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

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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.
- 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. 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 treatment facility.
- Brushes, swabs, sponges, and rags saturated with cleaner should be disposed of properly.

Relevant Specifications 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. 301-9), 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 surface 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 terpene 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 or 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. 1), 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:

- MIL-C-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 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)
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:

The information presented in these sheets is a summary of the sources listed. EPA and ICOLP, in furnishing or distributing this information, do not make any warranty or representation, either express or implied, with respect to its accuracy, completeness, or utility; nor does EPA and ICOLP assume any liability of any kind whatsoever resulting from the use of, or reliance upon, any information, material, or procedure contained herein, including but not limited to any claims regarding health, safety, environmental effects, or fate, efficacy, or performance, made by the source of the information. It is critical that the aircraft and/or equipment manufacturer's maintenance and overhaul documentation is consulted for more specific cleaning instructions prior to the implementation of a new cleaning operation.

- MIL-C-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 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

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 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.

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 -- 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) Rolls-Royce Engine Overhaul Processes 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, plasma/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 water 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 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 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 Alkaline Cleaner, Descaler and Rust Remover (900-1-3-2 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.

Materials and Equipment Required:

- 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 heavy-duty 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 heavy-duty 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.

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. 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 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/steam. 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.

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 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).

- O-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 150°F (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).

- O-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 (150-170°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 Which May Need to Be Considered:

- O-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.

The information presented in these sheets is a summary of the sources listed. EPA and ICOLP, in furnishing or distributing this information, do not make any warranty or representation, either express or implied, with respect to its accuracy, completeness, or utility; nor does EPA and ICOLP assume any liability of any kind whatsoever resulting from the use of, or reliance upon, any information, material, or procedure contained herein, including but not limited to any claims regarding health, safety, environmental effects, or fate, efficacy, or performance, made by the source of the information. It is critical that the aircraft and/or equipment manufacturer's maintenance and overhaul documentation is consulted for more specific cleaning instructions prior to the implementation of a new cleaning operation.

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 naphtha. Check federal and local regulations.
- Brushes containing spent solvent should be disposed of properly.

Relevant Specifications Which May Need to Be Considered:

- TT-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 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 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 nausea.
- 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." Boeing 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 Specifications Which May Need to Be Considered:

- MIL-T-27602 (trichloroethylene).

- O-T-634 (trichloroethylene).

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

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 a 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:

- O-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).
- O-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 abrasive paper.
- 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.

The information presented in these sheets is a summary of the sources listed. EPA and ICOLP, in furnishing or distributing this information, do not make any warranty or representation, either express or implied, with respect to its accuracy, completeness, or utility; nor does EPA and ICOLP assume any liability of any kind whatsoever resulting from the use of, or reliance upon, any information, material, or procedure contained herein, including but not limited to any claims regarding health, safety, environmental effects, or fate, efficacy, or performance, made by the source of the information. It is critical that the aircraft and/or equipment manufacturer's maintenance and overhaul documentation is consulted for more specific cleaning instructions prior to the implementation of a new cleaning operation.

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

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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, agents 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 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.

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.

CASE STUDIES 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

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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 for 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 of 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-T851 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.

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.

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.

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

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),
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 3.5 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). GDFW's 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. The 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 and 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

VI. For Further Information

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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 Linköping, 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.

VI. For Further Information

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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 Linköping, 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

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[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 CS-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 ultrasonic agitation 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 (μg/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.

VI. For Further Information

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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.

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.

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 involve 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 though 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 liquid/vapor 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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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
16961 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 Ltd.
Solvents Marketing Dept.
P.O. Box 18
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

Modern Chemical Inc.
P.O. Box 368
Jacksonville, AR 72076
Tel: (501) 988-1311
Fax: (501) 682-7691

McGean-Rohco, 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
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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 06813-1961
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

Electrovert 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
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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) 886-4469

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 Sandhills 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.
Torry
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

International Cooperative FOR OZONE LAYER PROTECTION

The International 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 Methodes 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 "OZONACTION," and has relevant information on the alternatives to ozone-depleting solvents. OZONET not only contains technical publications, conference papers, and reports on the most recent developments of alternatives to the current uses of ozone-depleting solvents, but it also contains:

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

Information about ICOLP can be obtained from:

Mr. 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 Linköping, Sweden	
Scandinavian Airlines System Maintenance Base	Copenhagen, Denmark
Volvo Aero Support Arboga, 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
CentralGlass	CG Triflon
Showa Denko	Flon Showa 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

APPENDIX E

DOUGLAS AIRCRAFT COMPANY
CUSTOMER SERVICE DOCUMENT #1

APPENDIX F

BOEING CORPORATION
DOCUMENT D6-17487