, rev. 5/10/92.
(2) Lockheed Fort Worth Company

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Coating
Chromate Conversion Coating

Chemical(s) Currently Used: Methyl. chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe

Feasible Alternative: Semi-aqueous cleaning -- alkaline and aliphatic naphtha

Special Notes on Alternative Process:

- **Soils removed --** Light oil and grease.
- **Substrates cleaned** -- Aluminum alloys.

Alternative Cleaning Process:

1. Prepare cleaning solution by mixing alkaline cleaner, water, and aliphatic naphtha as instructed.
2. Apply cleaner to surface.
3. Let cleaner stand for at least 10 minutes. Reapply cleaner as necessary to prevent surface from drying.
4. Scrub surface vigorously with soft-bristled brushes. Pay special attention to countersink areas and around rivet heads.
5. Flush surface thoroughly with high-pressure water rinse.
6. Check for water breaks. If water breaks are observed, repeat cleaning cycle.

Materials and Equipment Required:

- Alkaline cleaner.
- Aliphatic naphtha solvent.
- Soft-bristled brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Workers may need to wear protective eyewear and clothing when handling cleaning solution.
- Wastewater may require treatment on-site before it is sent to a public wastewater treatment facility
- Aliphatic naphtha is flammable. Workers should observe normal fire safety precautions when handling the material.
- VOC recovery may be required when using aliphatic naptha. Check federal and local regulations
- Brushes containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- 1T-N-95, Type I (aliphatic naphtha).

Additional specifications may exist.

Sources: (1) Boeing 747 Maintenance Manual, Cleaning Skin Prior to Alodine Treatment (51-24-07, pp. 702-3), rev. 12/25/90.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Coating

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Varied (depends on cleaner)

Feasible Alternative: Organic Solvent cleaning

Special Notes on Alternative Process:

- Different coatings often require different types of cleaning solution. This sheet presents various solvents that may be used prior to a number of aircraft coating operations.

  -- Intumescent (heat protective) finish: methylene chloride

  -- Conductive coating for exterior fiberglass and Kevlar: aliphatic naphtha

  -- Corrosion inhibiting coating: butyl acetate, methyl isobutyl ketone (MIBK), toluene, xylene

  -- Non-glare finish: toluene, xylene, MIBK, methyl ethyl ketone (MEK)

  -- Non-skid finish: aliphatic naphtha, MIBK, MEK, toluene

  -- High temperature coating for titanium: mineral spirits, waterbased alkaline

Alternative Cleaning Process: .

- Varies with cleaner chosen.

Materials and Equipment Required:

- Varies with cleaner chosen.

Environment, Health, and Safety Considerations:

- Varies with cleaner chosen.

Relevant Specifications Which May Need to Be Considered:

- MIL-D-6998 (methylene chloride).
- TT-N-95 (aliphatic naphtha).
- TT-B-838 (normal butyl acetate).
- TT-M-268 (methyl isobutyl ketone).
- TT-T-548 (toluene).
- ASTM 845 or 846 (xylene).
- TT-M-261 (methyl ethyl ketone).

Additional specifications may exist.

Sources: (1) Boeing 767 Maintenance Manual, Coatings (51-21-11,51-24-03 to 07), rev. 2/10/90, 8/10/91, 2/10/90, 5/10/91, 2/10/90, 2/10/90).

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Adhesive Bonding

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Spray or Hand-Wipe

Feasible Alternative: Organic solvent cleaning -- isopropyl alcohol

Special Notes on Alternative Process:

- Soils removed - Finger grease and tape residues.
- Substrates cleaned - Safe for most materials including metal alloys, composites, plastics/polymers and elastomers.

Alternative Cleaning Process:

1. Wipe with a clean cloth moistened with isopropyl alcohol.

Materials and Equipment Required:

- Isopropyl alcohol cleaner.
- Clean cloths.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Isopropyl alcohol is flammable. Workers should observe normal fire safety precautions when handling this material.
- VOC recovery may be required when using isopropyl alcohol. Check federal and local regulations.
- Cloths containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

Additional specifications may exist.

Sources: (1) Delta Airlines Standard Operating Practice.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Adhesive Bonding

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe

Feasible Alternative: Semi-Aqueous Cleaning -- Terpene

Special Notes on Alternative Process:

- Soils removed - Grease and oil contaminants.
- Substrates cleaned - Safe on most materials, including aluminum and graphite composite.

Alternative Cleaning Process:

1. Wipe surface to be bonded using absorbent cotton cloth moistened with citrus cleaner.
2. Wipe surface using water-moistened absorbent cotton cloth remove any residue contaminants.
3. Immediately wipe surface dry with clean cloth.

Materials and Equipment Required:

- Terpene Cleaner -- d-limonene based.
- Absorbent cotton cloths.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Terpene cleaner is flammable. Workers should observe normal fire safety precautions.
- Prolonged skin contact with terpene cleaner may cause dryness and burns. Workers inhaling highly concentrated cleaner may experience headaches and nausa.
- Workers should wear protective eyewear and clothing when handling cleaner.
- Cloths containing spent cleaner should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- MIL-C-85704.
- MIL-C-87937, Type I (terpenes, citrus).

Additional specifications may exist.

Sources: (1) Citrikleen Product Description and Material Safety Data Sheet, Pentone Corporation.
(2) Rillings Jr., Kenneth W. "Replacement of Hazardous Solvents with a Citrus Based Cleaner for Hand Cleaning Prior to Painting and Structural Bonding." .Boelng Waste Reduction. 1991.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Fluorescent Penetrant Inspection

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Chlorinated solvent cleaning -- trichloroethylene

Special Notes on Alternative Process:

- **Soils removed --** Most organic soils, finger grease, inorganic salts, and residues.
- **Substrates cleaned --** Safe for most engine parts. May be unsafe for titanium engine parts.
- This cleaning process is primarily used prior to fluorescent penetrant inspection of engines.

Alternative Cleaning Process:

1. Lower part into trichloroethylene degreaser at a maximum rate of 11 feet (3.35 m) per minute.
2. Remove part and wipe with clean cloth.

Materials and Equipment Required:

- Trichloroethylene cleaner.
- Vapor degreaser.
- Clean cloths.
- Fire. protection equipment may be required.

Environment, Health, and Safety Considerations:

- Trichloroethylene has been classified as a VOC, hazardous air pollutant, and toxic substance in many countries. Check federal and local regulations for emissions control measures, worker exposure limits, and VOC recovery requirements.
- Spent solvent may be classified as a hazardous waste and should be disposed of properly.
- Cloths containing spent solvent should be disposed of properly.

Relevant Specificatiobs Which May Need to Be Considered:

- MIL-T-27602 (trichloroethylene).
- 0-T-634 (trichloroethylene).

Additional specifications may exist.

Sources (1) Boeing 747 Maintenance Manual, Fluorescent Penetration Inspection - Maintenance Practices (70-10-90), rev. 4/25/84.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Fluorescent Penetrant Inspection

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Organic solvent cleaning -- methyl ethyl ketone

Special Notes on Alternative Process:

- Soils removed - All.
- Substrates cleaned - Titanium engine parts.
- This cleaning process is primarily used prior to fluorescent penetrant inspection of engines.

Alternative Cleaning Process:

1. Wipe part with clean cloth moistened with methyl ethyl ketone.

Materials and Equipment Required:

- Methyl ethyl ketone cleaner.
- Clean cloths.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- MEK is toxic and highly flammable. Cleaning with these substances should not occur in the presence of sparks or flames. Workers should avoid, prolonged breathing of vapors. Protective clothing should be worn when handling the solvent.
- VOC recovery may be required when using MEK Check federal and local regulations.
- Spent solvent may be classified as hazardous waste and should be disposed of properly.
- Cloths containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-M-261 (MEK).
- MIL-I-25B5E (wipe off cleaner/remover for fluorescent penetrant inspection).

Additional specifications may exist.

Sources: (1) Boeing 747 Maintenance Manual, Fluorescent Penetrant Inspection - Maintenance Practices (70-10-09), rev. 4/25/84

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

During Fluorescent Penetrant Inspection

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Organic Solvent cleaning -- isopropyl. alcohol, methyl ethyl ketone, or acetone

Special Notes on Alternative Process:

- **Soils removed** -- All organic soils, finger grease, and shop dirt.
- **Substrates cleaned --** Safe for use on all metals.

Alternative Cleaning Process:

1. Apply fluorescent penetrant as instructed.
2. Wait appropriate length of time to allow penetrant to be absorbed by surface. Wipe excess penetrant off with clean cloth.
3. Use ultraviolet light to determine whether unwanted penetrant remains on surface. If so, use clean cloth moistened with solvent to remove. If penetrant still remains on part, use solvent spray.
4. Apply developer as instructed.
5. While inspecting the part under ultraviolet light, wipe clean area once with solvent and cotton swab or small, high quality hair brush.
6. After inspection, remove developer and penetrant from part with water spray or brush and water.
7. If developer or penetrant remains on part, remove with solvent spray or soak part in solvent.

Materials and Equipment Required:

- Isopropyl alcohol, methyl ethyl ketone, or acetone cleaner.
- Cloths, brushes, spray equipment.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- Isopropyl alcohol, MEK, and acetone are flammable. Workers should observe normal fire safety precautions when handling the material.
- Spent solvent may be hazardous and should be disposed of properly. Check federal and local regulations.
- VOC recovery may be required when using isopropyl alcohol, MEK, or acetone. Check federal and local regulations.
- Cloths and brushes containing a spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- 0-A-51, Federal specification (acetone).
- TT-M-261, Federal specification (MEK).
- MIL-I-25B5E (wipe off cleaner/remover for fluorescent penetrant inspection).

Additional specifications may exist.

Sources: (1) Boeing 767 Maintenance Manual, Fluorescent Penetrant Inspection - Maintenance Practices (70-11-06). rev. 11/10/91.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Reassembly

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe or Immersion

Feasible Alternative: Hydrocarbon cleaning

Special Notes on Alternative Process:

- **Soils removed** -- Preservative oils and temporary markings.
- **Substrates cleaned** - Corrodible steels/light alloys.

Alternative Cleaning Process:

1. Wipe, swab, or immerse part in hydrocarbon cleaner.
2. Allow part to air dry or assist with compressed air.

Materials and Equipment Required:

- Medium flashpoint hydrocarbon cleaner.
- Clothes, mops, swabs, or immersion tanks.
- Forced air drying equipment.

Environment, Health, and Safety Considerations:

- Cloths, mops, and swabs containing solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

Additional Specifications may exist.

Sources: (1) Rolls-Royce Standard Operating Practice.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Welding

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Hand-Wipe or Immersion

Feasible Alternative: Organic Solvent cleaning -- methyl ethyl ketone or acetone

Special Notes on Alternative Process:

- **Soils removed --** All organic soils.
- **Substrates cleaned --** Safe for use on all metals..

Alternative Cleaning Process:

1. Use stainless steel rotary brush or abrasive medium (see equipment) to remove dirt, paint, and scale and carbon deposits from front and back surface of weld area.
2. If surface to be welded is made of aluminum, use abrasive medium to remove any chemical protective coatings. Clear front and back surfaces within 0.5 inches of weld area.
3. Perform appropriate machining operations in area with crack in preparation for welding.
4. Clean weld area with methyl ethyl ketone (MEK) or acetone and clean cotton cloth.
5. Etch and weld area as instructed.

Materials and Equipment Required:

- Methyl ethyl ketone or acetone cleaner.
- Stainless steel rotary brush; or 80-320 grit abrasive roll, disk, or sheet.
- Clean cotton cloth.
- Fire protection equipment may be required.

Environment, Health, and Safety Issues:

- Methyl ethyl ketone and acetone are toxic and highly flammable. Cleaning with these substances should not occur in the presence of sparks or flames. Workers should avoid prolonged breathing of vapors. Protective clothing should be worn when handling the solvents.

- Spent solvent may be hazardous and should be disposed of properly. Check federal and local regulations.
- VOC recovery may be required when using MEK or acetone. Check federal and local regulations.
- Cloths contaminated with cleaner should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-M-261 (MEK). .
- 0-A-51 (acetone).

Additional specifications may exist.

Sources: (1) General Electric Commercial Engine Standard Practices Manual, Welding and Brazing Practices (70-41-00), rev: 7/15/84.
(2) Boeing 767 Maintenance Manual, Material Equivalents, rev. 4/24/91.

AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEET

Prior to Painting

Chemical(s) Currently Used: Methyl chloroform (1,1,1-trichloroethane)

Cleaning Methods Employed: Aerosol Spray or Hand-Wipe

Feasible Alternative: Organic solvent cleaning -- methyl ethyl ketone and toluene

Special Notes on Alternative Process:

- Soils removed - Residual coatings, adhesive flash, stripper residue, loose dust, and. water soluble contaminants.

- Substrates cleaned - Surfaces with chrome conversion coatings should not be abrasive cleaned.

Alternative Cleaning Process:

1. Mask or cover areas that should not come into contact with solvents, cleaners, and chrome conversion coating.

2. Scrub surface with MEK or toluene to remove residual coatings and adhesive flash. Use wooden or plastic scrapers, sand paper, or 100-240 grit aluminum oxide abrasive pads if necessary.

3. If contaminants remain on surface, remove with stripper. Do not allow stripper to come into contact with fiberglass, alumized fiberglass, acrylic windows, or sealant fillets.

4. Use hot water (135-125°F, 57-63°C), at 10-20 gpm per station, to remove stripper residue, loose dust, and water soluble contaminants.

5. Moisten a stiff bristle brush with an MEK-toluene mixture (1:1 by volume). Use brush to scrub around fasteners, seams, and lap joints.

6. Clean surface to be painted with MEK-toluene mixture.

7. Wipe surface dry with absorbent cotton cloth.

8. If cloth contains visible residue, repeat MEK-toluene cleaning procedures (steps 6 and 7).

9. Abrade stainless steel and titanium surfaces with silicon carbide paper. Do not abrade aluminum frame-sprayed fiberglass or chrome conversion coated surfaces.

Materials and Equipment Required:

- Methyl ethyl ketone (MEK) and/or toluene.
- Stripper.
- Sandpaper wooden or plastic scrapers, or aluminum oxide abrasives.
- Silicon carbide paper.
- Clean, absorbent cotton cloths.
- Stiff bristle brushes.
- Fire protection equipment may be required.

Environment, Health, and Safety Considerations:

- MEK and toluene are toxic and highly flammable. Workers should avoid breathing vapors for long periods of time. Protective clothing should be worn when handling the solvents. Spent solvent may be classified as a hazardous waste and should be disposed of properly.
- Spent solvent may be hazardous and should be disposed of properly. Check federal and local regulations.
- VOC recovery may be required when using MEK or toluene. Check federal and local regulations.
- Brushes, cloths, and other items containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-M-261 (MEK).
- TT-T-548 (Toluene).
- JAN-T-171, Grade A (Toluene).

Additional specifications may exist.

Sources: (1) Boeing 747 Maintenance Manual, Interior and Exterior Finishes - Cleaning/Painting, (51-21-02, pp. 701-2), rev. 8/25/84.

SOURCES USED IN AIRCRAFT MAINTENANCE ALTERNATIVE CLEANING SUMMARY SHEETS

1. Boeing 747 Maintenance Manual
2. Boeing 767 Maintenance Manual
3. Continental Airlines Cleaning Shop Process Chart
4. DC-10 Maintenance Manual
5. Delta Airlines (DAL) Process Standard
6. General Electric Commercial Engine Standard Practices Manual
7. Lockheed L-1011 Maintenance Manual
8. MD-80 Maintenance Manual
9. Rilings Jr., Kenneth W., Martin Marietta Astronautics Group, "Replacement of Hazardous Solvents with a Citrus Based Cleaner for Hand Cleaning Prior to Painting and Structural Bonding."
10. Rolls-Royce Engine Overhaul Processes Manual

USE OF CFC-113 AND METHYL CHLOROFORM IN NONCLEANING APPLICATIONS

While the major uses of CFC-113 and methyl chloroform in aircraft maintenance procedures are for cleaning of metal and electronic assemblies, there are several additional applications in which these substances are used in smaller quantities. These uses include:

- Coatings
- Adhesives
- Lubricant Carrier
- Mold Release Agent Carrier
- Thermal Stress Testing
- Diluting Agent
- Patch Testing

This section presents a brief description of the substitutes currently available for CFC-113 and methyl chloroform in these applications.

Coatings

Methyl chloroform has been used in recent years as a replacement for solvents classified as volatile organic compounds (VOCs) in aerospace coatings. The advantages offered by methyl chloroform over other solvents such as in the formulation of coatings include its lack of offensive odor and its nonflammability.

Due to the impending phaseout of methyl chloroform. aerospace manufacturers and maintenance facilities alike have been forced to develop alternative coatings formulations. The most likely alternative, which has already been recommended by one large aircraft manufacturer, is the replacement of solvent-based coatings with water-based formulations. Other alternatives to methyl chloroform include a return to the chlorinated solvents used prior to the introduction of methyl chloroform (perchloroethylene and methylene chloride), reformulation with alcohols or other oxygen-containing hydrocarbons, and the use of powder coatings which are applied with heat.

Adhesives

The currently available alternatives to the use of methyl chloroform in the formulation of adhesives for the aerospace industry are similar' to those described above for coatings. In addition to water-based and solvent-based adhesives, hot-melt adhesives have already garnered a large share of the adhesives market. This type of adhesive is applied in a molten state and forms a strong bond upon cooling to room temperature. When the phaseout of methyl chloroform is complete, it is expected that water-based and hot-melt adhesives combined will account for between 50 and 75 percent of all formulations.

Lubricant Carrier

CFC-113 is occasionally used in a special technique for lubricating instrument bearings with very small amounts of lubricant. An example of these occasions are ball bearings which need to carry small amounts of thin film lubricant which will remain "stable" on the ball and contact surfaces for extended periods of time. In such applications, the lubricating oil is placed in a solution of CFC-113 which is then applied to a clean, dry bearing. Lubricants typically used in these processes are polyalphaolephins. A solution might consist of approximately 60 mg of polyalphaolephin in 5 ml of CFC-113. The solution is applied using a syringe or an automated precision dispenser. Another minor use of CFC-113 is as a carrier agent for certain solid film lubricants that are applied to faying surfaces.

The properties which make CFC-113 useful as a lubricant carrier include its low surface tension (allowing for better surface wetting), its high evaporation rate, and its chemical stability. The most likely alternatives to the small amounts of CFC-113 used in these applications are HCFC-141b and n-hexane. Both have similar physical properties to CFC-113 with respect to lubricant transport, chemical properties, and drying characteristics. It is generally believed that HCFC-141b is preferable to n-hexane since it has no flash point. However, at the low levels of n-hexane .which would be used, and with adequate safety precautions, the risk of fire would be low.

Mold Release Agent Carrier

Methyl chloroform is sometimes used as a solvent in mold release agents which are sprayed onto a mold prior to molding (these agents are commonly known as external release agents). The active ingredient in these agents is often a wax, fatty acid, silicone oil, or fluoropolymer. The active component is combined with solvent until the active ingredient makes up between one and five percent of the mixture. This dilution allows for an even application of the release agent.

The general trend in industry is currently to move away from external release agents in favor of internal release agents, agent which are mixed with the molding compound. The use of internal release agents does not require methyl chloroform use. The other primary alternative under investigation is the use of water-based external release agents. The primary problems with these formulations however, is the fact that they evaporate very slowly and can reduce the temperature of the mold.

Thermal Stress Testing

Chlorofluorocarbons have commonly been used in thermal stressing procedures to determine the location of faulty components in failed electronic circuit boards. To check a component, solvent is directly applied to the component using an aerosol spray. When the solvent evaporates, it quickly lowers the temperature of the component to approximately -60°F (-51°C). Thus, solvents used in thermal stressing are often referred to as "freezing compounds".

Currently, four techniques have the potential to replace the use of chlorofluorocarbons for thermal stressing. One alternative uses compressed air in a mechanical device containing a Vortex tube to produce cold air. Another alternative uses a small hand held Dewar flask containing liquid nitrogen. Through various nozzle arrangements, the technician can achieve a fair amount of control over the discharge of a small stream of nitrogen. However, care must still be taken not to overcool the component. At least one major U.S. airline has successfully replaced CFC-12 with liquid nitrogen in this application.

Both of these alternatives have an advantage over using aerosol freezing compounds in that they discharge fluid free of electrostatic charge. The aerosol cans, on the other hand, currently emit solvent with an electrostatic charge ranging from 50 to 600 volts.

The third alternative utilizes a small, hand-held cylinder from which carbon dioxide is supplied through a hose and nozzle. The nozzle design permits some control of the discharge temperature. At least one major company in the U.S. has successfully implemented this alternative.

A fourth alternative uses an aerosol can containing HFC-134a to cool components. This method is also being used successfully at a major airline in the U.S. The primary advantage of this alternative is the similarity with CFC-based aerosols in the method of use. Its major drawback, however, is its relatively high cost compared to the other three alternatives presented here.

Diluting Agent

CFC-113 is sometimes used as a diluting agent for oils and other substances. For example, during a patch test, hydraulic oil is removed from a particular location on the aircraft and diluted with solvent to reduce its viscosity. The diluted oil is then passed through a filter to capture any existing particulate contamination for further examination.

Patch Testing

During normal operations, aircraft hydraulic systems may become contaminated with metallic and nonmetallic panicles resulting from internal wear, failure of system components, or incorrect maintenance and servicing operations. Excess concentration of these particles could result in failure of the hydraulic system. Regular testing is required to insure that contamination levels remain within acceptable limits.

Contamination testing has traditionally been performed using what. is known in the field as the "patch test." In this procedure, hydraulic fluid is drawn from the system, diluted to a known volume with an approved solvent, and passed through a test filter membrane of known porosity. All particulate matter in excess of a size determined by the filter characteristics is retained on the surface of the membrane. This causes the membrane to discolor by an amount proportional to the particulate level of the fluid sample.

Solvents currently used as diluting agents are CFC-113, MCF, and a petroleum distillate defined by U.S. federal specification PD-680, Type II. CFC-113 is generally the preferred solvent for these' maintenance activities because its complete and rapid evaporation allows for quick sample readings.

Elimination of ozone-depleting substances will leave PD-680, Type II as the only approved solvent for use in patch tests. While PD-680 offers an acceptable temporary alternative, it is not a permanent solution. Problems associated with using PD-680, Type II in the patch test include increased drying time, use of inaccurate color standards, and subjective interpretation of those standards. The end result is a time consuming and sometimes inaccurate testing procedure for hydraulic fluid contamination.

Use of an electronic particle counter offers a viable alternative to the patch test itself. This equipment requires no hazardous solvents, and test results are accurate and non-subjective. Prototypes of this equipment are currently in use at four U.S. Navy intermediate maintenance-level facilities. Results of the testing so far have been extremely positive.

RECAP

The discussions presented in this manual have described a step-by-step approach to eliminating CFC-113 and methyl chloroform in aircraft maintenance cleaning operations. The steps include:

- Determine where and why CFC-113 and methyl chloroform are used in cleaning operations;
- Characterize existing cleaning materials and methods;
- Establish criteria for selecting alternative cleaning methods;
- Perform the necessary qualification tests of alternative cleaning methods as required by aircraft and engine manufacturers.
- Review feasible alternatives to replace solvent cleaning and determine which alternative best suits the cleaning needs;
- Consider options for wastewater treatment and waste, water, and air emissions reduction.

The next section presents several case studies which provide examples of successful programs to eliminate CFC-113 and methyl chloroform in the aircraft maintenance industry.

CASESTUDIES OF INDUSTRIAL PRACTICES

The following section presents actual industrial experiences with some of the alternative technologies discussed earlier in this manual.

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 express or implied by EPA, ICOLP, ICOLP committee members, and the companies that employ the ICOLP committee members.

Case Study #1:	De-Waxing Aircraft Components Using Steam Instead of Solvents
Case Study #2:	An Alternative to Freon CFC Sprays for Component Cooling on Printed Circuit Boards
Case Study #3:	Development and Use of a Volatile Aqueous Cleaner
Case Study #4:	Substitution of Low Vapor Pressure Organic Solvents and Aqueous Cleaners for CFC-113 Based Cleaning Solvent
Case Study #5:	Replacement of a CFC-Based Release Agent
Case Study #6:	Replacement of Trichloroethylene at Saab Aircraft
Case Study #7:	An Alternative to Patch Test for Determining Hydraulic Fluid Contamination Levels
Case Study #8:	Reduction of Ozone-Depleting Solvent Use at British Airways

CASE STUDY #1: DE-WAXING AIRCRAFT COMPONENTS USING STEAM INSTEAD OF SOLVENTS

I. Summary

Warner Robins Air Logistic Center's Plating Shop eliminated its use of 1,1,1-trichloroethane to remove wax from masked parts. Wax is 'now removed from aircraft parts using high pressure steam cabinets.

II. Introduction

Aircraft parts are masked prior to chrome plating in order to prevent electroplating in areas not required. Warner Robins uses micro-crystalline beeswax in combination with electroplating tape to mask its parts. Before converting to nonozone-depleting technology, Warner Robins removed the wax after chrome plating by placing the part in a vapor degreaser for several hours. The heated vapor of 1,1,1-trichloroethane dissolved the wax. Approximately 500 chrome plated parts were de-waxed in two vapor degreasers every month, causing wax to accumulate on the bottom of the degreaser and form a thick sludge. The degreasers had to be cleaned out weekly to maintain cleaning efficiency and prevent massive accumulation of the wax sludge. Four hundred gallons of 1,1,1-trichloroethane were used per week to replenish the two degreasers. Approximately 300 gallons of wax-contained solvent were cleaned out from the degreasers and recycled in another organization on-base.

Because of the Air Force's stringent ozone depleting substance (ODS) elimination goals, the Plating Shop needed to find a replacement for vapor degreasing subsequent to chrome plating. This would mean finding an alternative that could serve the same dual role -- removing wax and degreasing parts. Unfortunately, the alternatives to degreasing such as aqueous cleaning and parts washing could not remove the wax sufficiently. Therefore, Warner Robins was forced to find a separate solution for degreasing and de-waxing the aircraft parts.

The company now uses steam to remove the wax but continues vapor degreasing to degrease parts. Using the new de-waxing method, parts are placed inside de-wax cabinets after chrome plating. The de-wax cabinets are equipped with numerous high pressure steam nozzles directed toward the center of the cabinet. High pressure steam directed at the part. is used to impinge the wax from the surface. The steam spray and the heat work in combination to remove the remaining wax.

III. The Alternative Selection Process

The plan to install de-wax cabinets was incorporated into Warner Robin's larger renovation project to overhaul the entire plating portion of the facility. The selection of technology was performed by the company's production/ process engineers in cooperation with the renovation design contractors. The design contractors wrote specifications for the de-wax cabinets and a team of base engineers (Plant Services, Civil Engineering, Environment Management, Base Safety, etc.) reviewed the specifications prior to inclusion into the renovation project.

Because wax was only used in the chrome plating process, de-waxing became a part of that plating line. This created a space constraint since the system could be no larger than the chrome plating tanks. The problem was solved when the engineering team contacted the manufacturer of the plating system, which advertised in a metal finishing trade magazine that it built steam heated cabinets which were capable of de-waxing parts. The design contractor wrote specifications for the equipment, and the de-wax steam cabinets were installed.

Cost data for the cabinets installed at Warner Robins are not available because the equipment was part of the larger overhaul contract. However, cost information and vendor literature can be obtained from the manufacturer:

D.C. Cooper Corporation
1467 S. Michigan Ave.
Chicago, IL 60605-2810
Tel: 312-427-8046
Fax: 312-427-9461

IV. Environment, Health, and Safety

The Plating Shop accounts for 75 percent of the entire base's 1,1,1-trichloroethane consumption. Eliminating this source of ODS consumption will help the base reach the Air Force's stringent ODS elimination goals. Currently, vapor degreasers are still used to degrease parts. However, because degreasers are no longer used to de-wax, the need to clean out the equipment has decreased from weekly to monthly. Additionally, the distillation columns in recycling equipment also require less frequent cleaning because the used solvent is cleaner since there is less wax.

V. Conclusion

Through cooperation between production/process engineers and design contractors, Warner Robins was able to incorporate de-wax cabinets into its Plating Shop renovation contract. The cabinets are now an intricate part of the chrome plating line, used to remove beeswax after plating. This procedure replaces the former method of wax removal, which involved dissolving the wax in 1,1,1-trichloroethane vapor degreasers. By eliminating the need to de-wax using 1,1,1-trichloroethane, Warner Robins moved one step closer to meeting stringent Air Force ODS elimination goals.

VI. For Further Information

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CASE STUDY #2: AN ALTERNATIVE TO FREON CFC SPRAYS FOR COMPONENT COOLING ON PRINTED CIRCUIT BOARDS

I. Summary

Allied-Signal eliminated the use of CFC-12 (Freon R-12) to chill individual components on printed circuit boards by using carbon dioxide as a replacement coolant.

II. Introduction

In the past, Freon R-12 was used to locate weak or defective components on printed circuit boards. The R-12 was sprayed directly onto active components, causing thermal stressing in the parts. Thermal stressing, in turn, caused weak components to fail, allowing the faulty components to be identified prior to use. This procedure was used for many years to ensure the reliability of circuits. There were typically 30 locations performing this test. Each station used an average of ten 30 pound cylinders per year. The result was 300 cylinders per year being used, releasing 9,000 pounds of ozone depleting R-12 into the atmosphere.

Taking a proactive stance in preserving the atmosphere, Allied-Signal decided in 1992 to eliminate its use of Freon R-12 in component cooling.

III. The Alternative Selection Process

Allied-Signal's Health, Safety & Environmental Department (HS&E) evaluated various alternatives for Freon R-12. It selected a cooling system based on the evaporative cooling effect of carbon dioxide after successfully building and testing a prototype.

Through contacts with a local welding distributor, Allied-Signal learned of Va-Tran Systems in Chula Vista, CA, a company that might be able to manufacture the carbon dioxide cooling devices. Va-Tran already manufactured the SNO-GUN™, an ultra-clean device used for sub-micron particle removal in the semi-conductor and hybrid circuit industry. With slight alterations, the SNO-GUN could be used to chill components on a printed circuit board. Va-Tran was able to meet Allied-Signal's design requirements, and produced the Component Cooler model CC-1.

The cooling job performed by the CO_2 system was actually superior to that of the Freon system because it required a shorter blast of coolant to chill the components to the required temperature. Thus, by switching from Freon to CO_2, Allied-signal was able to speed up its rate of defect detection in printed circuit boards.

Allied-Signal purchased 50 units of the component cooler model CC-1 and 50 corresponding CO_2 cylinders at $340.00 per set. This presented a total capital cost of $17,000 to replace all of the Freon cooling systems. Since one cylinder of CO_2 provided the same cooling power as one cylinder of R-12, 300 cylinders of CO_2 replaced the 300 Freon R-12 cylinders used per year. With CO_2 at $6 per cylinder and Freon R-12 at $105.00 per cylinder, Allied-Signal calculated its cost savings per year to be $29,700. Therefore, the company would recover lost capital in .57 years, or less than 30 weeks. The cost breakdowns are presented in Exhibits CS-1, CS-2, and CS-3. This cost analysis was based on the price of R-12 in 1992. On January 1,1993 the increase on tax on R-12 caused the price of the solvent to nearly double 1992 prices. The tax on R-12 is scheduled to increase in future years until the solvent is completely phased out on December 31, 1995.

Exhibit CS-1 CAPITAL COST BREAKDOWN	
Cost of CC-1 Comp Cold	$250.00
Cost of CO_2 Cylinder	$90.00
Cost of CO_2 System	$340.00
CO_2 Systems Purchased	50
Total Capital Cost	$17,000.00

Exhibit CS-2 BREAKDOWN OF ANNUAL COST OF FREON R-12	
Number of Freon R-12 Cylinders Used	300/year
1992 Cost per Cylinder	$105.00
Annual Cost of Freon R-12	$31,500.00

Exhibit CS-3 BREAKDOWN OF SAVINGS ON COOLANT PER YEAR	
Cost to Refill CO_2 Cylinder	$6.00
Cost of R-12 Cylinder	$105.00
Savings per Cylinder	$99.00
Cylinder per Year	300
Savings on Coolant Per year	$29,700.00
Capital Cost Recovery Time = 0.57 Year (less than 30 weeks)	

IV. Environment, Health and Safety

Carbon dioxide is an inert gas that does not support combustion. Its only harmful effect is the displacement of oxygen. OSHA permits a concentration of 10,000 ppm for an 8-hour exposure time. The small amount released by the CC-1 at 0.6 pounds per minute is much less than the amount typically released in an environmental test chamber.

V. Conclusion

The conversion to carbon dioxide component cooling was a win-win situation for Allied-Signal. What the company perceived as an action necessary to protect the ozone layer provided a big benefit to cost reduction and improved product throughput. The environment won and so did Allied-Signal.

VI. For Further Information

Additional information can be obtained by contacting:

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Phone: 619-423-4555
Fax: 619-423-4604

CASE STUDY #3: DEVELOPMENT AND USE OF A VOLATILE AQUEOUS CLEANER

I. Summary

A volatile aqueous cleaner replaced CFC-113, which was being used as a cleanroom wiping solution at the Kansas City Division (KCD) of Allied Signal Aerospace.

II. Introduction

In a Miniature Electro-Mechanical Assembly cleanroom, approximately 100 operators daily used cleanroom wiping cloths dampened with CFC-113 to wipe work surfaces of laminar flow work stations. The CFC-113 was also used to remove light soils and particulate contamination from finger cots, latex gloves, assembly tooling and fixtures. During periods of high production, 2,000 pounds of CFC-113 were used each month for these cleanroom operations.

By 1987, environmental and financial concerns surrounding the use of CFC-113 prompted the company to investigate alternative cleaning solutions for use in the KCD cleanroom. In the search for an adequate replacement, it was necessary to find a cleaner that would dissolve organic and inorganic contaminants and allow loose contaminants to be picked up and held by cleanroom wiping cloths.

III. The Alternative Selection Process

The requirements for the CFC-113 replacement solution were similar to those met when CFC-113 was originally selected. The new solution was to be employee safe, function as well as CFC-113 for wiping, be very high purity, essentially 100 percent volatile, reasonably inexpensive, and most importantly, the formulation had to be KCD-controlled.

A literature search revealed that most commercial cleanroom decontamination solutions couldn't meet the stringent requirement of volatility and formulation control. Because of this, engineers in the KCD Precision Cleaning Laboratory blended a volatile aqueous cleaner (VAC) based on a formulation recommended by Air Products, Inc. (Allentown, Pennsylvania), a manufacturer of specialty chemicals used in the coatings, ink, and adhesives industry.

Two formulations using reagent grade, ultrapure materials have been used at the Kansas City Plant; they are shown in Exhibits CS-4. Formulation A was the original blend; it contained 1.8 percent ammonium hydroxide and had a pH of 11.0. Although it functioned well, it was modified because of safety concerns regarding ammonium hydroxide exposure. Formulation B was blended using additional isopropyl alcohol but without the ammonium hydroxide. This allowed the solution to evaporate faster, have a near-neutral pH, and be free of an ammonia odor. Flash points for formulation A and B are 125 and 110 degrees F, respectively.

Exhibit CS-4
Volatile Aqueous Cleaner

Formula (wt%)	A	B
Isopropyl Alcohol	5.00	12.50
Surfynol 61 (2)	.80	.80
Aerosol OT-75 (3)	.02	.02
Ammonium Hydroxide	1.80	0.0
Deionized Water	92.38	86.68
Total	100.00	100.00

The VAC (Formulation B) is supplied to the operators in pre-rinsed and extracted spray bottles. The solution is lightly sprayed on cleanroom cloths for wiping work surfaces and gloved hands prior to assembly operations.

The solution has worked well €or removing light oils and greases as well as water-soluble contaminants. When used in ultrasonic cleaners capable of handling combustible liquids, it removes machining, grinding, and some polishing residues, along with fibers and other particulate contaminants.

Substitution of the Volatile Aqueous Cleaner obviated the need for 2,000 pounds ($11,000 at 1993 prices) per month of CFC-113. The new solution costs approximately $1.00 per gallon when prepared using reagent grade, ultra pure materials.

IV. Environment, Health, and Safety

The Volatile Aqueous Cleaner has a VOC content approximately 13.3 percent by weight. Since the material is lightly sprayed on wiping cloths, liquid wastes are extremely low. (In fact, the wiping cloths can be saved and laundered for use elsewhere in the facility, thereby eliminating a large portion of a solid waste).

The new solution has a light camphor odor and a near-neutral pH. It is nonozone-depleting and has a flash point comparable to most household window cleaners. Together, these properties make the VAC a safe alternate to CFC-113 for cleanroom applications.

v. Conclusion

The new solution has been used in KCD cleanrooms since 1988. In “addition, new applications that are ideally suited for its use are frequently being discovered. For example, the solution can be used in the ultrasonic cleaning of complicated machined assemblies for high vacuum components used on the Superconducting Super Collider.

By using essentially 100 percent volatile ingredients, engineers in the KCD Precision Cleaning Laboratory have developed and implemented an alternative to CFC-113 for cleanroom applications that offers better cleaning characteristics, lower cost, and greatly reduced environmental impact.

VI. For Further Information

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CASE STUDY #4: SUBSTITUTION OF LOW VAPOR PRESSURE ORGANIC SOLVENTS AND AQUEOUS CLEANERS FOR CFC-113 BASED CLEANING SOLVENT

I. Summary

Lockheed Fort Worth Company (LFWC) (formerly General Dynamics Fort Worth Division) has substituted low vapor pressure organic solvents and aqueous cleaners for a CFC-113 based general purpose cleaning solvent used in the surface wiping of aircraft parts, components, and assemblies in all aspects of aircraft manufacturing. The project has resulted in major reductions in solvent use and air emissions, elimination of ozone depleting compounds from cleaning during aircraft assembly, cost reductions, and improved chemical handling and usage practices.

II. Introduction

From 1986-1992, General Dynamics Fort Worth Division (GDFW) used a general purpose wipe solvent containing 85 percent CFC-113 by weight throughout the manufacturing process. The use of this solvent resulted in the emission of approximately 255 tons-per-year of CFC-113 and 45 tons-per-year of volatile organic compounds (VOC). Throughout the 6 years, GDFW produced mainly F-16 fighter aircraft at a rate of 220 to 350 aircraft per year.

The overall objective of this project was to eliminate the use of ozone depleting chemicals, chlorinated solvents, ketones, and any of the 189 compounds listed as hazardous air pollutants (HAP) in the U.S. Clean Air Act Amendments of 1990, and to further reduce the VOC emissions associated with solvent cleaning. The strategy was to develop cleaners with low evaporation rates to minimize solvent usage and to further reduce VOC emissions by collecting the used cloths in vapor proof bags. The substitute material was required to possess the following properties:

- Effective cleaner for a variety of organic soils;
- Non-corrosive;
- Non-flammable;
- Low toxicity;
- Mild to moderate odor;
- Low evaporation rate;
- No non-volatile residue;
- Dries at ambient temperature;
- Leaves a bondable surface;
- Contains no compounds with ODP, halogenated compounds, water, ketones, aromatics, or any of the 189 HAPS.

The project was established under the Environmental Resources Management Program, which was founded on the vision of GDFW being an industry leader in environmental management through a caring partnership with customers, suppliers, associates, and citizens. The program's goal was to minimize hazardous chemical usage and emissions to the greatest extent technically feasible, in accordance with the company's commitment to "Zero Discharge" of hazardous waste and emissions. In addition, GDFW created the Hazardous Material Management Program Office (HMMPO), consisting of representatives from the Environmental Resources Management, Research and Engineering, Production, Facilities, Process Control, and Material organizations. The function of the HMMPO was to integrate the cross-functional activities of each group to ensure effective teamwork, focus, and prioritization of activities. The HMMPO's effort was energized by customer concerns with ODC elimination, state environmental regulatory agency concerns with VOC reduction, and LFWC commitments to ODC elimination and cleaning solvent use reduction.

III. The Alternative Selection Process

In 1985, GDFW used a 100 percent VOC Solvent blend with a vapor pressure of approximately 45 mm Hg. In 1986, GDFW substituted an 85 percent CFC-113 - 15 percent VOC blend for wipe operations. With this change, VOC emissions were reduced by approximately 60 percent of 1985 levels. In 1992, a new low vapor pressure solvent and cloth management system was implemented, decreasing VOC emissions by an additional 78 percent based upon the initial two months of solvent use, for a 91 percent reduction in VOC emissions from the original 1985 levels.

The new wipe solvent, FMS-2004 (Ft. Worth Specification Number 2004), was selected after full-scale laboratory evaluations of several solvent blends. The evaluations consisted of numerous corrosion tests and cleaning performance tests. Five formulations were evaluated. DS-101, DS-102, DS-103, DS-104, and DS-105.

The corrosion test involved immersing stressed aluminum and steel C-rings in test cleaners (ASTM G38-78) for 2,000 hours at ambient temperatures. No corrosion resulted when three alloys, 2123-T85 1 aluminum, 7475-T351 aluminum, and 300M steel, were immersed in each of the solvent blends.

The cleaning test involves the following five steps:

1. Contaminate substrate with SAE standard contaminant, a nine-component blend of oils and greases designed to simulate fingerprint and airborne contamination.

2. Clean substrate with test solvents.

3. Apply coatings to substrate:

   - sealants
   - adhesives
   - primers
   - topcoats

4. Soak substrate in fuel or other fluid.

5. Evaluate coating adhesion:

   - Screen peel test
   - T-peel test
   - lap shear test
   - flatwise stud tension test
   - wet tape test
   - scrape adhesion test.

The substrates and coatings used in the cleaning test are listed in Exhibit CS-5.

Exhibit CS-5
Cleaning Performance Test Results

Class	Substrate	Coating
Paints/ Primers	Anodized Aluminum Chemical Film Epoxy Primer Waterborne Primer Composites Titanium Cadmium Plating	Epoxy Primer Waterborne Primer Urethane Topcoat High Solids Topcoat Fuel Tank Coating Rain Erosion Coating Adhesive Sealant Primer
Sealants	Epoxy Primer Waterborne Primer Composites Fuel Tank Coating Adhesive Sealant Primer	Polysulfide Fuel Tank Fluorosilicone
Adhesives	Composites Adhesive Sealant Primer Epoxy Primer Waterborne Primer Anodized Aluminum	Acrylic Adhesive Epoxy Adhesive Adhesive Sealant

There were no coating adhesion failures to the cleaned substrates using any of the solvent blends.

The material properties of the solvents were then' compared to determine the most suitable solvent for cleaning. Exhibit CS-6 presents the cleaning efficiency, flammability, toxicity, and odor of the five solvents.

DS-104 was selected as most suitable due to its non-flammability, low toxicity, and mild odor. Additional material properties of DS-104 (also known as FMS-2004) are listed in Exhibit CS-7.

Surfaces that can be cleaned using FMS-2004 include metals, painted surfaces, fabrics, glass, rubber (may swell but recovers without deterioration), wood, most plastics (not acrylics),

Exhibit CS-6 Fort Worth Solvent Blends				
Product Name*	Cleaning Efficiency	Flammable	Toxicity	Odor
DS-101	Good	No	Very low	Strong
DS-102	Good	No	Very low	Strong
DS-103	Good	Yes	Low	Very mild
DS-104	Good	No	Low	Moderate
DS-105	Good	No	Moderate	Mild

* Product information available from Dynamold Company (817) 335-0862, Mr. Mike Peck.

Exhibit CS-7 Wipe-Solvent Properties	
	FMS-2004 (DS-104)
Components	Propylene Glycol Methyl Ether Acetate
	Isoparaffins
	Butyl Acetate
Cleaning Efficiency	
Hydrocarbon Soils	Excellent
Inks/Dyes	Good
Uncured Resins	Good
Flash Point, °F	104
Toxicity, Exposure Limit, PPM	150
Odor	Moderate
Evaporation Rate (Butyl Acetate = 100)	30
Vapor Pressure (mmHg)	4.0
Dries at Room Temperature	Yes
Residue	None
CFCs, Water, MEK, Aromatics	None

ceramics, composites, and cement. Soils that can be removed using FMS-2004 include:

- Oils, greases, and waxes
  - -- Forming oils
  - -- Hydraulic fluids
  - -- Petrolatum
  - -- Preservative oils
  - -- Lubricating oils
  - -- Machining greases
  - -- Wax drilling lubricants
  - -- China marker
- Factory contaminants
  - -- Fingerprints
  - -- Machining dust
  - -- Shop dirt
  - -- Carbon black
- Marking inks
  - -- Layout fluid
  - -- Marks-a-Lot
  - -- Mill marks
- Resins (uncured)
  - -- Epoxy
  - -- Polyurethane
  - -- Polysulfide
  - -- Acrylic

The solvent has a vapor pressure of 35 mm Hg. The use of aluminized bags offers the potential for major additional emissions reduction as shown in Exhibit CS-8. Although capture efficiency decreases with increased vapor pressure, the reduction is not significant.

Exhibit CS-8 Laboratory (Maximum) Capture Efficiency Using Aluminized Plastic Bags	
4 mmHg Solvent Blend	97%
6 mmHg Solvent Blend	94%
20 mmHg Solvent Blend	86%
45 mmHg Solvent Blend	80%

The development of FMS-2004 is described in detail in the publication "Environmentally Compliant Wipe-Solvent Development" by Weltman and Phillips" (SAE Technical Paper Series #921957, Society of Automotive Engineers, Inc. (SAE), SAE Publications Group, Warrendale, PA 10 pp.).

The new wipe solvent, FMS-2004, is used in all wipe applications where specifications require a thoroughly clean surface prior to application of coatings, adhesives, or sealants. Certain sensitive plastics and transparencies still require the use of specialty cleaners.

FMS-2004 cannot be used as a flushing or rinse agent or in DeFOD operations. DeFOD operations are flushing operations which remove FOD (Foreign Object Debris) from the aircraft component or assembled aircraft. For less critical cleaning operations possessing less stringent cleanliness requirements, other solutions have been implemented. B6274-1 (a blend of C10 and C11, branched hydrocarbons) is an effective flushing agent in certain operations. B6274-2 (a 10 percent isopropanol, aqueous solution) is used to rinse the remaining B6274-1 residual film, which is slow to evaporate off certain aircraft components. For other DeFOD operations, a 10 percent soap and water (B6274-3) spray wash, followed by a deionized water spray rinse, is effective. Forced air can then be used to dry the component. B6274-1, B6274-2, and B6274-3 are GDFW engineering standards. The soap in B6274-3 is currently Boraxo's "Liquid Lotion Soap," Product No. 2709.

The key to the successful implementation of GDFW's project has been an intensive, ongoing awareness and education effort. This factory-wide education effort was undertaken to inform the users of the project's value from a safety, health, environmental, and business standpoint and to introduce the changes in materials and procedures. A 30 minute introduction was held in a classroom setting prior to implementation of the new cleaning solvents. A 10 minute videotape consisting primarily of comments and discussion from fellow users during factory trials introduced these concepts. A question and answer period followed the video. During implementation, a more detailed follow-up meeting was held in each work area to re-introduce and reinforce the procedures and to address any additional issues that pertained to the given work area. In addition, a combination of pamphlets, memos, posters, and weekly reviews with Labor Union representatives was used to communicate information and provide technical and engineering support to users. The posters are currently posted where FMS-2004 is used.

While the low vapor pressure solvent reduced the quantity of cleaner used in cleaning operations the rag management system captured the majority of the wipe solvent remaining on the cloth, thereby preventing additional fugitive VOC emissions. The waste cloth management and disposal system involves the use of aluminized plastic bags and a compactor for compacting the bags into fiber drums. Used cloths are placed into the aluminized bags upon completion of a cleaning operation. The bags are kept closed when not in use and tied shut at the end of each eight hour shift. The bags are then compacted into fiber drums. The drums of compacted cloths are used as high-energy value supplemental fuel in cement manufacturing by pyrolysis of the entire fiber drum in a specially-designed furnace and injection of the high-energy pyrolysis gases into the kiln.

GDFW audited the factory capture efficiency of the bagging system in mid-November 1992 under the oversight of the Texas Air Control Board (TACB). GDFWs compliance plan with the TACB required a minimum capture efficiency of 50 percent of the solvent used and the use of a low vapor pressure wipe solvent. This wipe solvent was defined as one possessing 20 mm Hg or less vapor pressure at 25 degrees Celsius. "be emissions capture efficiency was measured at 81 percent (weighted average for the areas of the factory audited).

IV. Environment, Health, and Safety

In addition to the previously stated environmental benefits, the industrial hygiene and safety aspects of ..solvent cleaning have been improved. Awareness and availability of proper hand, eye, and respiratory protection have increased. Information, such as MSDSs and warnings, are more easily accessible. Proper labeling of all solvent containers dispensing bottles has been enhanced. Use of flammable solvents has been eliminated and the airborne exposure hazards associated with solvent cleaning have been reduced.

V. Conclusion

LFWC has successfully implemented low vapor pressure cleaning operations and a waste cloth management and disposal system. Since their implementation in September 1992, the following reductions presented in Exhibit CS-9 have been measured and documented. These reductions compare the use of an 85 percent CFC-113 - 15 percent VOC blend (previous material) with the use of low vapor pressure solvents, aqueous cleaners and the cloth management system (substitute).

Exhibit CS-9
Reductions in Solvent Use, Costs, and Emissions Since September 1992

Solvent use reduction	68-71%, by volume
Solvent Purchase Cost Savings	86-88%
CFC Emission Reduction	100%
VOC Emission Reduction	75-78%, by weight
Total Air Emission Reduction	95-97%, by weight

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CASE STUDY #5: REPLACEMENT OF CFC-BASED RELEASE AGENT

I. Summary

Saab Aircraft replaced its CFC-113 based release agent with an alternative formulation in 1991. The alternative formulation now employed does not contain CFCs or any other halogenated solvents.

II. Introduction

Saab Aircraft is located in Linkoping, Sweden and manufactures commercial and military aircraft. Its primary products are commercial turbo-prop and jet-prop aircraft (Saab 340 and Saab 2000) and the JAS 39 Gripen combat aircraft.

During the manufacturing process, Saab uses release agents in its composite manufacturing shop and in its bonding shop. The release agent used in these applications prior to 1991 contained CFC-113. Saab Aircraft began its search for a replacement release agent which was not based on ozone-depleting solvents in 1989. This early start was driven in part by Swedish regulations calling for the elimination of CFC-113.

III. The Alternative Selection Process

Saab developed a four step methodology for qualifying substitute release agent formulations prior to their full-scale use. First, Saab's Safety and Environmental Department studies the health and environmental effects of different release agents and approves them for testing by the Department of Material and Process Technology. Second, the release agent is tested and approved by Saab's Department for Material and Process Technology. Third, the approved release agent is introduced on a small-scale basis into the workshop for a trial period. Finally, feedback from the workshops conducting the test is gathered to determine the suitability of the alternative formulation for widespread use.

After the Safety and Environmental Department at Saab gives its approval to candidate release agents, the Department of Material and Process Technology tests each candidate based on the following criteria:

- Ability to release all composite materials used in Saab manufacturing from tool surfaces
- Application method
- Contamination of composite surfaces
- Effect on secondary bonding, painting, and sealant application with and without surface treatment

Only release agents that satisfactorily meet the requirements of the Department of Material and Process Technology are sent on to selected workshops for actual production testing.

The alternatives which have been approved are introduced into workshops and are used on a limited number of parts to determine their efficiency in Saab's manufacturing process. The parts on which the alternatives are tested are selected as representative of the parts with the most complex shapes., The rationale in this methodology is that if a release agent works with the most complex part geometries, it will also work with the simpler shapes.

After each alternative has been given a sufficient test period, feedback is gathered from engineers in the workshop to evaluate the performance of the alternative. If the results are acceptable, and the product is economical, the release agent is approved for use in composite manufacture. If the evaluation reveals problems, a decision is made to continue or cancel the test program. In some cases, process changes may be made or limitations on usage may be set to allow the use of an alternative release agent.

In late 1989, Saab began evaluation of two alternative release agents: Release-All 19 and Frekote MW 390. Release-All 19 is a water borne wax emulsion, and Frekote MW 390 is a solvent-borne formulation. Both products were approved by the Department of Material and Process Technology and introduced into Saab workshops for testing.

Early workshop tests showed that Release-All 19 was difficult to apply to parts with complex geometries. Testing was then limited to parts with simple shapes. Further usage revealed two additional problems with the product: (1) corrosion was detected on tools, and (2) it became evident that it would be necessary to treat the tool with the release agent prior to every use. These findings were considered economically unacceptable by Saab and the decision' to discontinue use of Release-All 19 was made in 1990.

Workshop testing of the Frekote MW 390 release agent showed that the product functioned well in Saab's applications. However, while testing was still underway, the product was withdrawn from the market by its manufacturer in 1990. The manufacturer cited problems with separation during storage as the reason for discontinuing the product.

Saab then began looking at new products which had come onto the market during 1990. After a short period of time for market surveys and preliminary tests, a product called Frekote 44 NC was approved in 1991 for workshop testing. Frekote 44 NC, produced by Dexter in the United States, is a solvent-borne dibutylether wax emulsion containing one percent wax. Feedback thus far has been positive and the product appears to be technically and economically comparable to the CFC-based release agent (Frekote 33) previously used at Saab.

IV. Environment, Health, and Safety

The primary consideration associated with the use of the new Frekote 44 NC release agent is its effect on workers. Exposure to excessive dibutylether vapor may cause irritation of the respiratory tract, headaches, nausea, and dizziness. Therefore, Saab has ensured that this product is used in well ventilated areas. In addition, personal protective equipment is worn by the workers.

Frekote 44 NC contains no ozone-depleting substances. With its implementation, refrigeration has become the only application at Saab which still uses ozone-depleting substances. However, Frekote 44 NC is a VOC and its emissions must therefore be controlled.

V. Conclusion

Saab Aircraft has successfully identified, evaluated, and implemented a CFC-free release agent in its aircraft production shops. The new release agent, Frekote 44 NC, has no significant occupational hygiene or worker safety problems. Furthermore, the new product is comparable technically and economically to the previously used CFC-based release agent.

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CASE STUDY #6: REPLACEMENT OF TRICHLOROETHYLENE AT SAAB AIRCRAFT

I. Summary

Saab Aircraft conducted pilot projects to reduce trichloroethylene (TRI) use in vapor degreasers that clean metal aircraft parts. In 1988, Saab initiated these projects based on an internal reduction policy established in response to expectations of more stringent regulations governing the use of TRI from the government.[1]

By following simple procedures, such as regularly servicing degreasers, reducing contamination on metal parts, and consolidating degreasing operations, Saab significantly reduced the amount of TRI used in metal cleaning. However, Saab had to identify effective alternatives in an attempt to completely eliminate the use of TRI. Aliphatic hydrocarbon degreasing and water-based alkaline cleaning were identified as promising alternative metal cleaners. Saab has already replaced TRI in a few metal cleaning operations using water-based cleaners.

II. Introduction

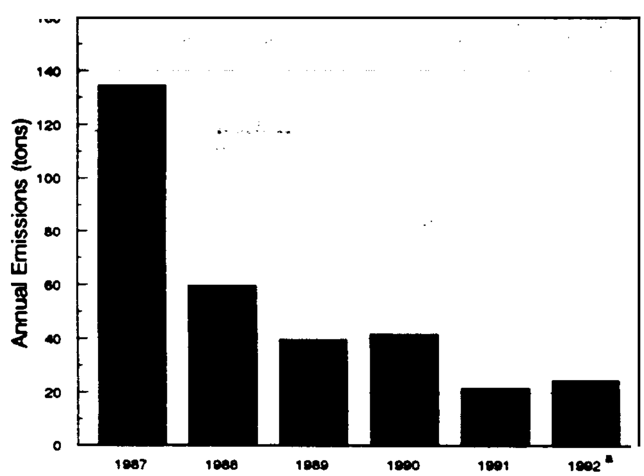
Saab Aircraft is located in Linkoping, Sweden, and manufactures commercial and military aircraft. Its primary products are commercial turbo-prop and jet-prop aircraft (Saab 340 and Saab 2000) and the JAS 39 Gripen combat aircraft.

In 1988, Saab Aircraft initiated pilot projects to reduce solvent emissions of TRI in its manufacture of civilian and military aircraft. Saab reduced emissions of TRI by 85 percent, from 135 tons in 1987 to 25 tons in 1992 (see Exhibit CS-10). Saab reduced emissions while at the same time doubling the number of aircraft produced. Saab achieved these reductions by:

- reducing the number of vapor degreasers from 18 to 7
- optimizing the cooling and recovery systems of the. remaining degreasers and containing emissions by encapsulation
- changing cleaning guidelines for some parts that previously required vapor degreasing prior to surface treatment. Parts not contaminated with oils or grease are no longer cleaned with TRI. Instead, normal alkaline cleaners used in the pretreatment cycle are used.
- reducing contamination of the metal parts. For example, "peelable" protective plastic coatings are used in place of corrosion inhibition compounds
- replacing TRI vapor degreasing with water-based alkaline spray or dip/ultrasonic cleaning for general cleaning of steel, magnesium, and aluminum after machining.

EXHIBIT CS-10

Emissions of Trichloroethylene at Saab Aircraft



[a] Effective 1992, government regulations require emissions of TRI not to exceed 30 tons per year. Use of trichloroethylene is prohibited after 1996.

[1] In 1991, the government of Sweden banned the use of TRI after January 1, 1996.

For the following processes, TRI vapor degreasing is still used because, until now, Saab has been unable to identify alternatives:

- Metal forming - to remove oils, grease, and marking inks before heat treatment, and lubricant oils after metal forming

- surface treatment - to remove contaminants before metal coating

- Penetrant flaw detection - to remove contaminants that may hide a crack

- General cleaning - such as removal of corrosion inhibiting compound before visual inspection of components from subcontractors.

III. The Alternative Selection Process

During TRI vapor degreasing elimination projects, Saab found it necessary to address the following questions in its search for alternatives:

- Why do the parts need to be cleaned and is the cleaning necessary?

- What type of material are the parts composed of?

- What type of contamination is on the part before cleaning?

- What degree of cleanliness is required for the part?

The most important question to ask is, "Why do the parts need to be cleaned?" In addition, one must consider whether cleaning is necessary or can be avoided through some process change. For example, if a part is treated with corrosion inhibiting oil and needs to be cleaned, it may be possible to treat the part with a dry protective method instead of the oil. Thus cleaning can be avoided. Some pretreatment processes (such as pretreatment before adhesive bonding) will need to be completely reevaluated if cleaning is to be avoided.

Knowledge of the material composition of the part to be cleaned is important in determining the appropriate cleaning method to replace TRI vapor degreasing, especially in the aircraft industry. Certain materials, such as high strength steel, are susceptible to hydrogen embrittlement from water-based alkaline replacement cleaners. Hydrogen embrittlement tests must be performed when using this alternative. Other materials, such as aluminum, are susceptible to etching when highly alkaline solutions are used. Silicates can be added to inhibit etching but may impede proper paint and adhesive bonding.

Knowing the type of contaminant on the part and how much contamination needs to be removed are important in the design of a TRI elimination project. A thick film of viscous drawing oil may require an aliphatic hydrocarbon solvent for removal. Different types of contaminants have affinities for different surfaces and need to be examined to identify the proper cleaning method for removal.

Finally, the choice of a replacement cleaning system for TRI vapor degreasing will depend on the required degree of cleanliness. A method of quantitatively determining the degree of cleanliness will help eliminate alternatives that cannot meet such specifications while helping to identify possible alternatives early in the evaluation process. This will inevitably reduce unnecessary testing and save significant amounts of money., In addition, such a quantitative cleanliness assessment will be important in establishing process controls for the new cleaning process.

Example: .Replacement of TRI in the Metal Forming Shop - A Development Project at Saab

TRI vapor degreasing is used to remove different types of lubricating oils before heat treatment and for general cleaning before the metal part is further processed. The TRI vapor degreaser has the following dimensions: length 4.5 m, width 1.2 m, and height 1.8 m. Approximately 300 square meters of material are cleaned in the degreaser daily. To determine which alternative cleaners to use, Saab first examined the material composition of the parts to be cleaned and the contamination that was to be removed. Saab sent materials to its laboratories to conduct tests to determine which alternative cleaning methods could best replace

TRI vapor degreasing. A screen was conducted to determine suitable ..contaminants to use in the cleaning test. Different oils were tested in water-based cleaners and the one with the worst emulsifying properties was selected as the test contaminant. A drawing oil containing both mineral and vegetable oil was determined suitable for the cleaning tests. A stretch formed aluminum part, AA 2024, was selected as the test part. The following cleaning systems were tested for their ability to clean the aluminum part:

- trichloroethylene degreasing
- water-based alkaline cleaning, silicated and non-silicated
- aliphatic petroleum hydrocarbon
- limonene (some tests)

The cleaning tests were carried out using (1) newly applied oil and (2) oil that was allowed to remain on the part for six weeks at room temperature. Three different cleaning, methods - dipping, dipping with mechanical agitation, and dipping with ultrasonic agitation - were tested using the cleaners listed above.

A variety of methods were used to test the cleanliness of the metal part. These included visual inspection, gravimetric testing, and heat treatment. To quantify the degree of cleanliness, a combustion method linked to an infrared spectrometer was used.

As shown in .Exhibit (3-11, the results demonstrate that both water-based alkaline cleaners and aliphatic hydrocarbons are suitable alternatives to TRI vapor degreasing from a quantitative cleanliness point of view. It is, however, necessary to use ultrasonicagitation when using the water-based alkaline cleaners to achieve the required cleaning standards. These results from this investigation were used when Saab specified the requirements for new cleaning equipment.

EXHIBIT CS-11

Results of Saab Cleaning Tests

Cleaning Agent	Measured Residual Carbon ($\mu g/cm^2$)	
	Newly Applied Oil	Aged Oil
Trichloroethylene	0.3	1.6
Alkaline Cleaner:		
dip	50;51	-
agitation	-	56;146
ultrasonic	0.4;0.8	0.2;0.3
Aliphatic Hydrocarbons:		
dip	0.5	-
agitation	-	2.3
ultrasonic	0.2	1.6
Limonene:		
dip	0.6	-
agitation	-	29.1
ultrasonic	0.7	1.0
Reference	244	238

IV. Environment, Health, and Safety

The use of trichloroethylene has always caused problems in the work environment. The occupational exposure limit in Sweden for TRI is 10 ppm, a level that has been difficult to remain below. The critical effect of TRI is neurotoxicity, but carcinogenic and genotoxic potential are factors that also must be taken into account.

The water-based alkaline and aliphatic hydrocarbon products are not likely to create any problems in the work place. The use of terpenes such as d-limonene could eventually cause problems as it is a minor skin sensitizer.

Saab attempts to choose an aliphatic hydrocarbon product with a high flash point and a low vapor pressure. This has two advantages; the need for flameproof apparatus is avoided, and low emissions to the air are achieved. Normally, it is necessary to install a condensing plant. With a large water-based system (alkaline cleaner), it may be necessary to use ultrafiltration for treating and recycling the bath. In other cases, it can be very expensive to send the bath for treatment and disposal at an off-site facility. Ultrafiltration in these cases will also minimize the quantity of chemical consumed. To allow for effective treatment at a wastewater treatment plant, care must be taken to ensure that the tenside and complex binder in the alkaline cleaner are biologically degradable.

Saab is evaluating a back-flow rinse water system to minimize the amount of water consumed. To achieve a totally closed rinse water system, it is usually necessary to use reverse osmosis filters.

V. Conclusion

Saab Aircraft has reduced consumption and emissions of trichloroethylene in its manufacturing facilities without switching to chlorinated solvents or volatile organic compounds (VOCs). This strategy has afforded environmental benefits and created a safer workplace. Saab's experience has shown that it is possible to reduce TRI emissions even further with cleaning technologies that are not harmful to human health or the environment. These pilot projects have expanded Saab's understanding of other cleaning processes and their significance for safe and efficient manufacturing.

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CASE STUDY #7: AN ALTERNATIVE TO PATCH TEST FOR DETERMINING HYDRAULIC FLUID CONTAMINATION LEVELS

I. Summary

Four U.S. Navy intermediate maintenance-level facilities have instituted the use of electronic particle counters in lieu of the traditional patch test method to determine contamination levels of aircraft hydraulic fluid.

II. Introduction

During normal operations, aircraft hydraulic systems may become contaminated with metallic and nonmetallic particles resulting from internal wear, failure of system components, or incorrect maintenance and servicing operations. Excess concentration of these particles could result in failure of the hydraulic system. Regular testing is required to insure that contamination levels remain within acceptable limits.

Contaminant testing has traditionally been performed using what is known in the field as the "patch test." In this procedure, hydraulic fluid is drawn from the system, diluted to a known volume with an approved solvent, and passed through a test filter membrane of known porosity. All particulate matter in excess of a size determined by the filter characteristics is retained on the surface of the membrane. This causes the membrane to discolor by an amount proportional to the particulate level of the fluid sample.

Solvents currently used as diluting agents are CFC-113, MCF, and a petroleum distillate defined by U.S. federal specification PD-680, Type II. CFC-113 is generally the preferred solvent for these maintenance activities because its complete and rapid evaporation allows for quick sample readings.

Elimination of ozone-depleting substances will leave PD-680, Type II as the only approved solvent for use in patch tests. While PD-680 offers an acceptable temporary alternative, it is not a permanent solution. Problems associated with using PD-680, Type II in the patch test include increased drying time, use of inaccurate color standards, and subjective interpretation of those standards. The end result is a time consuming and sometimes inaccurate testing procedure for hydraulic fluid contamination.

Through a U.S. Navy-funded effort to eliminate the use of ozone-depleting substances, and in conjunction with the Navy's Reverse Engineering Program (a hands-on effort to help field activities comply with rapidly changing environmental regulations), electronic particle counters have been introduced at four prototype sites to eliminate the need for CFC-113 patch tests.

III. The Alternative Selection Process

The goals of the hydraulic fluid contamination testing project were to eliminate the need for the use of ozone-depleting substances, and to reduce the need for the patch test. Subtasks of the project included reviewing the sampling frequency requirements, evaluating field replacements for the patch test, investigating alternative solvents, and testing the most promising candidates in the field.

Electronic particle counting has long been approved as a means of determining contamination levels in hydraulic systems (NAVAIR 01-1A-17 Aviation Hydraulics Manual), but has been a depot maintenance-level practice due, in part, to the cost and complexity of the equipment. Bench-top and portable particle counting equipment was evaluated with the goal of finding an inexpensive, portable unit suitable for deployment.

After investigation it was determined that none of the portable units were suitable for prototype at field activities. Although rather costly, the HIAC Model 8011 benchtop particle counter appeared to be the best alternative. After a successful two week initial prototype aboard the U.S. Navy vessel the USS Theodore Roosevelt, four of the units were procured for prototype at four sites: NAS Miramar, NAS Cecil Field, NAS Oceana, and USS Theodore Roosevelt. The total cost for the units was$71,000.

After several months in the prototype stage, the results are extremely positive. The sample turnaround time has proven to be well within requirements to maintain fleet readiness. The correlation between patch test results and particle counter results has also been acceptable. The mechanics using the equipment are satisfied with its operation and prefer its use to the patch test. The USS Theodore Roosevelt switched entirely to use of the particle counter during its 1993 six-month cruise.

Current efforts continue toward evaluating portable particle counters and alternative solvents for the patch test due to the cost of the benchtop particle counting units.

IV. Environment, Health, and Safety

The use of the particle counters has completely eliminated the need for CFC-113 in the hydraulic shops. This is significant because, while CFC-113 was available, mechanics found numerous additional uses for it. Now that CFC-113 is no longer a requirement for the patch test its use in the shops has been completely eliminated. When hydraulic fluid became contaminated with CFC-113, it was disposed of as a hazardous waste. Elimination of CFC-113 from the shop has completely eliminated this waste stream.

V. Conclusion

The conversion to particle counters as a means to determine contamination of hydraulic systems has reduced hazardous waste generation and has eliminated a need for ozone-depleting substances at intermediate maintenance activities. Although the alternative requires an initial investment, it yields continuous savings in hazardous waste generation and hazardous material procurement. More importantly, it allows the U.S. Navy to continue to meet mission requirements without the requirement for an ozone-depleting material in hydraulic fluid testing.

VI. For Further Information

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CASE STUDY #8: REDUCTION OF OZONE-DEPLETING SOLVENT USE AT BRITISH AIRWAYS

I. Summary

In 1989, British Airways recognized that, while alternatives to ozone-depleting solvents are being investigated and tested, simple measures could be taken to significantly reduce the consumption of ozone-depleting solvents. These measures are not a solution to the problem, but are an effort to reduce the magnitude of the problem quickly and efficiently while potential solutions are evaluated. Through the use of “good housekeeping” and control of solvent usage, British Airways was able to reduce its consumption of CFC-113 by nearly 50 percent in three years. This success has allowed British Airways engineers to more precisely focus their efforts for identifying alternative cleaning techniques onto the more difficult applications.

II. Introduction

As of 1989, the phaseout dates for the elimination of ozone-depleting solvents (CFC-113 and methyl chloroform) were in the late 1990s, and therefore did not pose an immediate problem. The use of these solvents was widespread and common in aircraft maintenance practices at the time. However, concern for the environment prompted British Airways to evaluate the use of these substances and minimize their consumption as a prelude to eventual replacement with nonozone-depleting alternatives. Initial efforts were directed at the use of CFC-113 as this has the highest ozone-depletion potential (ODP) of all solvents used by British Airways. This case study details the activities undertaken to substantially reduce CFC-113 usage.

British Airways Engineering is a large organization with over 10,000 employees at its two major engineering bases: London Heathrow and London Gatwick. The range of activities at these bases covers minor and major aircraft maintenance and component overhaul. Aircraft types maintained are BAe Concorde, Boeing 737, Boeing 757, Boeing 767, Boeing 747, McDonnell Douglas DC-10, Lockheed L-1011, and Airbus A320. The component overhaul workshops are responsible for landing gear, hydraulics pneumatics, environmental systems;’ avionics, engines, and other minor components.

III. The Alternative Selection Process

The British Airways solvent reduction program did not invoke the selection of an alternative cleaning process, but rather the characterization and evaluation of existing solvent usage. The first task undertaken was to identify the location and applications in which CFC-113 was being used at British Airways. This was accomplished by touring the workshops and questioning the supervisors and shop-floor personnel about applications and quantities used. It soon became clear that, although CFC-113 was thought of as a safe material in regards to worker exposure and component compatibility, there was little consideration given to consumption levels and the environmental effects of CFC-113. Annual usage was about 24,000 liters.

At the time of the survey, the major users of CFC-113 were (not in order of consumption): avionics, engines, environmental systems, hydraulics, and pneumatics. There were other minor users, but it was decided to concentrate on the major users as this would bring about the greatest reduction in the shortest time. Early in 1990, two work areas were selected for solvent reduction trials: avionics and hydraulics. The supervisors in both areas were anxious to see the use of CFC-113 significantly reduced.

In the avionics area, all practices using CFC-113 in benchtop applications were discouraged, and isopropyl alcohol was often used as a direct substitute. This use was further discouraged because suitable alternatives such as watch cleaning solution were already available for small mechanical component cleaning. In addition to benchtop applications in the avionics workshops, there is also a large ultrasonic liquid/vapor degreasing unit in use. At the time of the trial, no individual was directly responsible for the operation and maintenance of this unit. Consequently, the unit was often used in an inefficient and wasteful manner. As part of the trial, one of the workshop foremen took responsibility for the plant and access to the area was restricted to capable personnel only. These measures focused the attention of the shop personnel on the importance of reducing the usage of CFC-113. As a result, usage has fallen significantly over the last three years, and increased worker awareness has aided in the testing of substitute materials.

The hydraulics workshops used CFC-113 in bench cleaning applications and in numerous small, open-top ultrasonic tanks. A small liquid/vapor unit was used for precision cleaning of valve components. In all' cases, there was no control over access or use. CFC-113 usage in these applications was at the time very wasteful, as most solvent was used only once and then put in a barrel for recovery. Initial measures instituted were designed to reduce the number of open-top units used and to eliminate benchtop cleaning using CFC-113. Where possible, white spirit (stoddard solvent) was immediately substituted for the CFC-113. Access to CFC-113 was restricted on a "need-to-use" basis instead of the previous "easy-to-use" basis. Later in 1990, British Airways decided to replace all of the open-top ultrasonic cleaners with two low-emission liquidhapor units. The liquid/vapor units are suitable for conversion to trichloroethylene to allow for the complete elimination of CFC-113. As a result of these efforts, CFC-113 usage in the hydraulics workshops has fallen greatly over the past three years.

IV. Environment, Health, And Safety

The British Airways solvent use reduction effort has no negative impacts on the environment, health, and/or safety. All of the effects are positive and are a result of the decreased quantity of CFC-113 consumed. As cleaning alternatives are identified and implemented, environment, health, and safety issues will be evaluated on a case-by-case basis by British Airways.

V. Conclusion

As a result of these successful trials, the same types of usage control measures described above were applied to other areas where CFC-113 was used. In general, the results have been very good and usage has fallen dramatically. Through its solvent reduction program, British Airways has significantly cut its usage of CFC-113 by gaining more control over its use and eliminating its use in applications for which it was not intended. The following is a summary of the reductions achieved:

Fiscal Year	CFC-113 Usage (liters)	Percent Reduction
1989/1990	23,895	---
1990/1991	19,489	18.4
1991/1992	12,343	48.0

A major benefit of the solvent usage reduction measures undertaken has been to highlight applications where replacement is not straightforward. This has helped to direct British Airways' efforts towards finding substitutes in these more difficult applications.

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United Nations Environment Programme. 1991. *Solvents, Coatings, and Adhesives Technical Options Report.*

U.S. EPA/ICOLP. 1991. *Alternatives for CFC-113 and Methyl Chloroform in Metal Cleaning.*

U.S. EPA/ICOLP. 1991. *Eliminating CFC-113 and Methyl Chloroform in Precision Cleaning Operations.*

Weltman, Henry J. and T. L. Phillips. 1992. Environmentally Compliant Wipe Solvent Developement. SAE Technical Paper Series 921957.

Weltman, Henry J. and S. P. Evanoff. 1991. Replacement of Halogenated Solvent Degreasing with Aqueous Immersion Cleaners. Proceedings of the 46th Industrial Waste Conference, Lewis Publishing Co., Chelsea, Michigan.

Zavodjancik, John. 1992. Aerospace Manufacturer's Program Focuses on Replacing Vapor Degreasers. *Plating and Surface Finishing,* Volume 79. pages 26 and 28.

List of Vendors for CFC-113 and Methyl Chloroform Solvent Cleaning Substitutes*

Aqueous Cleaners

Ardrox
1691 Knott Avenue
La Mirada, CA 90638
Tel: (714) 739-2821

Brent Europe Ltd.
IVER
Bucks 5LO9JJ
United Kingdom
Tel: 0753-630200

Brulin Corporation
2920 Dr. Andrew J. Brown. Ave.
PO Box 270
Indianapolis, IN 46206
Tel: (317) 923-3211

Colgate-Palmolive
300 Park Avenue
New York, NY

Dow Chemical Co;
Advanced Cleaning Systems
2020 Dow Center, Lab 9
Midland, MI 48674
Tel: (517) 636-1000

Diversey Ltd.
Weston Favell Centre
Northampton
NN3 4PD
United Kingdom
Tel: 0604 405311

DuBois Chemicals, Inc.
511 Walnut Street
Cincinnati, OH 45202
Tel: (513) 762-6839

Freemont Industries, Inc.
Valley Industrial Park
Shakopee, MN 55379
Tel: (612) 445-4121

Hubbard-Hall, Inc.
P.O. Box 790
Waterbury, CT 06725
Tel: 203-754-2171

ICI PLC
Cleaning Technology Business
P.O. Box 19
Weston Point
Runcorn Cheshire
WA7 4LW
United Kingdom
Tel: 0728 514 444

International Chemical Company
2628-T N. Mascher St.
Philadelphia, PA

Intex Products Co.
P.O. Box 6648
Greenville, SC 29606
Tel: (803) 242-6152

Modem Chemical Inc.
P.O. Box 368
Jacksonville, AR 72076
Tel: (501) 988-1311
Fax: (501) 682-7691

McGean-Ronco, Inc.
Cee-Bee Division
9520 East Ceebee Dr.
P.O. Box 7000
Downey, CA 90241-7000
Tel: (310) 803-4311
Fax: (310) 803-6701

* This is not an exhaustive list of vendors. For more names check the Thomas Register. Vendors can be cited in subsequent editions of this document by sending information to ICOLP. ICOLP's address is provided in Appendix A. Listing is for information purposes only, and does not constitute any vendor endorsement by EPA or ICOLP, either express or implied, of any product or service offered by such entity.

Oakite Ltd.
West Carr Rd.
Retford
Notts
DH22 75N
United Kingdom
Tel: 0777-704 191

Oakite Products, Inc.
50 Valley Road
Berkeley Heights, NJ 07922
Tel: (201) 464-6900

Pacific Chemical International
610 Loretta Dr.
Laguna Beach, CA 92651

Parker-Amchem
32100 Stephenson Highway
Madison Heights, MI 48071
Tel: (313) 583-9300

Proctor & Gamble Co.
1 Proctor & Gamble Plaza
Cincinnati, OH

Qual Tech Enterprises, Inc.
1485 Bayshore Blvd.
San Francisco, CA 94124
Tel: (415) 467-7887
Fax: (415) 467-7092

Turco Ltd.
Brunel Rd.
Earlstress Ind. Est.
Corby
Northants
NN17 2JW
United Kingdom
Tel: 0536-63536

W.R. Grace & Co.
55 Hayden Avenue
Lexington, MA 02173
Tel: (617) 861-6600

Zip-Chem Products
1860 Dobbin Dr.
San Jose, CA 95133
Tel: (408) 729-0291
Fax: (408) 272-8062

3-D Inc
2053 Plaza Drive
Benton Harbor, MI 49022
Tel: (800) 272-5326

Aqueous Cleaning Equipment

American Metal Wash
360 Euclid Avenue
PO. Box 265
Canonsburg, PA 15317
Tel: (412) 746-4203
Fax: (412) 746-5738

Bowden Industries
1004 Oster Drive NW
Huntsville, AL 35816
Tel: (205) 533-3700
Fax: (205) 539-7917

Branson Ultrasonics Corp.
41 Eagle Road
Danbury, CT 06813-1%1
Tel: (203) 796–0400

Care Ultrasonics
Unit 4
Poole Hall Industrial Est.
Ellesmere Port
South Wirral
L66 1 ST
United Kingdom
Tel: 051 356 4013

Crest Ultrasonics Corp.
Scotch Rd.
Mercer County Airport
P.O. Box 7266
Trenton, NJ 08628
Tel: (609) 883–4000

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

Finnsonic Oy
Parikankatu 8
SF-15170 Lahti
Finland
Tel: 358 18 7520 330
Fax: 358 18 752 005

FMT Machine & Tool, Inc.
1950 Industrial Dr.
Findlay, OH 45840
Fax: (419)422-,0072

Graymills
3705 N. Lincoln Ave.
Chicago, IL 60613
Tel: (312) 268-6825

Jensen Fabricating Engineers
P.O. Box 362
East Berlin, CT 06023
Tel: (203) 828-6516

J. M. Ney Company
Neytech Division
Bloomfield, CT 06002
Tel: (203) 342-2281
Fax: (203) 242-5688

Lewis Corporation
102 Willenbrock Rd.
Oxford, CT 06478
Fax: (203) 264-3102

Marr Engineering, Ltd.
22 Globe Rd.
Leeds
LS11 5QL
United Kingdom
Tel: 0532-459144

Ransohoff Co.
N. 5th at Ford Blvd.
Hamilton, OH 45011
Fax: (513) 863-8908

Rinco Ultrasonics (G.B.) Ltd.
20 Stadium Court
Bardot Hall Industrial Est.
Rotherham
South Yorkshire
562 6EW
United Kingdom
Tel: 0707 836521

Stoelting Inc,
502 Highway 67
PO Box 127
Kiel, WI 53042
Tel: (414) 894-2293
Fax: (414) 894-7029

Ultraseal International, Ltd.
Centurion House
Roman Way
Coleshill
Birmingham B46 1HQ
United Kingdom
Tel: 0675-467 000

Unique Industries
11544 Sheldon St.
P.O. Box 1278
Sun Valley, CA 91353
Tel: (213) 875-3810

Alternative Solvents

Allied-Signal
PO Box 1139 R
Morristown, NJ 07960
Tel: (201) 455-4848
Fax: (201) 455-2745

Arco Chemical Company
3801 West Chester Pike
Newton Square, PA 19073

Arrow Chemicals, Ltd.
Stanhope Rd.
Swadlincote
Burton-on-Trent
DE11 9BE
United Kingdom
Tel: 0283-221044

Daikin Industries, Ltd.
Chemical Division
1-1 Nishi Hitotsuya
Settsu-Shi, Osaka 566
Japan
Tel: 81–6–349-5331

Dow Chemical
Advanced Cleaning Systems
2020 Dow Center, Lab 9
Midland, MI 48674,
Tel: (517) 636-1000

Dow Chemical Co., Ltd.
Lakeside House
Stockley Park
Uxbridge
Middlesex UB11 1BE
United Kingdom
Tel: 081-848 5400

DuPont Chemicals
Customer Service
B-15305
Wilmington, DE 19898
Tel: 1-800–441-9450

Exxon Chemical Company
P.O. Box 3272
Houston, TX 77001
Tel: (800) 231-6633

GAF Chemicals Corporation
1361 Alps Rd.
Wayne, NJ 07470
Tel: (201) 628-3847

ICI Americas Inc.
P.O. Box 751
Wilmington, DE 19897
Tel: (302) 887-3564

ICI Ltd.
Solvents Marketing Dept.
P.O. Box 18
Weston Point
Runcorn Cheshire
WA7 4LW
United Kingdom
Tel: 0728 514 444

Multisol Ltd.
48A King St
Knutsford
Cheshire
WA16 6DX
United Kingdom
Tel: 0565-755 434

Samuel Banner & Co.
54/61 SandhiIls Lane
Liverpool
L5 9XL
United Kingdom
Tel: 051 922 7871

Zip-Chem Products
1860 Dobbin Dr.
San Jose, CA 95133
Tel: (408) 729–0291
Fax: (408) 272-8062

Semi-Aqueous Cleaners

Dow Chemical Co..
Advanced Cleaning Systems
2020 Dow Center, Lab 9
Midland, MI 48674
Tel: (517) 636-1000

Oil Technics
88 Sinclair Rd.
Tarry
Aberdeen
AB1 3PN
United Kingdom
Tel: 0224 248 220

Orange-Sol Inc.
Dennis Weinhold
P.O. Box 306
Chandler, AZ 85244
(602) 497-8822

Petroferm
5400 East Coast Highway
Fernandina Beach, FL 32034
Tel: (904) 261-8286
Fax: (904) 261-6994

Turco Ltd.
Brunel Rd.
Earlstress Ind. Est.
Corby
Northants
NN17 2JW
United Kingdom
Tel: 0536-63536

Union Camp
P.O. Box 37617
Jacksonville, Fl 32236
Tel: (904) 783-2180

Zip-Chem Products
1860 Dobbin Dr.
San Jose, CA 95133
Tel: (408) 729-0291
Fax: (408) 272-8062

Semi-Aqueous Cleaning Equipment

Care Ultrasonics
Unit 4 '
Poole Hall Industrial Est.
Ellesmere Port
South Wirral L66 1 ST
United Kingdom
Tel: 051 356 4013

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

Detrex Corporation
P.O. Box 569
401 Emmett Ave.
Bowling Green, KY 42102
Tel: (502) 782-1511

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

Golden Technologies Company, Inc.
Biochem Systems Division
15000 W. 6th Avenue
Suite 202
Golden, CO 80401
Tel: (303) 277-6577
Fax: (303) 277-6550

Marr Engineering, Ltd.
22 Globe. Rd.
Leeds
L511 5QL
United Kingdom
Tel: 0532-45 9144

Penetone Corporation
74 Hudson Avenue
Tenafly, NJ 07670
Tel: (201) 567-3000

Rinco Ultrasonics (G.B.) Ltd.
20 Stadium Court
Bardot Hall Industrial Est.
Rotherham South Yorkshire
562 6EW
United Kingdom
Tel: 0707 836521

Ultraseal International, Ltd.
Centurion House
Roman Way
Coleshill
Birhmingham
B46 1HQ
United Kingdom
Tel: 0675-467 000

Alcohol Cleaning Equipment

Electronic Control Design
13626 South Freeman Road
Milwaukie, OR 97222-8825
Tel: (503) 829-9108
Fax: (503) 659-4422

Herbert Streckfus GmbH
Elektronik-Sondermaschinenbau
7814 Eggenstein 1
Kruppstrabe 10
Germany
Tel: (0721) 70222-24
Fax: (0721) 785966

KLN Ultraschall GmbH
Siegfriedstr. 124
D-6148 Heppenheim
Germany
Tel: 6252/14-0
Teletex: 625290
Fax: 6262/14-277

Streckfuss USA, Inc.
3829 W. Conflans
P.O. Box 153609
Irving, TX 75015-3409
Tel: (214) 790-1614

Other

Duerr Industries, Inc.
Finishing Systems
40600 Plymouth Rd.
P.O. Box 2129
Plymouth, MI 48170-4297
Tel: (313) 459-6800
Fax: (313) 459-5837

Octagon Process, Inc.
725 River Rd.
Edgewater, NJ 07020

Pennwalt Corp.
Three Parkway
Philadelphia, PA 19102

Westco Chemicals
11312 Hartlands St.
North Hollywood, CA 91605

GLOSSARY

Acute toxicity -- The short-term toxicity of a product in a single dose. Can be divided into oral, cutaneous and respiratory toxicities.

Adsorption -- Not to be confused with absorption. Adsorption is a surface phenomenon whereby products form a physicochemical bond with many substances.

Alcohols -- A series of hydrocarbon derivatives with at least one hydrogen atom replaced by an -OH group. The simplest alcohols (methanol, ethanol, n-propanol, and isopropanol) are good solvents for some organic soils, notably rosin, but are flammable and can form explosive mixtures with air their use requires caution and well-designed equipment.

Aqueous cleaning -- Cleaning parts with water to which may be added suitable detergents, saponifiers or other additives.

Azeotrope -- A mixture of chemicals is azeotropic if the vapor composition is identical to that of the liquid phase. This means that the distillate of an azeotrope is theoretically identical to the solvents from which it is distilled. In practice, the presence of contaminants in the solvent slightly upsets the azeotropy.

Batch cleaning -- Processes in which the parts must be loaded onto and unloaded from the cleaning equipment for each cleaning cycle.

Biodegradable -- Products in wastewater are classed as biodegradable if they can be easily broken down or digested by, for example, sewage treatment.

Blasting -- The process of removing soils by directing a high pressure spray of a given media at surface to be cleaned. Used primarily to remove scale, corrosion, and carbon deposits.

Builders -- The alkaline salts in aqueous cleaners. Most aqueous cleaners contain two or more builders.

CFC -- An abbreviation for chlorofluorocarbon.

CFC-113 -- A common designation for the most popular CFC solvent, 1,1,2-trichloro-1,2,2-trifluoroethane, with an ODP of approximately 0.8.

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

Chronic toxicity -- The long-term toxicity of a product in small, repeated doses. Chronic toxicity can often take many years to determine.

COD -- An abbreviation for chemical oxygen demand.

Composite materials -- Graphite/epoxy, kevlar, and kevlar/graphite composite materials are used on certain flight control surfaces due to their high strength, high stiffness, and low density characteristics.

Corrosion inhibitor -- A constituent of many water-based cleaner formulations which helps to reduce the risk of corrosion of parts.

Detergent -- A product designed to render, for example, oils and greases soluble in water, usually made from synthetic surfactants.

Fatty acids -- The principal part of many vegetable and animal oils and greases, also known as carboxylic acids which embrace a wider definition. These are common contaminants for which solvents are used in their removal. They are also used to activate fluxes.

Flight control surfaces -- The primary flight control surfaces of the airplane are the inboard and outboard ailerons, the elevators, and the rudder. The secondary flight controls are the spoiler/speedbrakes, the horizontal stabilizer, and the leading edge and trailing edge flaps.

Fluorescent penetrant inspection. -- The process of using a fluorescent penetrant and ultraviolet light to examine a part for small cracks. The surface must be thoroughly cleaned prior to inspection for the process to be effective.

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 man-made 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.

HCFC -- An abbreviation for hydrochlorofluorocarbon.

HFC -- An abbreviation for hydrofluorocarbon.

Hydrocarbon/surfactant blend -- A mixture of low-volatile hydrocarbon solvents with surfactants, allowing the use of a two-phase cleaning process. The first phase is solvent cleaning in the blend and the second phase is water cleaning to remove the residues of the blend and any other water-soluble soils. The surfactant ensures the water-solubility of the otherwise insoluble hydrocarbon. Terpenes and other hydrocarbons are often used in this application.

Hydrochlorofluorocarbon -- An organic chemical composed of hydrogen, chlorine, fluorine and carbon atoms. These chemicals are less stable than pure CFCs, thereby having generally lower ODPs.

In-line cleaning.-- Processes in which parts are being continuously cleaned. In-line equipment is usually highly automated.

Metal cleaning -- General cleaning or degreasing of metallic components or assemblies, without specific quality requirements or with low ones.

Methyl chloroform -- See 1,1,1-trichloroethane.

ODP -- An abbreviation for ozone depletion potential.

Organic solvents -- Ketones, alcohols, esters, etc. Used often in aircraft cleaning.

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.

Perfluorocarbons (PFCs) -- A group of synthetically produced compounds in which the hydrogen atoms of hydrocarbon are replaced with fluorine atoms. The compounds are characterized by extreme stability, non-flammability, low toxicity, zero ozone depleting potential, but high global warming potential.

POTW -- Publicly Owned Treatment Works.

SAE/AMS -- Society of Automotive Engineers/Aircraft Maintenance Standards.

Saponifier -- A chemical designed to react with organic fatty acids, such as rosin, some oils and greases etc., in order to form a water-soluble soap. This is a solvent-free method of defluxing and degreasing many parts. Saponifiers are usually alkaline and may be mineral (based on sodium hydroxide or potassium hydroxide) or organic (based on water solutions of monoethanolamine).

Semi-aqueous cleaning -- Cleaning with a nonwater-based cleaner, followed by a water rinse.

Solvent -- Although not a strictly correct definition, in this context a product (aqueous or organic) designed to clean a component or assembly by dissolving the contaminants present on its surface.

Surfactant -- A product designed to reduce the surface tension of water. Also referred to as tensio-active agents/tensides. Detergents are made up principally from surfactants.

Terpene -- Any of many homocyclic hydrocarbons with the empirical formula $C_{10}H_{16}$ characteristic odor. Turpentine is mainly a mixture of terpenes. See hydrocarbon/surfactant blends.

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.

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 nonproprietary 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, affiliate, and associate members include:

- AT&T
- Boeing Corporation
- British Aerospace
- Compaq Computer Corporation
- Digital Equipment Corporation
- Ford Motor Company
- Hitachi Limited
- Honeywell
- IBM
- Matsushita Electric Industrial
- Mitsubishi Electric Corporation
- Motorola
- Northern Telecom
- 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), Association Pour la Research et Development des Methods et Processus Industriels, Electronic Industries Association, Halogenated Solvents Industry Alliance, Japan Electrical Manufacturers Association, and Korea Specialty Chemical Industry Association. Government organization affiliates include the City of Irvine (California), the Russian Institute of Applied Chemistry, the Swedish Environmental Protection Agency, the U.S. Air Force, and the U.S. Environmental Protection Agency (EPA). Other organization affiliates are the Center for Global Change (University of Maryland), Industrial Technology Research Institute of Taiwan, Korea Anti-Pollution Movement Association, National Academy of Engineering, and Research Triangle Institute. The American Electronics Association, the Electronic Industries Association, the Japan Electrical Manufacturers Association, the Swedish National Environmental Protection Agency, the U.S. EPA, the U.S. Air Force, 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, nonproprietary 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 through the United Nations Environment Programme (UNEP) database "OZNACTION," and bas 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. Andrew Mastrandonas
ICOLP
2000 L Street, N.W.
Suite 710
Washington, D.C. 20036
Tel: (202) 737-1419
Fax: (202) 296-7442

Appendix B

Sites Visited by Committee Members

In preparing this manual, members of the technical committee visited aircraft maintenance and manufacturing facilities in Denmark, Germany, Sweden;. United Kingdom, and the. United States. Committee members investigated phaseout efforts and observed processes in which CFC-113 and MCF are still being used, as well as 'those in which they have been phased out. The committee thanks the following facilities' and their representatives for hosting site visits:

Facility	Location
American Airlines Maintenance Base	Tulsa, Oklahoma, USA
British Airways Maintenance Base	London, United Kingdom
Continental Airlines Maintenance Base	Los Angeles, California, USA
Delta Air Lines Maintenance Base	Atlanta, Georgia, USA
Lufthansa German Airlines Maintenance Base	Hamburg, Germany
Kelly Air Force Base	San Antonio, Texas, USA
Lockheed Fort Worth Company (formerly General Dynamics - Fort Worth Division) F-16 Manufacturing Facility	Fort Worth, Texas, USA
McDonnell-Douglas Aircraft Manufacturing	Long Beach, California, USA
Northwest Airlines Maintenance Base	Atlanta, Georgia, USA
Saab Aircraft	Linkoping, Sweden
Scandinavian Airlines System Maintenance Base	Copenhagen, Denmark
Volvo Aero Support	Arbugd, Sweden

APPENDIX C

CFC-113 AND MCF TRADE NAMES AND MANUFACTURERS

A. CFC TRADE NAMES[1]

Manufacturer	Trade Name
ICI	Arklone
DuPont	Freon
Atochem	Flugene
Hoechst	Frigen
Kalichem	Kaltron
ISC Chemicals	Fluorisol
Allied	Genesolve
Montefluos	Delifrene
Asahi Glass	Fronsolve
Daikin	Daiflon
Central Glass	CG Triflon
Showa Denko	Flon Show Solvent

B. METHYL CHLOROFORM TRADE NAMES[1]

Manufacturer	Trade Name
ICI	Genklene
	Propaklone
DOW	Chlorothene
	Prelete
	Proact
	Aerothene TT
Atochem	Baltane
Solvay	Solvethane
Vulcan	1,1,1 Tri
PPG	Tiethane
Asahi Glass	Asahitriethane
Toagosei	1,1,1 Tri
Kanto Denka Kogyo	Kandentriethane
Central	1,1,1 Tri
Tosoh	Toyoclean

[1] 1991 UNEP Solvents, Coatings, and Adhesives Technical Options Report. December 1991.

APPENDIX D

CONTINENTAL AIRLINES
CHEMICAL QUALIFICATION SHEET

CHEMICAL QUALIFICATION SHEET

Continental

The following information must be submitted to Continental prior to purchasing any chemical. This information will b‹ reviewed and approved by the Engineering, Safety and Environmental. Failure to submit this information will prevent use o the product by Continental. If proprietary information is associated with a chemical, detailed regulatory information in PART C must also be completed. A Material Safety Data Sheet must be attached to this form, in compliance with the Occupationa Safety and Health Act.

PART A

1. **Product Name** ______________________ **Sizes** ______________________
2. **Chemical Type** ______________________
3. **Supplier** ______________________ **Phone** ______________________
   ____
   ____
4. **Contact** ______________________ **Phone** ______________________
   ____
5. **Manufacturer** ______________________
   24-hour Emergency Contact Number ______________________
6. **Chemical Composition:**

Name	CAS #	PEL	TLV

7. **Chemical Data:**

At Shipping State:		At Dilution/Usage State:	
pH		pH	
Flashpoint		Flashpoint	
Specific Gravity		Specific Gravity	
Solids at 105C		Solids at 105C	
VOCs(g/l)		VOCs(g/l)	
Vapor Pressure (mm/Hg)		Vapor Pressure (mm/Hg)	
Explosive Limits		Explosive Limits	
Extinguishing Agent		Extinguishing Agent	
Water Reactive?		Water Reactive?	
Shelf Life		Shelf Life	
Pounds of VOCs per gallon of solids			

8. Composition Information: Does the material exceed listed limits for the following parameters; circle yes or no:

Arsenic	5.0 mg/l	yes	no
Barium	100 mg/l	yes	no
Beryllium	100 mg/l	yes	no
Boron	1000 mg/l	yes	no
Cadmium	100 mg/l	yes	no
Chromium	1000 mg/l	yes	no
Chromium VI	500 mg/l	yes	no
Copper	1000 mg/l	yes	no
Cyanides(free)	500 mg/l	yes	no
Cyanides(total)	500 mg/l	yes	no
Fluorides	1000 mg/l	yes	no
Lead	500 mg/l	yes	no
Mercury	0.2 mg/l	yes	no
Nickel	100 mg/l	yes	no
Phenol	10,000 mg/l	yes	no
Selenium	100 mg/l	yes	no
Silver	5 mg/l	yes	no
Thallium	100 mg/l	yes	no
Tin	1000 mg/l	yes	no
Zinc	100 mg/l	yes	no
Phosphates(Total)	1 %	yes	no
Ammonia(Total)	1 %	yes	no
Nitrates	1 %	yes	no
Chlorides	1 %	yes	no
Dichloromethane	100 mg/l	yes	no

(Distribution: Original to Environmental Programs; Copy to Safety, Engineering and Purchasing)

CHEMICAL QUALIFICATION SHEET

Continental

9. **Describe use of the product, including mixing instructions:** ____________________

10. **Is personnel protective equipment required during planned use?**
If yes, please describe: ____________________

11. **Approvals and Specifications:**

Please list specifications the product meets and customer's approvals: ____________________

12. **Does the product meet the following requirements or appear as a regulated chemical on the following lists?**

Hydrogen Embrittlement (ASTM F519)	yes	no
Stress Craze (ASTM F484)	yes	no
Effect on Painted Surfaces (ASTM F502)	yes	no
Effect on Unpainted Surfaces (ASTM F485)	yes	no
Sandwich Corrosion (ASTM F1110)	yes	no
Immersion Corrosion (ASTM F483)	yes	no
SCAQMD Regulation No. 1124	yes	no
SCAQMD Regulation No. 1129	yes	no
SCAQMD Regulation No. 1151	yes	no
SCAQMD Regulation No. 1171	yes	no
Clean Air Act Amdts of 1990, Section 112	yes	no
Douglas CSD No. 1	yes	no
Boeing D6-17487	yes	no

Does this chemical contain CFCs?	yes	no
Does this chemical contain Halons?	yes	no
Does this chemical contain Glycol Ethers?	yes	no

13. **Other Effects:**
Circle the appropriate effects using the following legend:

Legend:	A = Stain	C = Harden	E = Craze	G = Incompatible
	B = Swell	D = Soften	F = No Effect	

Acrylic Latex Paint	A	B	C	D	E	F	G
Electrical Insulation	A	B	C	D	E	F	G
Epoxy/Polyurethane Paint	A	B	C	D	E	F	G
Neoprene	A	B	C	D	E	F	G
Natural Rubber	A	B	C	D	E	F	G
Silicone Rubber	A	B	C	D	E	F	G
Kydex	A	B	C	D	E	F	G
Royalite	A	B	C	D	E	F	G
Polyplastex	A	B	C	D	E	F	G
Aluminum	A	B	C	D	E	F	G
Magnesium	A	B	C	D	E	F	G
Plexiglass	A	B	C	D	E	F	G
Polysulfone	A	B	C	D	E	F	G
Polysulfide	A	B	C	D	E	F	G
Polycarbonate	A	B	C	D	E	F	G
Upholstery Fabrics	A	B	C	D	E	F	G
Kevlar Epoxy Composite	A	B	C	D	E	F	G
Graphite Epoxy Composite	A	B	C	D	E	F	G
Other ____________	A	B	C	D	E	F	G
____________	A	B	C	D	E	F	G
____________	A	B	C	D	E	F	G

(Distribution: Original to Environmental Programs; Copy to Safety, Engineering and Purchasing)

CHEMICAL QUALIFICATION SHEET

Continental

14. **Physiological Properties:**
   a. **Local Oral Toxicity:** ____________________
   b. **Local Effects on Eyes:** ____________________
   c. **Local Effects on Skin:** ____________________
   d. **Hazards of Inhalation:** ____________________
   e. **Exposure Properties (Irritation to Eyes, Nose, or Throat):** ____________________
   f. **Precautions of Normal Use:** ____________________
   g. ***Procedure in case of breakage or leakage:*** ____________________
   h. **Antidote in case of swallowing:** ____________________
   i. **Antidote in case of eye contact:** ____________________
   j. **Antidote in case of skin contact:** ____________________
   k. **Antidote in case on inhalation:** ____________________

PART B

The following information will be completed by Continental for all nonproprietary contents of the product. If proprietary information is associated with a chemical, detailed regulatory information in PART C must also be completed.

CHEMICAL NAME	CAS#	DOT	RCRA	CERCLA(RQ)	EHS/TRI	CAA-112

PART C

The following information will be completed by THE VENDOR for all proprietary contents of the product. Failure to complete this information will result in non-approval of the product by Continental. Indicate the chemical reference (e.g., Chemical #1), and how that chemical is regulated by the Department of Transportation (including the hazard category and the UN or NA number), the Resource Conservation and Recovery Act (including the RCRA waste code), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; including the reportable quantity [RQ]), whether the Superfund Amendments and Reauthorization Act lists this chemical as an Extremely Hazardous Substance (EHS) and if the chemical is reportable on the Toxic Release Inventory (TRI, and at what concentration), and whether the chemical is listed as a hazardous air pollutant under Section 112 of the Clean Air Act (CAA)

CHEMICAL REFERENCE	DOT	RCRA	CERCLA(RQ)	EHS/TRI	CAA-112

(Distribution: Original to Environmental Programs; Copy to Safety, Engineering and Purchasing)

PART D

The following Continental staff have reviewed the information on the subject chemical and indicated their recommendation for potential usage within Continental Airlines:

ENGINEERING:

Name: ____________________
Title: ____________________
Date: ____________________

I hereby approve/disapprove the use of this product within Continental Airlines: ____________________ (Signature)

SAFETY:

Name: ____________________
Title: ____________________
Date: ____________________

I hereby approve/disapprove the use of this product within Continental Airlines: ____________________ (Signature)

ENVIRONMENTAL PROGRAMS:

Name: ____________________
Title: ____________________
Date: ____________________

I hereby approve/disapprove the use of this product within Continental Airlines: ____________________ (Signature)

Upon completion of the review process, the Environmental Programs Group, as the last reviewer, will submit completed copies to Engineering, Safety, and Purchasing.

(Distribution: Original to Environmental Programs; Copy to Safety, Engineering and Purchasing)

APPENDIX E

DOUGLAS AIRCRAFT COMPANY
CUSTOMER SERVICE DOCUMENT #1

AOL

ALL OPERATOR LETTER

CUSTOMER SUPPORT

MCDONNELL DOUGLAS

Douglas Aircraft Company

August 2, 1988
C1-L00-141/TS/GFL
8-13-0
9-51-00
10-20-00

AOL 8-584B
AOL 9-665B
AOL 10-50B

To: All DC-8, DC-9 and DC-10 Operators

Subject: AIRCRAFT MAINTENANCE CHEMICALS

R | Applicable To: All DC-8, DC-9, C-9, MD-80, DC-10 and KC-10A Aircraft

R | Reference:
(a) Douglas Aircraft Company Customer Service Document (CSD) Number 1, Revised May 1988
(b) AOL 8-584A/9-665A/10-50A, dated March 12, 1979

REASON

DOUGLAS HAS REVISED THE QUALIFICATION TEST PROCEDURES FOR AIRCRAFT
R | MAINTENANCE CHEMICALS. THIS AOL SUPERSEDES AND CANCELS REFERENCE (B).

Douglas has collaborated with major commercial aircraft manufacturers, commercial airlines and military operator representatives to develop standardized test procedures for qualifying aircraft maintenance materials throughout the aircraft industry.

R | The enclosed reference (a) document contains these new test procedures developed through this coordinated effort. Reference (a) supersedes the CSD Number 1 issue, revised January 22, 1979, which was transmitted to all operators as an enclosure to reference (b).

Douglas will not test and approve maintenance chemicals for use on operational jet aircraft, as was done originally. The responsibility for approval of aircraft maintenance chemicals for use on Douglas manufactured aircraft is with the operator.

Operators are requested to use the enclosed CSD document, along with their own special requirements, as a guide for the approval of maintenance chemicals.

R. J. McKernon, Director
Government Special Products ILS
Integrated Logistics Support

T. J. Mangum, Director
Commercial Customer Support
MD-80 and DC-9 Programs

C. V. Nelson, Manage
Commercial Customer
DC-10 Program

GFL:sw
(NAA)
Enclosure: Noted

DOCUMENT:	Douglas Aircraft Company. Product Support Customer Service Document (CSD) No. 1. Revised May, 1988
TITLE:	Aircraft Maintenance Materials and Methods for Douglas In-Service Aircraft.
MODE:	Douglas Commercial Jet Aircraft
PREPARED BY:	W. C. Rooke, C1-E31

TABLE OF CONTENTS

A. INTRODUCTION

Aircraft maintenance programs incorporate many types of maintenance chemicals for use in cleaning, deoxidizing, polishing, stripping, or deicing. Certain maintenance chemicals may be harmful to components of the aircraft structure. The requirements and test methods in this document are presented as a guide for evaluating and selecting maintenance chemicals which will not damage the aircraft.

B. GENERAL INSTRUCTIONS

1. Qualification tests specified herein are those designed specifically to ascertain whether the materials are compatible and noninjurous to aircraft surfaces and finishes when used under specified conditions.

2. Qualification tests in addition to those set forth in this document should be required or conducted by operators when such tests are deemed necessary to assure aircraft and personnel safety.

3. The Manufacturer/Vendor of materials is given wide latitude in the selection of ingredients and composition. However, the compounds shall not contain ingredients for which the degree of hazard has not been appraised, nor any combination of ingredients that might be hazardous to the health of personnel. Safety Data Sheets shall be provided by the manufacturer of all products qualified under this document.

4. The Manufacturer/Vendor shall use the same ingredients and formulation procedures for production materials as for approval of the test sample materials. If it becomes necessary to make any changes in the components or processing, the Manufacturer/Vendor shall be required to requalify the materials. Procedures describing the manner and frequency of use on the aircraft shall not be altered or modified in any way without requalification.

N 5. Materials, methods, and processes specified in this specification may involve the use of hazardous materials; this specification, however, does not purport to address the hazards which may be involved. It is the responsibility of the user to ensure familiarity with the materials and processes involved and to take necessary precautionary measures to ensure the health and safety of personnel who may come in contact with the materials and for protection of the environment. Good work shop practices and referral to suppliers Materials Safety Data Sheets should be considered minimum requirements.

C. MATERIAL CLASSIFICATION AND QUALIFICATION REQUIREMENTS

1. This document covers the following types of Manufacturer/Vendor developed materials and procedures for use on commercial jet aircraft.

   a. TYPE I - Materials and procedures for general exterior cleaning of painted and unpainted surfaces.

   b. TYPE II - Materials and procedures for carbon exhaust deposit removal.

   R c. TYPE III - Materials and procedures for removing paint from aluminum surfaces and high strength steel components.

   d. TYPE IV - Materials and procedures for brightening, deoxidizing, and reconditioning aircraft surfaces.

   e. TYPE V - Materials and procedures for polishing exterior aluminum surfaces.

   f. TYPE VI - Materials and procedures for deicing exterior surfaces of aircraft.

2. Materials and processes developed under this document shall be those which will perform without injury to aircraft materials and finishes.

R 3. Unless otherwise specified by the aircraft operator, materials for regular use which cause hydrogen embrittlement of high strength steels will not be approved for use under this document.

4. Acid containing compounds, such as brighteners and deoxidizers or other materials which are embrittling to high strength steels, are not recommended. The Manufacturer/Vendor should exercise every effort to develop and submit only those materials which are compatible with high strength steel alloys, however, when it is deemed necessary to use embrittling type materials, the following specific requirements and limitations apply:

   a. The decision to use a material shall rest with the operator and should be made by their engineering personnel who fully recognize the hazards of hydrogen embrittlement.

   b. A positive means must be provided to prevent materials which may cause hydrogen embrittlement from contacting high strength steel parts or assemblies.

   R c. Operators shall reserve the right to disapprove the use of embrittling type materials whenever it is deemed essential to assure safety of the aircraft.

D. QUALIFICATION TESTING

Testing of Manufacturer/Vendor developed materials will be performed at their expense and shall be accomplished by an independent testing laboratory unless prior written approval is obtained from the operator authorizing the Manufacturer/Vendor laboratories to perform the qualification tests.

1. The laboratory conducting the qualification testing shall, when qualifying the materials, use the same compositions and concentrations as recommended by the Manufacturer/Vendor for actual use. When various concentrations are recommended for use, qualification testing shall be conducted using the minimum and maximum concentrations. When the Manufacturer/Vendor specifies mixtures of solvents and/or water, separate tests shall be conducted on the mixtures.

2. Upon completion of the tests specified herein, the testing laboratory will be required to prepare a test report stating whether the material meets the requirements of this document. The report shall bear a test report number and date, and will include a description of the tests conducted, the method of test, and the resulting test data. Specimens exposed to the test conditions, along with the unexposed control specimens, will be permanently identified and suitably mounted for display.

3. The material qualification tests are to be performed as outlined in Section G. and shall be as follows for each material type.

R

	MATERIAL TYPE (REFERENCE PARAGRAPH C.1)					
	I	II	III	IV	V	VI
QUALIFICATION TEST	GENERAL PURPOSE CLEANER	CARBON EXHAUST REMOVER	PAINT REMOVER	DEOXIDIZER/ BRIGHTENER	POLISHES	DEICING COMPOUNDS
Effects on Painted Surface	X	X	-	-	-	X
Residue	X	X	-	-	X	X
Sandwich Corrosion	X	X	X	X(1)	X	X
Stress Crazing of Acrylic Plastic	X	-	-	X	X	X
Immersion Corrosion, Aluminum	X	X	X	X	X	X
Hydrogen Embrittlement	X	X	X	-	X	X
Cadmium Removal	X	X	X	-	-	X

FOOTNOTE: (1) Test chemical conversion coated aluminum only (P/N 7452876-7,-11,-15 slight etching of the aluminum surface is acceptable.

4. Test Materials

Kit No. 7452876-501 is available for conducting laboratory tests on each type material listed in Paragraph C.1, and is comprised of the following parts:

PART NO.	KEY WORD	QUANTITY PER KIT
7452876-3	Test Panel - Painted Surfaces	2
-5	Test Panel - Residue	2
-7	Test Panel - Sandwich Corrosion	6
-9	Test Panel - Sandwich Corrosion	6
-11	Test Panel - Sandwich Corrosion	6
-13	Test Panel - Sandwich Corrosion	6
-15	Test Panel - Sandwich Corrosion	6
-17	Test Panel - Sandwich Corrosion	6
-19	Test Panel - Stress Crazing Acrylic Plastic	1
-21	Test Panel - Immersion Corrosion	3
-23	Test Panel - Cadmium Removal	3

NOTE: Stress rings and stress bars are not included in this kit, see Paragraph G.7.a.

Delivery of the kit starts immediately upon receipt of purchase order. The purchase order must specify this document number, the part number (7452876) of the kit and the number of kits desired. Individual kit parts (panels) are not available.

Direct purchase order to:

R

Douglas Aircraft Co.
Commercial Spares
Dept. C1-L31, MS 73-44
P. O. Box 1771
Long Beach, CA 90801

5. U.S. Government specifications referred to herein may be obtained from the Superintendent of Documents, Washington, D.C.

6. Publications of the American Society for Testing and Materials (ASTM) are available from ASTM, 1916 Race St., Philadelphia, PA, 19103.

6.1 References:

6.1.1	ASTM F 483	Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
6.1.2	ASTM F 484	Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
6.1.3	ASTM F 485	Effects of Cleaners on Unpainted Aircraft Surfaces
6.1.4	ASTM F 502	Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
6.1.5	ASTM F 519	Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals

E. USAGE AND APPLICATION REQUIREMENTS - PRODUCT BULLETIN

R 1. A product bulletin describing the material and method of use shall be provided by the Manufacturer/Vendor. The bulletin is intended to provide the operator detailed instructions for cleaning and maintaining the airplane using the Manufacturer/Vendor products and procedures. The product bulletin should include hazardous waste disposal recommendation, where appropriate.

2. The product bulletin shall be written in such a manner that the instructions and procedures apply specifically to the use of the product on the aircraft. The Manufacturer/Vendor is urged to use the following as a format when preparing the product bulletin.

   a. Bulletin Identification: The bulletin shall be identified by the Manufacturer/Vendor letterhead, the bulletin title, a bulletin number, and date of issue.

   b. Description of Product: This section shall contain a summary which describes in general detail the important characteristics and intended use of the product and a brief description of the method of product use. The type of the material, as defined in Paragraph C.1 shall be stated in this section.

R c. Method of Use: This section shall describe the method of product use, temperature limitations, areas of application, and frequency of use on the aircraft. The information should be sufficiently detailed and complete to provide instructions to operators for use of the product under all known and anticipated conditions.

   d. Mixing Instructions: The manner in which the product is mixed, diluted, or otherwise prepared for use on the various areas of the aircraft shall be contained in this section. Equipment and materials required for the product use as well as the recommended concentrations of use should be included.

E. (Cont'd)

2. e. Material Compatibility: This section shall contain information and data relating to the compatibility or incompatibility of the product upon the various surfaces and finishes of the aircraft.

   f. Properties: A description of the important chemical and physical properties of the material including toxicity, pH, flash point, odor, storage limitations, and handling instructions shall be included in this section.

   g. Safety Practices: This section shall describe the recommended safety practices, protective clothing and equipment as may be required for personnel to safely use the material. Any harmful or adverse effect to personnel that may result from exposure to the material shall be specifically noted, including first aid practices.

   h. Warranty: A clear concise warranty statement shall be made. This statement should clarify the Manufacturer/Vendor warranty position regarding the material formulation and its usage.

3. The Manufacturer/Vendor shall provide instructions, training or supervision as required to ensure proper use and control of the product by the operator.

F. SUBMITTAL OF DATA FOR PRODUCT APPROVAL

1. The Manufacturer/Vendor shall submit the following to the operator for evaluation and approval:

   a. A copy of the laboratory report covering the results of the material qualification tests. The laboratory report and test specimens submitted will be retained by the operator for record purposes.

   b. A copy of the product bulletin containing the information as described in Section E.

R c. A copy of the Material Safety Data Sheet, Office of Safety & Health Administration (OSHA) Form 174, or equivalent.

2. Operator acceptance or rejection of the material and the applicable product bulletin will be determined on the basis of safety of aircraft material and finishes as shown by the qualification test data.

G. QUALIFICATION TEST PROCEDURE

1. Effect on Painted Surface Test: The material shall not produce a decrease in paint film hardness greater than one pencil; that is, the number of the next softer pencil, or any discoloration or staining when tested in accordance with ASTM F 502. At least two panels shall be used per test.

2. Residue Test: The material shall leave no residue or stain when tested in accordance with ASTM F 485.

3. Sandwich Corrosion Test: The compound shall not cause significant corrosion of aluminum alloy faying surfaces when tested in accordance with the following conditions of temperature and humidity:

   a. Thirty-six test panels 2 x 4 x 0.040 inch shall be prepared as follows:

      Six each - Aluminum alloy panels P/N 7452876-7 (nonclad 2024-T3) Federal Specification QQ-A-250/4 Temp-T3, Alodined (colorless #1000 or 1500) per Military Specification MIL-C-5541, Class 3.

      Six each - Aluminum alloy panels P/N 7452876-9 (nonclad 2024-T3) Federal Specification QQ-A-250/4 Temp-T3, Chromic acid anodized per Military Specification MIL-A-8625, Type 1.

      Six each - Aluminum alloy panels P/N 7452876-11 (clad 2024-T3) Federal Specification QQ-A-250/5 Temp-T3, Alodined (colorless #1000 or 1500) per Military Specification MIL-C-5541, Class 3.

      Six each - Aluminum alloys panels P/N 7452876-13 (clad 2024-T3) Federal Specification QQ-A-250/5 Temp-T3, Chromic acid anodized per Military Specification MIL-A-8625, Type 1.

      Six each - Aluminum alloy panels P/N 7452876-15 (clad 7075-T6) Federal Specification QQ-A-250/13 Temp-T6, Alodined (colorless #1000 or 1500) per Military Specification MIL-C-5541, Class 3.

      Six each - Aluminum alloy panels P/N 7452876-17 (clad 7075-T6). Federal Specification QQ-A-250/13 Temp-T6, Chromic acid anodized per Military Specification MIL-A-8625, Type 1.

   b. A sandwich set shall consist of two panels of the same alloy and surface finish. Assemble the panels into three identical groups, each having six different sets of panels, suitably identified by permanent marking.

G. (Cont'd)

3. c. The material to be tested shall be applied at the use concentration with a clean brush to the face of one panel from each set in the first group. Dilution to use concentration, is required, will be accomplished with distilled water. The material shall be applied in an irregular manner and shall cover approximately one-half the panel face. The two similar panels shall be placed together in sandwich style with the test material in the faying surface between the two panels.

R d. The second group of panels will be sandwiched together in sets as described above except that the faying surface between the panel faces shall be coated with the material at the use concentration, diluted with tap water or solvent, as required.

e. The third group of panels will be sandwiched together in sets as described above except that the faying surfaces between the panel faces shall be wet with tap water. This test may be omitted if the material is used in the concentrated form only.

f. The three group of panels shall be exposed at alternate intervals of 16 hours in the humidity cabinet and eight hours in an oven. Beginning with the humidity cabinet exposure, the cycling test shall be continued for a total of seven days. The humidity cabinet shall be maintained at 100° ± 2°F (37.8° ± 1.1°C) and 98 to 100 percent relative humidity. The oven shall be maintained at 100° ± 5°F (37.8° ± 2.8°C). Each set of panels shall be exposed individually, not stacked, in a horizontal position. After exposure, the panels shall be rinsed in warm tap water and scrubbed lightly with a soft nonmetallic bristle brush. After drying, examine each panel under 10X magnification and rate each set according to the following:

0 - No visible corrosion
1 - Very slight corrosion or discoloration
2 - Slight corrosion
3 - Moderate corrosion
4 - Extensive corrosion.

g. The corrosion rating obtained on the sets of panels of the first and second groups shall be compared with the rating obtained on the third group. Corrosion on any panel in the first and second groups exceeding that obtained on the similar panels in the third group shall be considered as excessive.

h. The corrosion rating obtained on the sets of panels tested with concentrated materials, for which comparison panels were not run, shall not exceed a rating of 1, as defined above.

G. (Cont'd)

4. Stress Crazing Test on Acrylic Plastics: The compound shall not cause crazing, cracking, or other attack of acrylic based plastics when tested in accordance with ASTM F 484, using Type C material at a stress level of 4500 psi.

5. Immersion Corrosion Test: The average weight loss of aluminum alloy specimens shall not exceed 10 milligrams per coupon when tested per ASTM F 483. The aluminum alloy 7075-T6 alclad coupons shall conform to Federal Specification QQ-A-250/13 Temp T6, with corners and edges smoothed.

R 6. Cadmium Removal Test: The average weight loss of cadmium from low hydrogen embrittlement cadmium plated steel shall not exceed 10 milligrams per coupon when tested per ASTM F 483. The test duration shall be 24 hours. The test specimens shall be 1 x 2 x 0.040 inch 4130 steel panels (MIL-S-18729) with corners and edges smoothed and then plated with 0.003 to 0.006 inch of low hydrogen embrittlement cadmium plating (P/N 7452876-23).

7. Hydrogen Embrittlement Test: Hydrogen Embrittlement testing shall be in accordance with ASTM F 519, Type 1a, 1c, or 2a.

   a. Douglas sustained load stress rings Part Number S4776683-501 (4340 steel), and stress bars Part Number S4776683-505 (C1018 steel) may be purchased from:

R
Douglas Aircraft Co.
Commercial Spares
Dept. C1-L31, MS 73-44
P. O. Box 1771
Long Beach, CA 90801

Cleveland Pneumatic Co.
3781 East 77th Street
Cleveland, OH 44105

4469T

APPENDIX F

BOEING CORPORATION
DOCUMENT D6-117487

BOEING

CAGE CODE

THIS DOCUMENT IS:

CONTROLLED

ALL REVISIONS TO THIS DOCUMENT SHALL BE APPROVED BY THE ABOVE ORGANIZATION PRIOR TO RELEASE.

PREPARED UNDER ☐ CONTRACT NO.
☐ IR&D
☐ OTHER

PREPARED ON FILED UNDER

DOCUMENT NO. D6-17487 MODEL ALL

TITLE CERTIFICATION TESTING OF AIRPLANE MAINTENANCE MATERIALS

[X] THE INFORMATION CONTAINED HEREIN IS NOT PROPRIETARY.

☐ THE INFORMATION CONTAINED HEREIN IS PROPRIETARY TO THE BOEING COMPANY AND SHALL NOT BE REPRODUCED OR DISCLOSED IN WHOLE OR IN PART OR USED FOR ANY DESIGN OR MANUFACTURE EXCEPT WHEN SUCH USER POSSESSES DIRECT, WRITTEN AUTHORIZATION FROM THE BOEING COMPANY.

ORIGINAL RELEASE DATE

ISSUE NO. TO DATE

ADDITIONAL LIMITATIONS IMPOSED ON THIS DOCUMENT WILL BE FOUND ON A SEPARATE LIMITATIONS PAGE.

ORIGINAL

	SIGNATURE	ORGN	DATE
Original Supervised by	W. S. Hamilton		
Original Approved by	W. C. Potter		
Prepared by	J. G. McDougal		3/12/70
Supervised by	D. E. Austin		3/12/70
Approved by	J. C. McMillan		3/12/70

D0-6000-4540 ORIG. 12/87

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SECTION	PAGE NUMBER	REV SYM	ADDED PAGES PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM

REVISIONS

REV SYM	DESCRIPTION	DATE	APPROVAL
A	Para. 4.D. Combined classification of Carbon Removers for painted and unpainted surfaces. Para. 5.1 Changed Table to effect combination in Para. 4.D. Added B Para. 5.2 Added Boeing approved source for specimens to be used in tests per this document. Para. 5.2.1 Changed anodized substrate alloy to 7178-T6 due to its greater availability. Para. 5.3.1.1.3 Reversed test cycle and added requirement for positioning of panels in humidity cabinet. Para. 5.3.3.1 Added criteria for constituting a set of pencils. Para. 5.3.3.4 Added criteria for acceptance of materials subjected to paint softening test. Para. 5.3.4.4.4 Deleted anodic cleaning step and replaced with deoxidation soak. Changed succeeding paragraphs to conform to new soak procedure.	3-1-66	J. Steinhauser A. F. Sherman R. P. Thierry O. J. Lewis W. C. Potter
B	Para 5.1 Deleted requirement for corrosion testing of paint strippers meeting MIL-R-25134. Para. 5.2.1 Added corrosion test panels for paint strippers Para. 5.3.1 Added corrosion test for paint strippers.	4-11-66	E. A. Reed D. M. Erwein R. Y. Lindbom O. J. Lewis W. C. Potter
C	Para. 2. Clarified statements Para. 3.2 Clarified statements Para. 3.4 Added Para. 4. Clarified; added e. Para. 5. Table - Added Weight Loss Test for Paint Strippers; Added Deicers and related tests Para. 6-10. Rewrote tests for clarification and re-numbered Para. 10.3.f Added criteria for maximum heat peak of 1 Retyped entire document.	3-2-70	J.G. McDougal D.E. Austin J.C. McMillan

REVISIONS

REV SYM	DESCRIPTION	DATE	APPROVAL
D	4.f Added Toilet Flushing Fluids to the Material Classification Section. 5. Added Test Requirements for Toilet Flushing Fluids to Material Classification Table. 8. Added procedures and requirements for tests to determine material compatibility with toilet flushing fluids. 10. Added Drilube Company as an approved source for Hydrogen Detection Gauges 10.1 Deleted DTO, FS Switch, THI Meter and T_o from definitions. 10.3 Revised entire section to show the deletion of definitions removed from Section 10.1	12-10-71	P. O. Saelid G. L. Moore A. W. Bethune
E	**General** a. Changed "Qualification" to "Certification" in the document title and throughout the entire document. b. Retyped entire document. **Specific** 3.1 Added "no longer" to second sentence. 5.a Rewrote to clarify 6.1.b. Added 2024-T3 clad as an option to 7075-T6 clad 6.2.a. Added 2024-T3 clad as an option to 7075-T6 clad Section 9. Renumbered and rewrote to clarify specimen preparation and processing requirements. Section 10. Renumbered and rewrote to clarify testing requirements.	10-31-72	J. G. McDougal R. A. Anderson A. W. Bethune
F	10.4.2.(1) Correct typographical error 10.4.b.(10) Added provision to allow forced air drying 10.4.c.(8) Added provision to allow forced air drying 10.4.d. Added provisions to allow forced air drying (3) Added to assure testing of ambient temperature probe (7) Added requirement to turn probe off during majority of test immersion time. Also added minimum warm-up time for probe prior to making readings.	12-21-73	E. E. Brown R. A. Anderson A. W. Bethune

AD 1546 C

REVISIONS

REV SYM	DESCRIPTION	DATE	APPROVAL
G	This is a complete revision to update test requirements and procedures.	8-4-76	R. Lindbom; Approved; Engineering
H	This is a complete revision to update test requirements and procedures. Most of the pages have been renumbered.	5-21-80	Prepared; Approved; Engineering
J	Revised Section 12, Paint Softening Test, to delete obsolete paint systems and incorporate current paint systems. Revised Appendix I to clarify information on suppliers of coatings, sealants and rubber used for testing.	6-13-89	Prepared by; Approved by; Engineering

AD 1546 C

TABLE OF CONTENTS

J
J

1. INTRODUCTION

a. This document outlines the tests and criteria to be used by customer airlines in evaluation of materials developed by vendors for use in the general maintenance of Boeing airplanes.

b. The certification tests herein are intended only to ensure that the materials are not injurious to airplane surfaces when used as specified by the manufacturers. These tests are not intended to judge performance.

c. These tests are based on the materials and finishes present on the aircraft at the time of delivery by The Boeing Company. If either the materials or finishes present on the aircraft are changed subsequent to delivery, individual airlines may require that additional or different tests be included in any evaluation procedure (see Section 2.b(2) below).

2. GENERAL

a. The Boeing Company will not perform the tests described herein for the airlines nor will The Boeing Company act as an intermediary between vendors and airlines, except that for a fee, Boeing Technology Services 1/ will test materials to the requirements of this document and issue a test report.

1/ Boeing Technology Services
P.O. Box 3707
Seattle, Washington 98124

b. Additional Tests

(1) The Boeing Company reserves the right to make changes, without notice, to these tests.

(2) Customer airlines may specify use of their own tests and requirements in addition to tests described herein.

c. Certification of a material to these requirements may not be construed as a recommendation of the material by The Boeing Company. The final selection of materials rests with the user.

3. GENERAL MATERIAL REQUIREMENTS

a. Production material shall be exactly the same as sample material. If any change is made, the material shall no longer be certified. Modified materials, whether the modification is intentional or occurs spontaneously during storage, shall not be used prior to recertification.

b. Detailed instructions for the use of each product as it specifically applies to airplanes shall be supplied by the vendor in the form of a product support specification. This specification should contain the following minimum information:

(1) General Identification: Name of manufacturer, name and address of supplier, specification title, etc.

(2) Product Description: Intended use of the product, special characteristics, etc.

(3) Method of Use: Method and areas of application, frequency of use, etc. This should contain detailed instructions for use under all anticipated conditions.

(4) Mixing Instructions: How to mix, dilute, or otherwise prepare the product for use. Equipment and materials required for preparation as well as dilution ratios should be included.

(5) Material Compatibility: Information and data on compatibility of the product with the various surfaces and finishes on the airplane. Include certification test data.

(6) Limitations: Precautions, limitations, and restrictions; instances where contact will damage airplane materials.

(7) Handling Properties: Important chemical and physical properties of the material including toxicity, pH, flash point, etc. Include storage and handling instructions.

(8) Safety: Safety practices, equipment, and clothing; harmful results of exposure to personnel; antidotes, etc.

(9) Warranty: A guarantee by the vendor, supplier, or manufacturer that the material will not damage the airplane when used as specified by the manufacturer, and that the material shall not be modified without notice.

3. **GENERAL MATERIAL REQUIREMENTS** (Continued)

c. Instruction or training as necessary to ensure proper use of the product shall be provided by the supplier.

d. Specimen sets required for the tests outlined in Table I may be purchased from Federal Testing Labs, 29½ Dravis, Seattle, WA 98109, or they may be prepared as outlined in Sections 6 through 12.

4. **MATERIAL CLASSIFICATIONS**

Due to the differing characteristics of various types of maintenance materials, it is necessary to perform the tests only as indicated in Table I. The various types of maintenance materials are listed and defined below. See the applicable Maintenance and Overhaul Manuals for usage of these materials.

a. Manual Alkaline and Emulsion Cleaners and Liquid Waxes: Materials for general exterior cleaning of both painted and unpainted surfaces.

b. Acid Brighteners and Corrosion Removers: Materials for brightening and deoxidizing clad aluminum surfaces.

c. Paint Strippers: Materials for stripping paint from exterior metal surfaces.

d. Carbon Removers: Materials for removing carbon and exhaust deposits from unpainted or painted surfaces.

e. Airplane Deicers: Materials used for deicing or as a barrier to delay buildup of ice or snow on airplane exterior surfaces.

Facility Deicers: Materials for chemically deicing airport walkways, service aprons, or runways.

f. Toilet Flushing Fluids: Deodorants added to the toilet flushing system.

5. CERTIFICATION TESTING OF MATERIALS

a. Material certification test procedures are outlined in Sections 6 through 13 and shall be performed as required in Table I.

b. Each material shall be tested in the undiluted state and at the dilutions with water at which it will be used.

TABLE I

REQUIRED CERTIFICATION TESTS

CERTIFICATION TESTS	MANUAL ALKALINE AND EMULSION CLEANERS AND LIQUID WAXES	ACID BRIGHTENERS AND CORROSION REMOVERS	PAINT STRIPPERS	CARBON REMOVERS	AIRPLANE AND FACILITY DEICERS	TOILET FLUSHING FLUIDS
Sandwich Corrosion Test (Sec. 6)	X		X 1/	X	X	X
Immersion Corrosion Test (Sec. 7)			X 1/	X		
Acrylic Crazing Test (Sec. 8)	X	X		X	X	
Polycarbonate Crazing Test (Sec. 9)						X
Elastomer Degradation Tests (Sec. 10)						X
Tape Adhesion Test (Sec. 11)						X
Paint Softening Test (Sec. 12)	X	X		X	X	X
Hydrogen Embrittlement Test (Sec. 13)	X		X	X	X	

1/ Materials meeting MIL-R-25134 need not be tested for corrosion.

6. SANDWICH CORROSION TEST

6.1 TEST SPECIMENS

a. Panel Size: 2 x 4 x 0.040 to 0.060 inches

b. Panel Material

(1) Clad 7075-T6 aluminum alloy per QQ-A-250/13
(Optional: Clad 2024-T3 per QQ-A-250/5)

(2) Bare 7075-T6 aluminum alloy per QQ-A-250/12
(Optional: Bare 2024-T3 per QQ-250/4)
Anodized in accordance with BAC 5019 or MIL-A-8625 Type I

6.2 TEST PROCEDURE

a. Test panels required: Eight of each type per Section 6.1.b above.

b. Prepare two sandwich test specimens of each panel material as follows:

(1) Cut a filter paper (Whatman No. 5 or equivalent) to 1 x 3 inches and place in the center of one panel.

(2) Saturate the filter paper with the solution to be tested. Avoid excess solution.

(3) Place a second panel of the same material over the saturated filter paper, forming a sandwich. Hold the sandwich together with waterproof tape.

c. As a control, prepare two sandwich test samples for each material in accordance with Section 6.2.b, except use distilled or deionized water instead of the solution to be evaluated.

d. Expose the test panels in a controlled humidity cabinet according to Table II.

e. After the 64-hour humidity exposure, separate the sandwich and wash the panels with water and a soft bristle brush. Blot dry.

f. Corrosion in excess of that on the control panels is unacceptable.

6.2 TEST PROCEDURE (Continued)

TABLE II

SANDWICH CORROSION TEST SCHEDULE

STEP	EXPOSURE TIME 1/ HOURS ± 1/2	TEMPERATURE °F	RELATIVE HUMIDITY
1	8	100	Ambient
2	16	100	95-100
3	8	100	Ambient
4	16	100	95-100
5	8	100	Ambient
6	16	100	95-100
7	8	100	Ambient
8	16	100	95-100
9	8	100	Ambient
10	64	100	95-100

1/ Total testing time is 168 hours.

7. IMMERSION CORROSION TEST

7.1 TEST SPECIMENS

a. Clad 2024-T3 aluminum alloy per QQ-A-250/5

b. Bare 2024-T3 aluminum alloy per QQ-A-250/4, alodize per BAC 5719 Class A or MIL-C-5541

c. Bare 2024-T3 aluminum alloy per QQ-A-250/14, anodize per BAC 5019 or MIL-A-8625 Type I

d. Bare 7178-T6 aluminum alloy per QQ-A-250/14, anodize per BAC 5019 or MIL-A-8625 Type I

e. 4130 steel per MIL-S-18729, cadmium plate, bake, and postplate treat per BAC 5718 or BAC 5804

f. 4130 steel, cadmium plate per BAC 5701 or QQ-P-416

g. 6Al-4V titanium per MIL-T-9046 Type III, Comp. C

h. Bare AZ31B magnesium alloy per QQ-M-44 with MIL-M-3171 Type III (Scribe through MIL-M-3171 coating diagonally across each side of panel)

i. 4130 steel per MIL-S-18729

7.2 TEST PROCEDURE

The average weight loss of the Section 7.1 test specimens shall not exceed the following when tested per ASTM F483 for 24 hours:

a.	Aluminum	± 10 mg
b.	Cadmium-plated steel	± 10 mg
c.	Titanium	± 10 mg
d.	Magnesium	± 20 mg
e.	Bare steel	± 30 mg

8. ACRYLIC CRAZING TEST

The material being tested shall not craze, crack, or etch acrylic test specimens when tested in accordance with ASTM F484 using Type A acrylic stressed to an outer fiber stress of 3000 psi.

9. **POLYCARBONATE CRAZING TEST**

9.1 TEST SPECIMEN

Lexan 9600-116 sheet, General Electric Co., 0.060 ± 0.005 inch thick

9.2 TEST PROCEDURE

a. Load the specimen to obtain an outer fiber stress of 2000 psi. (This stress can be obtained by wrapping the specimen around a cylinder with a radius of 10.2 inches.)

b. While the specimen is under stress, place an absorbent cotton swatch, soaked with the material being tested, onto the test specimen. Do not let test solution touch edges of specimen.

c. Remove load and cotton swatch after 10 minutes exposure.

d. Any crazing or cracking shall be cause for rejection of the flushing fluid being tested.

10. **ELASTOMER DEGRADATION TESTS**

10.1 RUBBER TESTS

10.1.1 TEST SPECIMEN

a. Specimen material: BMS 1-59 - Obtain from an approved fabricator per Appendix I

b. Specimen configuration: ASTM D471

10.1.2 TEST PROCEDURE

a. Test specimens required:

(1) Three unexposed (control) specimens for tests a. and b. in Section 10.1.3

(2) Three exposed specimens for tests a. and b. in Section 10.1.3

(3) Three exposed specimens for test c. in Section 10.1.3

b. Immerse for 70 ± 2 hours in flushing fluid maintained at 158 ± 5F.

10.1.3 TOILET FLUID ACCEPTABILITY CRITERIA

When tested per ASTM D47, the changes in properties shall not exceed:

a. Tensile Strength -25%

b. Elongation: -25%

c. Volume Change: ±15%

10.2 SEALANT TEST

10.2.1 TEST SPECIMEN

a. Prime three test panels for each solution and one for control test per Section 10.2.2. Cure for 24 hours at 75 ± 5F.

b. Just prior to applying sealant, clean the panel with cheesecloth wetted with a 1:1 mix of MEK, toluene, or BMS 11-7. Dry the panel with dry cheesecloth before the solvent evaporates.

c. Apply a fillet of one of the BMS 5-32 sealants listed in Appendix I to the center of each panel. The dimensions of the fillet shall be approximately 4 x 1 inches x 1/4 inch thick. Fair the edges of the sealant to the enamel.

d. Allow the sealant to cure a minimum of 10 days at 75 ± 5F or cure the sealant for 24 hours at 75 ± 5F plus 24 hours at 140 ± 5F.

10.2.2 APPLICATION OF BMS 10-11 TYPE I EPOXY PRIMER

a. The test panel size, material, prepaint treatment, and conversion coating shall be in accordance with ASTM F502.

b. BMS 10-11 Type I primers and their mixing ratios are shown in Appendix I.

c. Allow the mixed primer to stand 30 minutes before application.

d. Spray the primer to a dry film thickness of 0.4 to 0.8 mil.

10.2.3 TEST PROCEDURE

a. Immerse the specimens in the flushing fluid for 70 ± 2 hours at 120 ± 5F. As a control, immerse one specimen in distilled or deionized water for 70 ± 2 hours at 120 ± 5F.

b. The sealant shall not lift at edges nor fail adhesively when pried away from the surface, and shall have equivalent or better adhesion than the control.

11 TAPE ADHESION TEST

11.1 TEST SPECIMEN

Apply a 2-inch strip of Permacel #306 tape to two panels painted and cured per Section 11.2. Cure for 24 hours at 120 ± 5F.

11.2 APPLICATION OF BMS 10-11 TYPE II ENAMEL

a. Apply the enamel over three panels prepared and primed per Section 10.2.2 and cured 1 to 4 hours at 75 ± 5F.

b. The enamel shall be BAC 792 gloss white or BAC 702 gloss white.

c. Consult Appendix I for approved Type II enamels and their mixing ratios.

d. Prepare Type II enamel for spraying by mixing the base material and catalyst and then adding sufficient thinner to give a viscosity of 19 to 25 seconds when measured with a No. 2 Zahn cup at 77 ± 2F.

e. Allow the mixed coating to stand 30 minutes prior to application.

f. Spray the enamel to a dry film thickness of 1.6 to 2.0 mils, not including primer.

g. Cure 7 days at 75 ± 5F and 30 to 60 percent relative humidity.

11.3 TEST PROCEDURE

a. Immerse taped panels in the flushing fluid at 75 ± 5F for 7 days.

b. Conduct 180-degree peel test in accordance with ASTM D1000 except use rigid (0.040 inch thick minimum) aluminum, any alloy, in lieu of steel.

c. The tape shall not lift at edges nor shall the 180-degree peel strength be reduced by more than 30%.

12 PAINT SOFTENING TEST PROCEDURE

a. Testing shall be in accordance with ASTM F502 using the following coating systems.

(1) BMS 10-79, Type II primer applied in accordance with BAC 5882 plus BMS 10-60, Type II enamel in accordance with BAC 5845.

(2) BMS 10-79, Type III primer applied in accordance with BAC 5882, plus BMS 10-100 coating in accordance with BAC 5797.

b. The material being tested shall not produce a decrease in film hardness greater than 2 pencils, or any discoloration on staining.

NOTE: Slight darkening of the BMS 10-100 surface is acceptable.

13 HYDROGEN EMBRITTLEMENT TEST

Hydrogen embrittlement testing shall be in accordance with ASTM F519 using Type 1a, 1c, or 2a specimens.

A. BMS 10-11 CHEMICAL AND SOLVENT RESISTANT FINISH

TYPE, CLASS 1/ AND COLOR	SUPPLIER	SUPPLIER PRODUCT	DESIG-NATION	MIX (PARTS BY VOLUME)
Type I Class A Green	DeSoto, Inc. Chemical Coating Div. 4th and Cedar Sts. Berkeley, CA	Base Curing Solution Thinner	515-003 910-012 910-025	1 1 0.1 max.
		Base Curing Solution Thinner	515-706 910-012 910-025	1 1 0.1 max.
	AKZO Coatings, Inc. Aerospace Finishes 434 W. Meats Blvd. Orange, CA 92665	Base Catalyst Thinner	463-4-4 X-301 TL-52	3 1 1 max.
		Base Catalyst Thinner	463-6-3 X-306 TL-52	3 1 0.8 max.
		Base Catalyst	463-6-27 X337 or X354	1 1
	Tempo Paint & Varnish Company 69 Howden Road Scarborough, Ontario Canada	Base Catalyst Thinner	4500-PB-30D 4500-C-30D 4500-S-30D	1 1 1
	Deft Chemical Coatings 17451 Von Karman Ave. Irvine, CA 92714	Base Catalyst Thinner	02-GN-40 02-GN-40 IS-101 or MEK	1 1 0.1 max.
		Base Catalyst Thinner	02-GN-40FD 02-GN-40FD IS-101 or MEK	1 1 0.1 max.

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A. BMS 10-11 CHEMICAL AND SOLVENT RESISTANT FINISH (Continued)

TYPE, CLASS 1/ AND COLOR	SUPPLIER	SUPPLIER PRODUCT	DESIG-NATION	MIX (PARTS BY VOLUME	
Type I Class B Green	DeSoto, Inc.	Base Curing Solution Thinner	515 X 314 910 X 471 020 X 331	4 1 4 max.	
Type I Class S Yellow	DeSoto, Inc.	Base Curing Solution Thinner	513-004 910-012 910-025	1 1 0.1 max.	
		Base Curing Solution Thinner	513-705 910-012 910-025	1 1 0.1 max.	
	AKZO Coatings, Inc.	Base Catalyst Thinner Retarder	463-6-5 X-306 TL-52 TL-82	3 1 0.8 max. 0.8 max.	J
Type I Class A Green Rule 66 2/	DeSoto, Inc.	Base Catalyst Thinner	515-701 910-707 910-025	1 1 0.1 max.	
		Base Catalyst Thinner	515 X 323 910-707 910-025	1 1 0.1 max.	
	AKZO Coatings, Inc.	Base Catalyst Thinner	463-6-11 X-315 TL-65	3 1 0.8 max.	J
	Deft Chemical Coatings	Base Catalyst Thinner	02-GN-39 [illegible]-GN-39 Methyl cellusolve or MEK	1 1 0.1 max.	

A. BMS 10-11 CHEMICAL AND SOLVENT RESISTANT FINISH (Continued)

TYPE, CLASS 1/ AND COLOR	SUPPLIER	SUPPLIER PRODUCT	DESIG-NATION	MIX (PARTS BY VOLUME
Type I Class A Yellow Rule 66 2/	AKZO Coatings, Inc.	Base	463-6-12	3
		Catalyst	X-315	1
	DeSoto, Inc.	Base	513-700	1
		Curing Solution	910-707	1
		Thinner	910-025	0.1 max.
		Base	513-706	1
		Curing Solution	910-707	1
		Thinner	910-025	0.1 max.
Type II Enamel Class A	AKZO Coatings, Inc.	Base	443-3 Gloss	3
		Catalyst	X-304	1
		Thinner	TL-29	2 max.

1/ Class A material is intended for conventional application methods including air or airless spraying. Class B is intended for application with electrostatic painting equipment as well as conventional methods.

2/ Meets requirements of Los Angeles Pollution District Rule 66, which restricts the use of photochemically reactive solvents and thinners.

B. BMS 1-59 RUBBER

APPROVED FABRICATORS

Cascade Gasket and Mfg. Co., Kent, WA
Elastomeric Silicone Products, McMinnville, OR
Groendyk Mfg. Co., Buchanan, VA
Hadbar Incorporated, Alhambra, CA
Haskon, Inc., Taunton, MA
Keene Technology Div, Ranch Cucamonga, CA
Kirkhill Rubber Co., Los Angeles, CA
Pacific Molded Products Co., Los Angeles, CA
Parker Seal Company, Culver City, CA
Raybestos-Manhattan, Inc., North Charleston, SC
Reeve Rubber Co., San Clemente, CA
Rubbercraft Corp., Torrance, CA 1/
SFS Industries, Inc. Cerritos, CA
Sargent Industries, Carlsbad, CA
Stillman Rubber Company, Culver City, CA
West American Rubber Products, Orange, CA

1/ Supplies sheet material only.

C. BMS 5-32 CLASS B SEALANT

SUPPLIER	PRODUCT
Chem Seal Corporation of America 11120 Sherman Way Sun Valley, CA 91352	CS 3200 B2
Products Research and Chemical Corporation 1/ 5454 San Fernando Road Glendale, CA 91209	PR 1224

1/ and their Licensees:

a. PRC Chemical Corp. of Canada, Ltd.
95 Rivalda Road
West Ontanio, Canada

b. Berger Chemical, Elastomers Division
Portland Road
Newcastle upon Tyne, NE2, 1 BL

c. Le Joint Francais
84-116 Rue Sallende
958571
Bazons, France

d. Yokohama Rubber Company
P.O. Box 46, SHIBA
Tokyo 105-91
Japan