AIR QUALITY MANAGEMENT

USING

POLLUTION PREVENTION:

A JOINT SERVICE APPROACH

Abridged Version

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Information was gathered from installations within the services, NASA, and Coast Guard and from other resources to assemble within this document. There was no data call and many valuable ideas may have been missed.

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This information resource is not a DoD Policy document. This document primarily contains ideas and information about what others in the DoD are doing. This document is for Air Quality Managers who would like to learn more about their options for using pollution prevention (P2) to manage air quality and achieve compliance. This is a forum for you to learn from each other, what works and what doesn't work. P2 means changing products used or manufacturing processes to reduce impact to the environment. Includes the regulatory framework for pollution prevention and compliance; process reviews for cleaning and degreasing, depainting, surface coating, combustion, storage, and training.

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Air Quality Management, Pollution Prevention (P2), process review, cleaning, degreasing, depainting, surface coating, combustion, storage, Ethylene Oxide Sterilizing, fuel dispension, pesticides, lubricants, adhesives and sealants.

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DISCLAIMER

This information resource is not a DoD Policy document. This document primarily contains ideas and information about what others in the DoD are doing. All decisions to implement any of the opportunities described herein should be authorized through normal channels.

The mention of product names in this document does not constitute endorsement by the Services, DoD, or other Federal agency, but is for clarification purposes only.

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The authors gratefully acknowledge the substantial contributions of the installations, as well as the National Aeronautics and Space Administration and the U.S. Coast Guard.

FOREWORD

This Joint document was created through the efforts of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), the U.S. Air Human Systems Center (HSC/OEBQ) and the Naval Facilities Engineering Service Center (NFESC). These three organizations have gathered information from installations within the Services, NASA, and Coast Guard and from other resources to assemble within this document. This document highlights pollution prevention (P2) techniques that have either been successfully implemented at facilities or have potential to be implemented successfully. The current status of some relevant research efforts is included where appropriate. This document is not comprehensive. There was no data call, and many valuable ideas may have been missed. It is our intent to update this document as our readers bring new information to our attention. This document is a clearinghouse of potential solutions to Air Compliance Programs using P2. The information herein is considered accurate as of the original publication date, March 1998.

POLLUTION PREVENTION AND AIR QUALITY MANAGEMENT

PURPOSE

This document is for Air Quality Managers who would like to learn more about their options for using pollution prevention (P2) to manage air quality and achieve compliance. This is a forum for you to learn from each other about what works and what doesn't work. Success stories from throughout the Services are the core of this document. In addition, background information and summaries of current research are included for some processes. All of this information in the body of the document is organized according to the affected process, with references to associated regulations. The appendices also contain a variety of useful information.

This document differs from and compliments the Joint Service P2 Technical Library and the Hazardous Air Pollutant (HAP) Status Binder. The Joint Service P2 Technical Library was created to outline "off the shelf" technologies for use by DoD installations. The HAP Status Binder was developed to keep DoD Air Quality Managers apprised of the status of National Emission Standards for Hazardous Air Pollutants (NESHAPs). So while the former is oriented toward what technologies are available, and the latter is oriented toward what the regulations require, this document presents what is actually being done now in the military. Web addresses are listed in Appendix B.

WHAT IS POLLUTION PREVENTION?

P2 means changing products used or manufacturing processes to reduce impact to the environment. This involves incorporating environmental considerations into product design and into the design, operation, and maintenance of production processes resulting in improved efficiency and performance. By operating more efficiently we protect human health, strengthen our economic well being, and preserve the environment. P2 is a cost-effective and sound approach to environmental protection and is key to obtaining environmentally sustainable economic development.

Executive Order 12856, signed by President Clinton in August 1993, required Federal facilities to comply with the Emergency Planning and Community Right to Know Act (EPCRA), which was authorized in October 1986, and the Pollution Prevention Act (PPA) which was authorized in December 1990. The DoD required every facility that was not scheduled for operational closure by 31 December 1997 to develop and implement a P2 plan. This plan is supposed to address the actions required by the facility for reducing pollution from all sources and to all media, including the installation's strategy for meeting the goal of a 50% reduction by 1999 in Toxic Release Inventory reportable releases and off-site transfers.

DoD Directive 4715.1 defined P2 as source reduction (as defined in the PPA of 1990, 42 U.S.C. Sections 13101-13109) and other practices that reduce or eliminate the creation of pollutants through: (a) increased efficiency in the use of raw materials, energy, water, or other resources; or (b) protection of natural resources by conservation.

The PPA defined source reduction as "any practice that (a) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, and disposal; and (b) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. The term includes equipment or technology modification, process or procedure modification, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control." Source reduction does not entail any form of waste management (e.g., recycling and treatment).

Under Section 6602(b) of the PPA, Congress established a national policy that:

- pollution should be prevented or reduced at the source whenever feasible;
- pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible;
- pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible;

And

- disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.

The primary focus of Air Quality Managers is to comply with regulations. Pollution prevention is a tool to meet or proactively surpass the regulatory requirements.

REGULATORY FRAMEWORK

EPCRA

The Emergency Planning and Community Right-to-Know Act (EPCRA) was promulgated as Title III of the Superfund Amendments and Reauthorization Act in 1986. The EPCRA requires covered facilities to:

1. Follow certain procedures in the event of a dangerous accidental release.
2. Conduct inventories of hazardous materials at the facility and make this information available to the local community.
3. Conduct a Toxic Release Inventory (TRI) each year and report to the EPA and the State the quantities of toxic chemicals released to the environment.

Federal facilities were not covered by EPCRA, but Executive Order 12856 directed Federal agencies to comply with EPCRA and to reduce their reportable releases and off-site transfers of toxic chemicals by 50% by 31 December 1999 using the 1994 TRI reports as the baseline.

In the DoD's 1994 TRI report, air emissions represented about two-thirds of all TRI reportable releases and off-site transfers (see Figure 1) and over 97% of all TRI reportable on-site releases (see Figure 2). The DoD did not realize the high percentage of toxic releases to the air until the release of the 1994 TRI report. These air emissions are primarily from maintenance activities associated with the painting and depainting of aircraft and cleaning and degreasing activities. The list of hazardous air pollutants (HAPs) included in the 1990 amendments of the Clean Air Act (CAA90) was based to a large extent on the TRI list. Title III of the CAA90 was one of the Environmental

Figure 1. TRI Reportable Releases and Off-Site Transfers for 1994 and 1995

Protection Agency's (EPA's) tools to achieve a reduction of TRI pollutants. Table 1 compares the TRI top ten chemicals reported for the DoD for 1994 and 1995. Notice that all but one is a HAP.

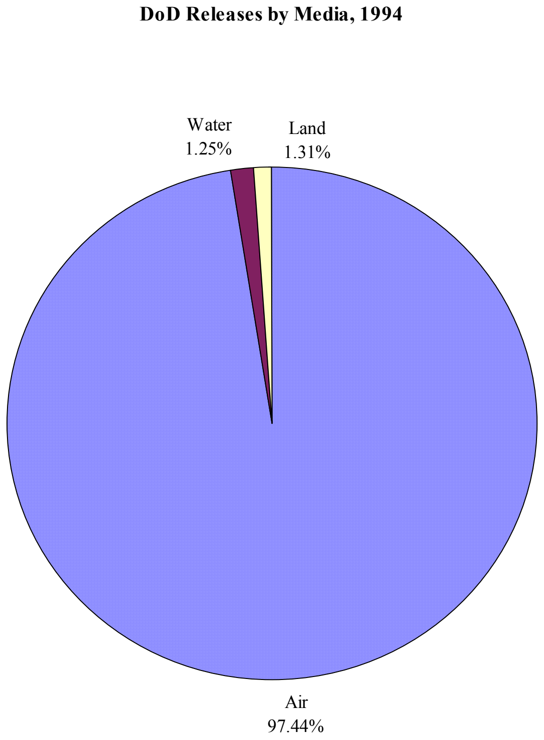

Figure 2. 1994 DoD TRI On-Site Releases by Media

Table 1. Change in Top 10 Chemical Releases and Transfers Information

Top 10 1994 Chemical	1994 (1,000 lbs.)	1995 (1,000 lbs.)	Change
*Dichloromethane (methylene chloride)	2,236	1,617	-28%
*Methyl ethyl ketone	1,505	1,097	-27%
*1,1,1-Trichloroethane (methyl chloroform)	1,232	751	-39%
*Ethylene glycol	537	329	-39%
*Toluene	445	235	-47%
*Phenol	412	267	-35%
Zinc compounds	409	45	-89%
*Tetrachloroethylene (perchloroethylene)	359	217	-39%
*Hexachloroethane	351	56	-84%
*Hydrochloric acid	298	Delisted	Not Applicable
*Note: * indicates this TRI substance is also a HAP*			

CAA

The primary goal of the Clean Air Act (CAA) is to "protect the public" from air pollution with an "adequate margin of safety". End-of-pipe control technologies have been the primary method of reducing pollution emissions.

Under CAA Title I Section (§)112 and §129, Congress mandates that stationary sources be required to use Maximum Achievable *Control Technology* (MACT) or Generally Achievable *Control Technology* (GACT). Title I requires the EPA to set National Ambient Air Quality Standards (NAAQS) and State and Local agencies have the option to use either tools developed by the EPA or within their own agencies to control air emissions from stationary sources. New Source Performance Standards, *Control Techniques* Guidelines, Alternative *Control Techniques,* Best Available *Control Technology,* Best Available *Control Measures,* and Reasonably Available *Control Technology* are examples of some of the methods State and Local agencies typically use to control emissions. The strong emphasis on controlling emissions using *control technologies* under the CAA is easy to see. Facilities generally find it much easier to install a standard control technology called out under a specific regulation than to identify and implement a P2 option.

In recent years, EPA has been writing P2 opportunities along with control technologies into their standards. The EPA has tried to change their focus to performance based and cost effective standards.

Developing P2 strategies may require longer term investing than the three years usually allotted for compliance with a standard. Some processes may require large equipment changes thus making P2 cost prohibitive under the current funding system, which does not accommodate longer payback periods. This encourages the use of control technologies in those cases where the up front cost is lower. The EPA has been trying to write into rules incentives for industry to develop P2 by giving longer time periods to comply if P2 initiatives are implemented (a one year extension is the typical length of the time period). The EPA also seeks to provide regulatory relief for the development of P2 through such cross media efforts as the Common Sense Initiative, Project XL, and ENVVEST. All of these programs have been very difficult to implement within both Industry and the DoD because consensus on solutions among industry, the EPA, and environmental groups has proved difficult to achieve.

The P2 initiatives that have been the most successful are those with a low up-front cost, such as coating and degreasing processes. Coating reformulation and application techniques have significantly contributed to HAP and volatile organic compound (VOC) reductions. Switching to aqueous degreasers has reduced both VOCs and operating costs.

RCRA

The Solid Waste Disposal Act (SWDA) of 1965 was the first Federal legislation that addressed the nation's waste management practices. This act, as amended by the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984, is commonly referred to as RCRA.

Within the DoD, P2 seems to focus on the minimization of hazardous and solid wastes. There are four possible reasons for this. (1) The Resource Conservation and Recovery Act (RCRA) is the environmental law for which the DoD has paid the most fines. In addition, a number of DoD employees have been prosecuted for violation of RCRA regulations. Reducing the use of hazardous materials reduces liability. (2) There are hazardous waste minimization requirements within RCRA. Hazardous waste generators must submit a Biennial Report, to include a description of the efforts undertaken and progress made to reduce the volume and toxicity of waste generated [40 CFR 262.41(a)(6,7)]. In addition, RCRA requires the permit holder of a treatment, storage, and disposal facility to have, at a minimum, annual certification that there is a program in place to reduce the volume and toxicity of the hazardous waste generated, and to minimize the present and future threat to human health and the environment [40 CFR 264.73 (b)(9)]. (3) Hazardous waste disposal costs are high, so that P2 in this area yields a direct and immediate cost savings. (4) Solid and hazardous waste quantities and costs are more easily determined than air emission quantities and costs.

Many Military documents focus on solid and hazardous waste P2. The Joint Service P2 Technical Library's introduction states that the purpose of the Library is "to identify available P2 technologies, management practices, and process changes that will reduce the amount of hazardous and solid waste being generated at joint service industrial facilities."

Some P2 initiated because of RCRA has benefited air quality, despite the apparent trend to pigeonhole P2 with hazardous/solid waste minimization efforts. Examples of common P2 applications which were initiated because of hazardous waste but have benefited air quality are: vapor degreasers replaced with aqueous parts washers, low VOC coatings formulated, and parts depainted using blasting techniques such as plastic, glass, wheat starch, or sodium bicarbonate where once solvents were used.

WHY INCORPORATE P2 INTO AIR PROGRAMS?

P2 is typically managed by the Hazardous Waste Manager or the P2 Program Manager. Consequently the installation's Air Program is not usually involved with P2 and opportunities may be missed. Yet there are often substantial benefits from incorporating P2 into Air Programs:

1. Immediate Cost Savings

- Costs. P2 can be more economical and many applications make good business sense. Material and process costs may be reduced.
- Fees. Annual permit fees can be reduced since fees are usually proportional to emission rates.
- Disposal costs. Disposal costs of hazardous by-products are often eliminated.

2. Regulatory Relief

- Liability. P2 yields reduced liability for commanders.
- Safety. P2 results in reduced health hazards for airmen, marines, sailors, soldiers, and civilians.
- Permitting. It may be possible in some cases to eliminate the need to be permitted, depending on Federal/State/Local requirements.
- Emission Reduction Credits. Voluntary emission reductions can be converted into Emission Reduction Credits (ERC's). ERC's can then be used for base growth. Usually New Source Review trading provisions allow for interpollutant trading (i.e., NO_x emissions can be traded for a new VOC source since both pollutants contribute to smog). Offset provisions need to be considered, however, when exercising these programs. In the South Coast Air Quality Management District in Los Angeles, CA, emissions trading occur under the Regional Clean Air Incentives Market (RECLAIM). Under RECLAIM, if a facility reduces the amount of emissions it is allocated before the compliance date, these emissions can be banked or traded for use by other facilities or in the future, creating a very robust emissions trading market. Also, in the FY98 DoD Authorization Bill, new ERC provisions authorized the Secretary of Defense to write regulations allowing the retention of proceeds to a cap of $500k DoD wide. The CAA Services Steering Committee is in the process of developing guidance to find the best way for installations to retain proceeds that previously were required to be deposited to the U.S. Treasury.
- Conformity Analysis. The CAA requires a Federal agency to demonstrate that a new Federal action will not cause deterioration of air quality or impact attainment status in a nonattainment or maintenance area in accordance with the State Implementation Plan (SIP). Military installations/units, functions, or weapons systems realignment occurring as a result of Base Realignment and Closure (BRAC) are required to comply with conformity. For example, a facility that is gaining aircraft and is located in a nonattainment area will have to offset the addition of emissions from the added equipment. If a facility can show that because of P2 projects (or otherwise) they have reduced emissions, the facility may then have sufficient emission offsets required to allow the introduction of the additional equipment. Therefore, a facility will have more growth potential if P2 is employed. Conversely, if the emission offsets are not available to meet the requirements of the SIP, the facility may not be able to increase operations.
- National Ambient Air Quality Standards (NAAQS) are tightening. Therefore emission offsets for conformity analysis and New Source Review will be increasingly more difficult to obtain.
- Regulatory Incentives. Even though CAA regulations are “control” oriented, efforts by EPA have been made to put incentives on P2 strategies in Air Quality Programs.
- §112(r) Relief. A number of installations are reducing the amount of chlorine associated with water treatment processes. If the process no longer exceeds the threshold of a substance regulated under the Accidental Release Provisions of §112(r)

(40 CFR 68), it will not be a covered process, and will not necessitate a Risk Management Program and Plan.

- Compliance deadlines. Compliance extensions may be granted when using P2 in lieu of controls for the more recently developed regulations.
- Recordkeeping. Monitoring, recordkeeping, and reporting may be substantially reduced or eliminated.
- Enforcement Agreements. EPA is developing a program through the Office of Enforcement and Compliance Assurance called "Identification of P2 Technologies for Possible Inclusion in Enforcement Agreements Using Supplemental Environmental Projects and Injunctive Relief". This program requires P2 during enforcement for those facilities/industries out of compliance for appropriate targeted sectors.
- Risk Assessment. California's Air Toxic "Hot Spots" Information and Assessment Act (Assembly Bill 2588) regulates HAP emissions based on risk. Facilities are required to inventory their hazardous emissions and conduct a Health Risk Assessment. This regulation has provided a powerful incentive for P2 as facilities are required to notify the public of the health risks imposed by the facility. Facilities are required to reduce their risks to the community to acceptable levels. CAA §112(f) Residual Risk program will be implemented by EPA in the near future and could have a similar impact nationally as Assembly Bill 2588 has had in California.

3. Regulatory Policy Compliance

- P2 Plans. P2 plans, which address all media, are required for all bases/installations.
- TRI. Installations that meet the threshold for TRI reporting must have a strategy to reduce toxic chemical releases and off-site transfers by 50% by December 1999. P2 will help meet the 50% reduction.
- Multi-media compliance. Some chemicals are regulated under multiple laws, such as CAA, CERCLA, CWA, OSHA, and/or the RCRA. From a multimedia regulatory framework, it makes more sense to substantially reduce or eliminate the use of such chemicals rather than trying to marshal resources to comply with the increasingly stringent regulations. For example, OSHA published standards governing methylene chloride that went into effect 10 April 1997. OSHA reduced the 8-hour time weighted average (TWA) from 500 ppm to 25 ppm. OSHA also reduced the existing short-term exposure limit from 2,000 ppm to 125 ppm, measured as a 15 minute TWA. An action level is now set at 12.5 ppm measured as an 8 hour TWA. What this means is that working with methylene chloride is becoming more and more difficult, and end of stack controls to meet the requirements of the CAA (outside) will not help facilities to meet the provisions of OSHA (inside). However, a P2 alternative to methylene chloride would satisfy regulations under all the laws. Recently the OSHA limits were also tightened for the use of methyl ethyl ketone, which is also strictly regulated by the CAA and RCRA.
- Safety. In some unusual circumstances, air pollution control devices have been associated with fire or explosions. Although these phenomena are uncommon, facilities would nevertheless decrease the risks of such occurrences. The EPA

extended the deadline for compliance with the Ethylene Oxide Sterilizers NESHAP because of reports of explosions at ethylene oxide sterilization facilities. Investigations at the sterilization facilities have not concluded that the explosions were caused by the air pollution control equipment, however, the EPA is recommending controls not be used until their investigation is completed. Additionally the EPA's Chemical Emergency Preparedness and Prevention Office (CEPPO) in May 1997 issued a warning about fire hazards associated with activated carbon systems if proper procedures are not followed.

- Greenhouse Gases. Combustion sources may be further regulated to meet the provisions of international agreements on greenhouse gases.

CROSS REFERENCES

The following tables cross-reference statutes, regulations, and executive orders to processes and sources. Success stories and potential alternatives gathered from Department of Defense installations are found under the Processes section.

Table 2. The Clean Air Act & Amendments Referenced to Regulations

Title	**Name**	**CAA Section**	**Regulation**
I	New Source Performance Standard (NSPS) Program	111	40 CFR 60
I	National Ambient Air Quality Standards (NAAQS) Program	105-110, 160-193	40 CFR 50-53, 55, 58, 81, 93
II	Mobile Sources Program	202-250	40 CFR 80, 85-88
III	National Emission Standards for Hazardous Air Pollutants (NESHAP) Program	112	40 CFR 61, 63, 68
IV	Acid Rain Program	401-416	40 CFR 72-78
V	Operating Permit Program	501-507	40 CFR 70-71
VI	Stratospheric Ozone Protection Program	601-618	40 CFR 82

Table 3. Laws Referenced to Processes

Laws and Regulations	**Affected Processes and their Section Numbers in This Document**
Accidental Release Prevention Program	5.1 Listed Substance Storage
Aerospace NESHAP	1.1 Methylene Chloride Cleaning 2.1 Paint Stripping: Methylene Chloride 3.1 Paint Gun Washers 3.2 Primers 3.3 CARC Painting 3.4 Touch Up Painting 3.5 General Painting
Architectural Coating NSPS	3.6 Architectural Coatings
Cadmium Compounds HAP	3.7 Cadmium Plating
Carbon Monoxide NAAQS	4.5 Boilers 4.7 Aerospace Ground Equipment
Chromium Compounds HAP	3.2 Primers 3.8 Chromic Acid Anodizing 3.9 Chromate Chemical Conversion Coating 3.10 Hard Chrome Plating
Engine Test Facilities NESHAP	4.9 Jet engine testing
Executive Order 12902, Section 305	4.5 Boilers
Existing Source Emission Guideline	4.1 Medical Waste Incinerators 4.3 Municipal Waste Combustors
Halogenated Solvent Cleaners NESHAP	1.1 Methylene Chloride Cleaning

	1.2 1,1,1-Trichloroethane
Hazardous Waste Combustor NESHAP	4.4 Treatment, Storage, Disposal Facility
Industrial Combustion Coordinated Rulemaking	4.2 Classified Waste Incinerators
Lead NAAQS	6.3 Weapons Training at Firing Ranges
New Source Performance Standard (NSPS)	4.1 Medical Waste Incinerators 4.3 Municipal Waste Combustors
Nitrogen Dioxide (NO_2) NAAQS	4.5 Boilers 4.7 Aerospace Ground Equipment 4.9 Jet Engine Testing
Ozone Depleting Substances	1.2 1,1,1-Trichloroethane 1.3 CFC-113 1.5 General Cleaning 1.6 Weapons Cleaning: Wipe Cleaning 1.7 Weapons Cleaning: Dip Tanks 1.8 Electronics Cleaning
Ozone NAAQS (measured in VOCs and NO_x)	4.5 Boilers 4.7 Aerospace Ground Equipment 4.9 Jet Engine Testing
Particulate Matter NAAQS	4.5 Boilers 4.7 Aerospace Ground Equipment 4.8 Generators 6.1 Fire Fighting Training 6.2 Field Training Exercises
Sulfur Dioxide (SO_2) NAAQS	4.5 Boilers
Ozone NAAQS (measured in VOCs and NO_x)	1.1 Methylene Chloride 1.2 1,1,1-Trichloroethane 1.4 Parts Washing: Stoddard Solvent 1.5 General Cleaning 1.6 Weapons Cleaning: Wipe Cleaning 1.7 Weapons Cleaning: Dip Tanks 2.1 Paint Stripping: Methylene Chloride 3.1 Paint Gun Washers 3.2 Primers 3.3 CARC Painting 3.4 Touch Up Painting 3.5 General Painting 3.6 Architectural Coatings 7.2 Fuel Dispensing 7.3 Pesticides 7.4 Lubricants 7.5 Adhesives and Sealants

Table 4. Processes Referenced to Laws, *Order of Appearance*

Processes Covered in this Document In Numerical Order By Section Number	**Laws and Regulations Affected by Change**
1.1 Methylene Chloride	Ozone NAAQS (measured in VOCs and NO_x) Halogenated Solvent Cleaners NESHAP Aerospace NESHAP
1.2 1,1,1-Trichloroethane	Ozone Depleting Substance Ozone NAAQS (measured in VOCs and NO_x) Halogenated Solvent Cleaners NESHAP
1.3 CFC-113	Ozone Depleting Substances
1.4 Parts Washing: Stoddard Solvent	Ozone NAAQS (measured in VOCs and NO_x)
1.5 General Cleaning	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances
1.6 Weapons Cleaning: Wipe Cleaning	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances
1.7 Weapons Cleaning: Dip Tanks	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances
1.8 Electronics Cleaning	Ozone Depleting Substances
2.1 Paint Stripping: Methylene Chloride	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
3.1 Paint Gun Washers	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
3.2 Primers	Ozone NAAQS (measured in VOCs and NO_x) Chromium compounds (HAP) Aerospace NESHAP
3.3 CARC Painting	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
3.4 Touch Up Painting	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
3.5 General Painting	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
3.6 Architectural Coatings	Architectural Coating NSPS Ozone NAAQS (measured in VOCs and NO_x)
3.7 Cadmium Plating	Cadmium Compounds HAP
3.8 Chromic Acid Anodizing	Chromium Compounds HAP
3.9 Chromate Chemical Conversion Coating	Chromium Compounds HAP
3.10 Hard Chrome Plating	Chromium Compounds HAP

4.1 Medical Waste Incinerators	Hospital/Medical/Infectious Waste Incinerator (HMIWI) New Source Performance Standard (NSPS) Existing Source Emission Guideline (EG)
4.2 Classified Waste Incinerators	Industrial Combustion Coordinated Rulemaking
4.3 Municipal Waste Combustors	Municipal Waste Combustor NSPS/EG
4.4 Treatment, Storage, Disposal Facility	Hazardous Waste Combustor NESHAP
4.5 Boilers	Carbon Monoxide (CO) NAAQS Executive Order 12902 Section 305 Nitrogen Dioxide (NO_2) NAAQS Ozone (measured in VOCs and NO_x) NAAQS Particulate Matter (PM) NAAQS Sulfur Dioxide (SO_2) NAAQS
4.6 Vehicles	PM and Ozone NAAQS Executive Order 13031
4.7 Aerospace Ground Equipment	Carbon Monoxide (CO) NAAQS Nitrogen Dioxide (NO_2) NAAQS Ozone (measured in VOCs and NO_x) NAAQS Particulate Matter (PM) NAAQS
4.8 Generators	Carbon Monoxide (CO) NAAQS Nitrogen Dioxide (NO_2) NAAQS
4.9 Jet engine testing	Engine Test Facilities NESHAP CO, NO_2, Ozone, PM NAAQS
5.1 Listed Substance Storage 6.1 Fire Fighting Training	Accidental Release Prevention Program (Risk Management Programs and Plans) Particulate Matter (PM) NAAQS - Fugitive Emissions
6.2 Field Training Exercises	Particulate Matter (PM) NAAQS – Fugitive Emissions
6.3 Weapons Training at Firing Ranges	Lead NAAQS
7.1 Ethylene Oxide Sterilizing	State-Specific Regulations
7.2 Fuel Dispensing	VOC and HAP Emissions
7.3 Pesticides	VOC and HAP Emissions
7.4 Lubricants	VOC and HAP Emissions
7.5 Adhesives and Sealants	VOC and HAP Emissions
7.6 Potential to Emit	Criteria and HAP Emissions

Table 5. Processes Referenced to Laws, *Alphabetical Order*

Processes Covered in this Document in Alphabetical Order (Section Number in Parentheses)	**Laws and Regulations Affected by Change**
1,1,1-Trichloroethane (1.2)	Ozone Depleting Substance Ozone NAAQS (measured in VOCs and NO_x) Halogenated Solvent Cleaners NESHAP
Adhesives and Sealants (7.5)	VOC and HAP Emissions
Aerospace Ground Equipment (4.7)	Nitrogen Dioxide (NO_2) NAAQS Particulate Matter (PM) NAAQS
Architectural Coatings (3.6)	Architectural Coating NSPS Ozone NAAQS (measured in VOCs and NO_x)
Boilers (4.5)	Executive Order 12902 Section 305 Sulfur Dioxide (SO_2) NAAQS Nitrogen Dioxide (NO_2) NAAQS Ozone NAAQS (measured in VOCs and NO_x) Particulate Matter (PM) NAAQS
Cadmium Plating (3.7)	Fugitive Emissions - Cadmium
CARC Painting (3.3)	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
CFC-113 (1.3)	Ozone Depleting Substances
Chromate Chemical Conversion Coating (3.9)	Chromium Compounds HAP
Chromic Acid Anodizing (3.8)	Chromium Compounds HAP
Classified Waste Incinerators (4.2)	Industrial Combustion Coordinated Rulemaking
Electronics Cleaning (1.8)	Ozone Depleting Substances
Ethylene Oxide Sterilizing (7.1)	State-Specific Regulations
Field Training Exercises (6.2)	Particulate Matter (PM) NAAQS – Fugitive Emissions
Fire Fighting Training (6.1)	Particulate Matter (PM) NAAQS - Fugitive Emissions
Fuel Dispensing (7.2)	VOC and HAP Emissions
General Cleaning (1.5)	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances
General Painting (3.5)	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
Generators (4.8)	Carbon Monoxide (CO) NAAQS Nitrogen Dioxide (NO_2) NAAQS Ozone NAAQS (measured in VOCs and NO_x)
Hard Chrome Plating (3.10)	Chromium Compounds HAP
Jet engine testing (4.9)	Engine Test Facilities NESHAP CO, NO_2, Ozone, PM NAAQS

Listed Substance Storage (5.1)	Accidental Release Prevention Program (Risk Management Programs and Plans)
Lubricants (7.4)	VOC and HAP Emissions
Medical Waste Incinerators (4.1)	Hospital/Medical/Infectious Waste Incinerator (HMIWI) New Source Performance Standard (NSPS) Existing Source Emission Guideline (EG)
Methylene Chloride (1.1)	Ozone NAAQS (measured in VOCs and NO_x) Halogenated Solvent Cleaners NESHAP Aerospace NESHAP
Municipal Waste Combustors (4.3)	Municipal Waste Combustor NSPS/EG
Paint Gun Washers (3.1)	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
Paint Stripping: Methylene Chloride (2.1)	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
Parts Washing - Stoddard Solvent (1.4)	Ozone NAAQS (measured in VOCs and NO_x)
Pesticides (7.3)	VOC and HAP Emissions
Potential to Emit (7.6)	Criteria and HAP Emissions
Primers (3.2)	Ozone NAAQS (measured in VOCs and NO_x) Chromium compounds (HAP) Aerospace NESHAP
Touch Up Painting (3.4)	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP
Treatment, Storage, Disposal Facility (4.4)	Hazardous Waste Combustor NESHAP
Vehicles (4.6)	PM and Ozone NAAQS Executive Order 13031
Weapons Cleaning: Dip Tanks (1.7)	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances
Weapons Cleaning: Wipe Cleaning (1.6)	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances
Weapons Training at Firing Ranges (6.3)	Lead NAAQS

PROCESSES

1. CLEANING AND DEGREASING

1.1 Methylene Chloride Degreasing	Ozone NAAQS (measured in VOCs and NO_x) Halogenated Solvent Cleaners NESHAP Aerospace NESHAP

P2 Option: N-Methylpyrrolidinone (NMP)

Success: The methylene chloride in three vapor degreasers was replaced with N-methylpyrrolidinone (NMP). NMP is a colorless liquid with a mild odor that is mildly toxic and an experimental teratogen. It is combustible when exposed to heat or open flame and is a powerful oxidizer. NMP does not work quite as well as methylene chloride since parts have to sit in the solution a little longer but NMP works "good enough". NMP is not a HAP but it is a VOC.

Success: An Air Force base is using NMP as an alternative solvent. Unfortunately it costs approximately $18.00 per gallon compared to methylene chloride at $10.00 per gallon. The base is attempting reclamation at this moment, but the results are pending.

P2 Option: Abrasive Blasting Media

Success: A methylene chloride dip tank was replaced with abrasive blasting media (plastic or glass) for use on aircraft parts, landing gear, and aircraft support equipment.

1.2 1,1,1-Trichloroethane Degreasing	Ozone Depleting Substance Ozone NAAQS (measured in VOCs and NO_x) Halogenated Solvent Cleaners NESHAP

Background: Vapor Degreasing

1,1,1-trichloroethane is used to clean metal surfaces and to remove carbonaceous material. Clean, grease free parts are a prerequisite to many of the maintenance operations. Typical degreasing operations are performed in heated vats called *vapor degreasers* that contain a liquid phase and a vapor phase of degreasing solvent. The metallic part, which has deposits of oily residues, is suspended in the vapor blanket for a specified time. The vapor condenses on the surface of the dirty part and trickles down to the liquid taking with it any oily deposits, thereby resulting in a clean part. During this process hundreds of pounds of the solvent are lost as vapor each year, contributing to air pollution. 1,1,1-trichloroethane has been identified as an ODS and thus is being phased out of production. Methyl ethyl ketone (MEK) is normally applied to surfaces that require painting after they have been cleaned with 1,1,1-trichloroethane.

P2 Option: Isopropyl Alcohol (IPA)/Cyclohexane Vapor Degreaser

Success: IPA replaced 1,1,1-Trichloroethane in vapor degreasers. The Navy has evaluated and implemented an alternative drying system that meets established military cleaning requirements for aircraft bearing cleaning. The system uses IPA vapor degreasing as an alternative to solvent cleaning.

Stoddard solvent is typically used to clean aircraft bearings during refurbishment. The cleaning process uses a cascading line of solvent immersion tanks to remove grease, oil, and carbon from the bearings. Following the cleaning process, a thin, residual solvent film remains on the bearings and must be removed before continued processing. Normally, the residual film is removed using a 1,1,1-trichloroethane vapor degreaser. Aqueous-based cleaners cannot replace solvent cleaners for cleaning bearings because they may cause flash rusting. The IPA system involves cleaning the bearings in IPA vapor; the vapor condenses on the bearings and flushes the surface clean of contaminants. The bearing is then withdrawn through cooling coils that flush any residual IPA off the bearings. The process was found to meet the established drying standards and eliminate the use of a Class I ODS and HAP. The turnkey unit costs approximately $200,000, including installation. The IPA Vapor Degreaser has been so successful that the Navy is pursuing procurement of another unit.

The IPA vapor degreaser has yielded the following benefits:

- Eliminated the use of a Class I ODS and helped achieve the Navy's ODS phase-out goals.
- Reduced solvent cost; vapor degreaser used about 150 gallons of 1,1,1-trichloroethane per year; the current cost being $150 per gallon. IPA sells for less than $5 per gallon, resulting in a savings of $21,750 per year.

P2 Option: Aqueous Cleaners

Success: Four vapor degreasers that used 1,1,1-trichloroethane were replaced with hot water (dishwasher type) aqueous cleaners. A different procedure is required when using an aqueous cleaner. Parts must be "blown down" with compressed air immediately after removal from the cleaner to prevent rusting. "Blowing down" the parts this way works just as well as rust inhibitors that are often used in aqueous cleaners. Drying the parts this way essentially flashes the water off because the parts are still hot. It's especially imperative to "blow down" the parts in the humid environment experienced in the southeast. Besides the potential for rusting, another problem to overcome occurred when cleaning mated parts. Vapor degreasers penetrate mated parts, but when the aqueous cleaners were used, weeping of oil from where the parts met occurred. Therefore mated parts must be disassembled before cleaning. Wastewater from the cleaners was sent to the Industrial Wastewater Treatment Plant (IWTP) for processing.

P2 Option: Aqueous Cleaners

Success: Eight aqueous parts washers have been successfully implemented in the cleaning, plating, stripping, welding and metal treatment shops of a Naval Facility. Initially there were four problem areas that have since been worked out. First, there was a tendency for heating elements to burn out. This can be prevented by ensuring that the washer has enough water before turning on the unit. A second challenge was to find compatible detergent and operating temperatures to ensure parts were cleaned adequately. Liquid detergent is easier to use than powder detergents, however the liquid detergent breaks down quickly over 160 degrees. Higher temperatures are needed for parts with heavy greases and waxes. Parts with only light grease can be cleaned adequately below 160 degrees with liquid detergent. For temperatures above 160 degrees and parts with heavy greases or waxes, powder detergents are required. Turco Aviation powder works adequately up to 190 to 200 degrees. The third problem area was rusting. The detergent contains rust inhibitor, and if there is not enough detergent, then rusting of parts can occur. Rust inhibitor may also be purchased separately and used to supplement what comes in the detergent. If the type of cleaning doesn't require detergent, rust inhibitor may even be used without detergent. Lastly, through trial and error it was also learned that the water needs to be changed out every 4-6 weeks. If water is not changed out there will be a film on the parts. Steam cleaning, ultrasonic cleaning and dip tanks are used to supplement cleaning of intricate parts that have recesses that the washing process does not reach.

Potential Problems of the Aqueous Cleaners

1. Proper approval must precede use of aqueous cleaning methods.
2. Depending on the materials being cleaned, the material being removed, and the cleaning methods used there may be potential for corrosion of parts. Proper use of additives is imperative to eliminate corrosion.
3. The Navy found that the wastewater generated from their aqueous cleaners did not meet requirements to discharge to the wastewater treatment plant. Therefore they are required to drum their water at a cost of $1.21/pound. They typically generate 56,000 pounds/year of this wastewater.

Research: Alternative Solvent Progress

Ongoing projects exist to explore the use of chemicals that can be substituted as alternatives to degreasing agents and maskant removers currently being used. The search for the replacement of 1,1,1-trichloroethane as a degreaser has been the topic of much research. The objective of several of these research studies is not only to develop a degreaser that will work as efficiently as 1,1,1-trichloroethane, but also to reduce air emissions. A number of chemicals have been suggested to replace 1,1,1-trichloroethane. Similar studies have been undertaken for replacing solvents such as MEK which are used to clean surfaces for painting purposes.

Although a suitable substitute may be found, it is important to keep in mind what limitations the new chemical may have. Some chemicals may work better on a selected application while performing poorly on others. Performance testing will be required for those chemicals that are chosen as a suitable substitute for 1,1,1-trichloroethane and MEK. Some of the products under consideration are shown in Table 1.2.1.

Table 1.2.1. Possible Substitutes for 1,1,1-trichoroethane (Heavy Degreaser/Maskant Remover)

Substitute Degreaser	Properties	Process Modification Required
Perchloroethylene	• Not an ODS • Is a HAP • Demonstrates excellent cleaning performance • Highly volatile	• Minor
Hydrofluoroether (HFE) Compounds e.g. AVD Rinsing Agent PF-5070	• Demonstrate excellent cleaning performance • Not an ODS • Short atmospheric lifetime • High wetting index • Not considered VOCs. • Can be mixed with other solvating agents to create intermediate cleaning compounds	• Minor
Supercritical Carbon Dioxide	• May be suitable for degreasing processes • May not be the best option for substitution • Extensive redesign required	• Extensive
FO 2085M	• Aqueous • Used in spray washers • Used in ultrasonic cleaners • Meets OSHA, RCRA, EPA Regulations	• Minor
Envirosolv CRX	• Removes oils, greases and carbons • Biodegradable • Anti-flash rust ingredients • Contains no acids or bases.	• Minor
Borothene	• Inert to metals and plastics • High solvency power • Works extremely well for vapor degreasing operations • Can be lost as toxic vapor	• Minor

1.3 CFC-113

Ozone Depleting Substances

Background: Liquid Oxygen (LOX), Gaseous Oxygen (GOX), And Liquid Nitrogen (LIN)

Liquid oxygen (LOX), gaseous oxygen (GOX), and/or liquid nitrogen (LIN) systems and components are found on virtually every aircraft weapons system and on numerous types of support equipment and production plants. In the Air Force at least 25 Technical

Orders (TOs) call for the use of Ozone Depleting Substance (ODS) solvents, mainly CFC-113 (Freon 113), to clean various components of these systems and equipment. Typical components include tubing, plumbing, fittings, gauges, converters, environmental controls, etc. New non-ozone depleting compounds are needed that will clean LOX/GOX/LIN components and remove virtually all hydrocarbon residue from any material that will come in contact with the LOX/GOX/LIN product. Additionally, due to the extremely low temperature of LOX and LIN, the cleaning process must leave no residual moisture that could freeze and damage the component or interfere with the flow of the LOX/LIN within the system(s).

Currently CFC-113, trichlorotrifluoroethane ($C_2F_3Cl_3$), is used for cleaning LOX/GOX/LIN system components in hand-wipe applications by the Air Force. CFC-113 works well for cleaning components that are removed from systems and for cleaning components left in place on LOX/GOX/LIN systems. CFC-113 however, is a Class I, Group I ODS.

P2 Option: Recovery of CFC-113

Success: The Air Force developed a solvent recovery process for CFC-113 used on flight vehicle parts cleaning. The system uses activated charcoal beds for bulk solvent recovery, with moisture removal by molecular sieves. The recovered solvent meets military specifications.

Solvent Substitution for CFC-113 in LOX/GOX/LIN

The 1990 Clean Air Act Amendments specifically direct that the production of all Class I chemicals to cease by 1 January 2000. Effective 1 January 1996, specific annual production limitations for each Class I substance, which includes CFC-113, were imposed. For these reasons it is important to find an acceptable substitute cleaner for CFC-113 and similar ODS cleaners.

Research is underway to identify environmentally acceptable chemical substitutes for use as cleaners for LOX/GOX/LIN system components in hand-wipe applications at Air Force bases. The substitutes are to be used for quick servicing maintenance activities. Much coordinated work between the Air Force, Navy, and NASA is ongoing with regard to substitute cleaners for LOX/GOX/LIN system components. This work will be summarized and recommendations will be made regarding how to proceed.

Potential Substitute Cleaners for LOX/GOX/LIN System Components

There are a variety of commercially available substitute cleaners for CFC-113 which are all less detrimental with respect to ozone depletion. These substitute cleaners are listed below in order of products that have undergone the most testing and show promise for cleaning LOX/GOX/LIN system components. The list is not necessarily complete, but it does provide a starting point for CFC-113 replacement. This list was compiled from commercial and government literature and word-of-mouth sources.

Substitute Cleaner - Trade Name (Other Data)

(1) HFE (hydrofluoroether) compounds (potentially expensive, approximately $180/gallon)
(2) Navy Oxygen Cleaner - Aqueous solution containing surfactants, (many cleaning steps)
(3) HCFC 141b (production and consumption banned effective 1 January 2003)
(4) Heavy Duty Cleaner & Degreaser #8260
(5) Zero-Tri
(6) OS-10
(7) QD Contact Cleaner 02180
(8) Ethyl lactate (flash point 47 degrees C)
(9) FO 655
(10) 749 N.O.D. Cleaner/Degreaser
(11) Borothene (works extremely well for vapor degreasing)
(12) N-methyl-pyrrolidone (biodegradable, capable vapor degreaser)
(13) MS-990 Solvent Flux Remover

Ongoing Air Force Efforts to Find Viable Substitute Cleaners for CFC-113 for LOX/GOX/LIN System Components

The Air Force is coordinating their replacement cleaner efforts with NASA and the Navy. The Air Force is currently considering the following CFC-113 replacement cleaners:

1. Navy Oxygen Cleaner is an aqueous mixture containing surfactants that are recirculated during the cleaning process. The Navy Oxygen Cleaner is good for use on removable parts that can be cleaned in a shop location. There are many rinsing and drying steps to the cleaning process using the Navy Oxygen Cleaner, with many checks. Because of this, use of the Navy Oxygen Cleaner is time consuming.
2. HCFC 141b, dichlorofluoroethane ($C_2H_3FCl_2$), has an ozone depletion potential of 0.12, and is banned for production and consumption effective 1 January 2003 and thus could be used as a temporary measure. There are two versions of HCFC 141b under consideration by the Air Force. The first is pure HCFC 141b, and the second is an aerosol recipe containing 5% isopropyl alcohol (IPA). HCFC 141b with 5% IPA has been used when slow drying times are required.
3. HFE compounds (hydrofluoroethers). These compounds are not ozone depleting substances and have been found initially to work well for cleaning LOX/GOX/LIN system components. However the current cost of HFE compounds for cleaning purposes is rather high (~$180/gallon).

Demonstration of cleaning efficiency for these potential replacement cleaners is being carried out by NASA . In addition, the Navy is also carrying out demonstration testing of these and other replacement cleaners. According to Air Force personnel, if the replacement non-ODS cleaners for LOX/GOX/LIN system components are demonstrated as acceptable for NASA and Naval submarine applications, they will be acceptable for Air Force base requirements.

Other Efforts to Find Viable Substitute Cleaners for CFC-113 for LOX/GOX/LIN System Components

There are two projects ongoing at an Air Force laboratory that may provide additional data and solutions for CFC-113 replacement cleaners for LOX/GOX/LIN system components:

1. Development of a CFC-free oxygen plasma cleaning process for aircraft oxygen systems.
2. Development and demonstration of use of laser technology for cleaning oils and other contaminants from oxygen lines of aircraft and ground support equipment without the use of ozone depleting chemicals.

1.4 Parts Washing: Stoddard Solvent	Ozone NAAQS (measured in VOCs and NO_x)

Background: Alternatives to P-D-680

The military specification for P-D-680 is held by the Army. Information on commercially available environmentally compliant solvent alternatives to P-D-680 can be found in U.S. Army Technical Advisory Message 92, "Substitutes P-D-680," 5 November 1996. The message lists several alternatives that meet P-D-680 performance parameters. These alternatives consist of highly refined aliphatic hydrocarbon compounds. The specification for P-D-680 is being revised to allow use of more environmentally compliant compounds. However, there is no aqueous based cleaner that meets the P-D-680 specification, essentially by definition. Therefore, to get approval for a water based cleaning process approval would be needed from the owner of the document that called out P-D-680.

P2 Option: Cyclonic Filter System and Cross Flow Filter System

Success: A Marine Corps base replaced their parts washing solvent with a less volatile parts cleaner (Petroleum NAPTHA 140 and 150). The solution is a Stoddard solvent that is not photochemically reactive. Based on the size of the vat at each parts cleaner location, a cyclonic filter system or cross flow filter system was installed. Since utilization of the new systems, the cross flow filter system has proven to be more environmentally friendly since it minimizes solvent change outs.

P2 Option: Microbial Water-Based Cleaning

Success: Microbial, water-based parts washing is an alternative to P-D-680 Stoddard solvent. A non-hazardous aqueous cleaner is used, which is kept serviceable and clean by a filter that is both mechanical and biological. Microorganisms are introduced into the cleaning process in the filter pad. The microorganisms remain dormant until the filter pad is inserted into the parts cleaning solution. As the solution begins circulating within the washer, the microorganisms break down and consume oil and grease particles. The cleaning solution used in these washers is generally a water based biodegradable, nonflammable, noncorrosive, nontoxic oil dispersant and cleanser that contains no VOCs, no known carcinogens, and no chemicals regulated by the Occupational Safety and Health Agency (OSHA) or Department of Transportation (DOT). Unlike P-D-680 or mineral spirits, the aqueous based solution does not sting or burn and emits a pleasant odor.

Cost: A cost-benefit analysis conducted by the Navy proved an annual cost savings of $3,264 per year and a 340 lb./year reduction in VOC generation for each Stoddard solvent unit replaced by a Smart Washer brand unit. Because the Smart Washer is self-cleaning, there are no monthly service charges for maintenance contracts. Typically, monthly filter replacement is the only required maintenance under normal use. Personnel in the shop consistently prefer to use the SmartWasher to clean parts.

The San Diego County Air Pollution Control District has declared the "Ozzy Juice" (from the Smart Washer brand) cleaning solution as exempt from District rules and permit requirements. Smart Washers may be purchased through the CNO Pollution Prevention Equipment Program (PPEP).

The Navy is currently evaluating a similar parts cleaner system. Another contractor's system also uses microbial enzymes to clean parts.

Notes:

1. These systems work only on natural oils and greases, not on the synthetic oils and greases used at many installations.
2. These systems require special maintenance to keep the microbes alive.
3. Water-based parts washers are not currently approved as a replacement for P-D-680 for use in the Army.

P2 Option: Aqueous Parts Washer

Success: Traditionally, the Navy has used P-D-680 (Stoddard solvent) and other types of hazardous solvents to clean various engine and aircraft components. The Navy reduced the number of cleaning units and replaced many cleaning processes that used the hazardous solvents with aqueous parts washers. The parts washers use heated aqueous solutions with alkaline detergent and a high-pressure spray. The washers feature a filter that continuously removes solid contaminants suspended in solution and a disc-type oil skimmer that removes floating oil. At one Naval facility, parts washers have eliminated 17 vapor degreasers, each containing 10 to 15 gallons of ODS. There have been no rusting problems or water disposal problems. Water is reused and only make-up water is added. Reusing water reduces the amount of water needing to be disposed. The washers have also significantly decreased the amount of labor required for cleaning. The Navy is exploring a more efficient recycling system to separate detergent and water and the viability of operating the power parts washer at lower temperature to reduce energy consumption. A Navy material laboratory will explore wider application of the power parts washer.

Eight additional aqueous parts washers have been installed. Installing the aqueous parts washer yielded the following benefits:

- Reduced the amount of P-D-680 used to clean engine and aircraft components.
- Eliminated air emissions and health risks associated with P-D-680 use.
- Reduced cleaning material costs by approximately $1,000 per year.
- Reduced off-site transfers and manifesting of used P-D-680 solvent.

Potential Problems of Aqueous Cleaning

1. Depending on the materials being cleaned and the cleaning methods used there may be potential for corrosion of parts.
2. Aqueous cleaners have not been approved for all applications or for all Services.

P2 Option: Replace P-D-680 Type II with P-D-680 Type III

Success: The Navy has initiated a program to reduce the procurement and use of the petroleum-based, dry-cleaning and degreasing solvent known as P-D-680 Type II which is used on a wide variety of shipboard systems. Type III has a higher flash point, lower aromatic content, and a lower vapor pressure. It is available in the supply system with the following NSNs:

- 6850-01-331-3349 (5 gallons)
- 6850-01-331-3350 (55 gallons)
- 6850-01-377-1808 (1 quart)
- 6850-01-377-1809 (1 gallon)
- 6850-01-377-1811 (1 pint)
- 6850-01-377-1812 (bulk)
- 6850-01-377-1916 (4 ounces)

P-D-680 Type III Standard PMS Identification Guide number is 2283. A Navy facility is changing all Maintenance Requirement Cards (MRCs) that require Type II to require Type III. MRCs are being updated with the technical approval from the In-Service-Engineer (ISEA) and/or Life-Cycle Manager. A Naval Center also has prohibited Type II on the Shipboard Hazardous Material List except in specific applications where no substitute has been found.

P2 Option: Solvent Substitution

Many bases throughout the Air Force have begun to use alternatives to P-D-680, Type II. An Air Force laboratory has put together a table of these alternatives with pros and cons.

Table 1.4.1. Possible Substitutes for P-D-680 Type II and Their Properties

Substitute for P-D-680	**Properties**	**Limitations**	**Process Modification Required**
Acetone	• Volatile and highly flammable • Solvent for wax, oils, plastics and lacquers	• Flash Rusting • No Ultrasonics	• Minor
Isopropyl Alcohol	• Flammable liquid • Solvent for cleaning electric circuits • Solvent for gums and oils • Not a corrosion inhibitor	• Flash Rusting • No Ultrasonics	• Minor
P-D 680, Type III	• Recommended substitute for P-D- 680, Type II • Has a higher flash point than P-D-680, Type II • Less volatile than P-D-680, Type II	• Not as aggressive as P-D-680, Type II	• None
Citrikleen	• For general cleaning purposes only • Not a corrosion inhibitor	• Used only if corrosion is not a problem	• Minor
Aqueous cleaners	• Used for general cleaning purposes only • Not a corrosion inhibitor	• Used only where rusting is not a problem	• Minor

1.5 General Cleaning	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances

P2 Option: Solvent Substitution

A wide variety of substitute solvents are commercially available that have a low vapor pressure, which means less of the solvent evaporates and pollutes the atmosphere. Table 1.5.1 lists several common substitutes. They have varying capabilities to clean metal components. The choice of solvent depends on the specific application. The effectiveness of a particular solvent at removing targeted contaminates must be evaluated on test parts, then qualified for use.

One disadvantage of solvents with a low vapor pressure is that more time must be allowed for residual solvent to evaporate after cleaning is completed. This delays further processing of the component. Another disadvantage is that several of the replacement solvents have a noxious odor, even in low concentrations, so adequate ventilation is essential.

Table 1.5.1. Possible Substitute Solvents for Cleaning

Substitute Solvent	Properties
Ethyl Lactate	• Reduces VOC emissions • Most metals not affected by short exposure • Flash point 47°C • Low order of toxicity • Ventilation recommended
Hydrofluoroether (HFE) Compounds e.g. AVD Rinsing Agent PF-5070	• Excellent cleaning performance • Not an Ozone Depleting Substance • Short atmospheric lifetime • High wetting index • Not considered VOCs. • Can be mixed with other solvating agents to create intermediate cleaning compounds
Borothene	• Inert to metals and plastics • High solvency power • Excellent for vapor degreasing operations • Can be lost as toxic vapor
Terpenes e.g. d-limonene and a-pinene	• Derived from natural sources such as citrus and pine oils • Requires ventilation • Not aggressive toward metals • Capable of dissolving heavy petroleum residues • Works at low temperatures
N-methyl-pyrrolidone (NMP)	• Reduces VOC emissions • Highly polar solvent • Miscible with water • Chemically stable • Low order of toxicity • Completely biodegradable • Can be used as a vapor degreaser

Background: Mechanical Cleaning

Abrasive Blasting

Abrasive blasting is an alternative to solvents for cleaning. In the blasting process, particulate media is propelled by compressed gases or a liquid to impinge on the contaminated surface. No toxic or hazardous chemicals are used; however, the blasting media can become contaminated with the material being blasted from the surface. There are several different types of blasting media, some multi-purpose and others single purpose. Several types of blasting media are described below:

Mineral Grit/Sand Blasting

Mineral grit and sand are effective blasting media because of their hard, abrasive qualities. However, the media and cleaning residue become mixed and difficult to separate. If the cleaning residue mixture is hazardous, it can be costly to properly dispose of the media/residue mixture.

Steel Shot/Grit

Steel shot is similar to bird shot. It is rough on a substrate but not nearly as rough as sand. Shot and grit can be mixed to achieve the desired performance. Advantages are that it can be magnetically separated from the residue and reused, and it does not create a hazardous dust. Wastes are kept to a minimum. Steel shot stripping is best done in an enclosure/glovebox or with sturdy, full body, personal, protective equipment.

Plastic Media

Plastic media is relatively easy on substrates and can be reused. The media can be tailored to a range of applications by using plastic beads of varying size and hardness. Systems are relatively inexpensive.

Plastic Foam

Oils, greases, dirt, and even paint can be removed from parts by blasting with small bits of urethane foam. If the soil is moist (i.e. oil and grease), the foam bits will absorb it. The foam can then be washed, dried and reused. Waste streams are similar to a parts washer with the advantage that the part itself does not get wet. For paint or scale removal, the foam can be wet to reduce dust generation.

1.6 Weapons Cleaning: Wipe Cleaning	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances

P2 Option: Ministeam Cleaners

Success: Ministeam cleaners called "Mini-Max" have been used to replace solvent wipe cleaning of small bore and medium bore weapons; i.e. rifles and guns. The Marines Corps has been extremely satisfied with the Mini-Max system. This handheld system replaces solvent cleaning and degreasing. The system has been expanded for use within aviation maintenance facilities for electronics cleaning and printed circuit boards. The system can also be used to clean automotive parts and other gear. The technology uses distilled water mixed with a cleaning solution to generate steam at 500 degrees F. The steam is delivered through a nozzle at 90-150 psi. The cleaning solution is non-toxic, non-flammable, biodegradable, and eliminates the use of solvents. An additive to inhibit rust may be used where flash rusting is of concern. This technology also saves labor, yielding an estimated payback period of 6 months. The unit is available through Government Services Administration (GSA) and the Navy. The unit has been used successfully not only in the Navy but also at Army and Air Force facilities. The unit was also used to clean electronics in ground support equipment and saved 40 hours of disassembly normally required using traditional solvent/wipe cleaning practices. The Marine Corps has not had any problems with rusting of their weapons and has fully sanctioned the use of the system. Very little water is used, and rags can manage any residue accumulated during the cleaning process. The system won the 1997 Clean Air Award for Technology for the California South Coast Air Quality Management District.

1.7 Weapons Cleaning: Dip Tanks	Ozone NAAQS (measured in VOCs and NO_x) Ozone Depleting Substances

Background: Aqueous Parts Washers

Aqueous, hot water parts washers use a combination of hot water and detergent to remove contaminants from parts. Most systems separate oil and solids from the cleaning solution that allows a batch of water and detergent to be used repeatedly before becoming too soiled to be effective. Wastes from this cleaning process include the spent detergent solution, oil, and solids/sludge. The quantity of waste is typically much less than the waste generated from solvent cleaning operations. One disadvantage to water-based parts washing is an increased potential for rust formation on the parts being cleaned. However, there are many detergent formulations available that include rust inhibitors to minimize this problem.

P2 Option: Aqueous Parts Washers

Success: A weapons pool, servicing a large volume of training weapons, replaced multiple large dip tanks containing Type II Stoddard Solvent with (dishwasher style) hot water parts washers.

1.8 Electronics Cleaning	Ozone Depleting Substances

Background: Widespread use of ODSs for electronics cleaning is now being replaced by a variety of materials, such as IPA, or processes, such as is described below.

P2 Option: Integrated Closed Loop Cleaning

Success: The Navy conducted research for five years to find a suitable P2 alternative for electronics cleaning. They found a system called PROZONE^{TM} in the United Kingdom with which they have been extremely satisfied. PROZONE^{TM} is a fully integrated process that needs only electrical power. No water mains or drainage are required. A one-step active water filtration system and concentrator dispenses with the need for water effluent systems. The system uses an oxygenated solvent developed specifically for electronics to remove flux and ionic residues. The system is being used throughout the world in electronics cleaning applications, from bare boards, assembled boards, components and screens, and conveyor fingers. The solvent is nonflammable and biodegradable. It has zero ozone depleting potential, low vapor pressure, low odor, and a water miscible formulation suited to a semiaqueous cleaning regime.

2. DEPAINTING

## 2.1 Paint Stripping: Methylene Chloride	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP

P2 Option: Benzyl Alcohol

Success: Benzyl alcohol has been a moderately successful replacement for methylene chloride. Those working with the product claim at times the benzyl alcohol doesn't work. Benzyl alcohol requires a longer residence time (less efficient than methylene chloride) and is labor intensive. This product is not approved by the Air Force yet due to concerns over the potential for corrosion. It also requires use of personal protective equipment. Benzyl Alcohol is a VOC.

P2 Option: Plastic Media Blasting

Success: Since the 1994 TRI baseline was established 95% of methylene chloride paint stripping at a naval facility has been eliminated. This has been accomplished using Plastic Media Blasting (PMB) with methylene chloride used to supplement the hard to reach areas.

Success: Some installations using plastic blasting media do not purchase the media, but hire a company to bring new media, and take away the spent media. The spent media can then be incorporated into recycled plastic products.

P2 Option: PMB or Benzyl Alcohol

Success: Paint stripping of aircraft is being accomplished using PMB. This method is restricted to thin skin laminate structures. It is expected that eventually benzyl alcohol will be used to supplement the stripping instead of methylene chloride to comply with the NESHAP. It is expected that the Flashjet process will be in use to depaint aircraft in approximately 5 years. However, methylene chloride will remain in use in small quantities for applications not prohibited by the rule.

P2 Option: Ultra High Pressure Water Jet Paint Removal

Success: Fugitive dust emissions from standard sand blasting of ship hulls is a source of fugitive emissions and must be controlled with containments. Use of the water jet blaster on one-half of the ship's hull prevented 50% of fugitive dust emission at the source. Air emission reduction is estimated at 4,000 pounds/hull. The system uses a manlift with a waterjet nozzle and recovery shroud mounted at the end of the boom in place of a personnel basket. The system does not require expensive, cumbersome containments and ventilation. The blast water is completely captured by the vacuum shroud at the surface being blasted. The water is transferred to a water reclamation trailer where it is processed for reuse. The system not only reduces pollutants but has significant cost savings. The ship does not need to be dry docked which is another added savings.

P2 Option: Pressure Water Stripping and Media Blasting Techniques

Success: An environmentally safe, high-pressure water stripping system is currently under development as an Air Force project. Initially aimed at stripping thin-skinned aircraft without damage, this system has progressed to include the stripping of radomes and developed into a joint initiative line item with the Navy to include ship and submarine coatings removal. The Navy's system has been demonstrated as an effective means of removing thick coatings on vessels in dry dock. It is portable and includes a contaminant recovery system, and removes coatings at a rate of 100-175 square feet per hour.

Problem: A medium pressure water stripping process was developed at an Air Force Base. The system (Aquimizer) operates at 15,000 PSI, and more than doubles the time needed to strip an aircraft. Typical stripping times go from 3 days by chemical means to 7 days with this system. The medium pressure water stripper removes paint and primer everywhere except on the leading wing edges. Leading edges still require the use of MEK, toluene, or methylene chloride, but in significantly lower quantities. Though effective at paint removal, this system is not considered to be cost-effective. The stripping and painting of the AWACS must be done in the same hanger as other aircraft, and the process is slow, causing scheduling delays of other aircraft in need of the stripping barns. In addition to the delays caused by using this system, the benzyl alcohol used to soften the paint prior to the water jet (Aquimizer) application will not attack epoxy primers such as Koroflex, which is used on J-Stars and AWACs and other airframes. This method is also not effective at temperatures below 70° F, and is not usable on low hanging C-130's. This system though, did help lead to the concept of the Large Aircraft Robotic Paint Stripping (LARPS) system being developed through the Air Force.

Research: Physical Removal Techniques

The Air Force has several paint removal programs including: LARPS; alternate chemical paint strippers; biodegradable plastic media; gel-encapsulated enzyme activated coatings removal; "smart" stripping processes; and next generation energetic stripping. "Smart" stripping is the ability to strip with a vision system that can adjust the stripping media to ensure a good job. The speed of the water gun can be reduced to get a deeper strip or increased to reduce wear on the substrate if the paint is peeling fast. Also, "smart" stripping can select between coatings. It has the ability to remove the topcoat, but leave the primer coat on the substrate.

P2 Option: Sodium Bicarbonate Blasting

Success: In the Navy, torpedoes are operationally tested on a range after which they are disassembled, refurbished, and then reassembled. As part of the refurbishment process, external torpedo components must be stripped and repainted. Torpedoes have an aluminum alloy shell and operate in a rigorous environment including salt water, sea pressure changes, Otto Fuel, and hydraulic fluid. At first, paint stripping was accomplished using methylene chloride dip tanks. The Navy considered carbon dioxide blast, flash lamp, and water jet blasting. The methylene chloride was replaced by plastic media blasting (PMB) and later by sodium bicarbonate blasting. The benefits of sodium bicarbonate blasting include reduction of the following: air emissions, worker exposure to toxic substances, disposal costs, liability, and solid waste. Blasting booth waste fell by over 90% over a five-year period.

Background: Alternative Solvents

Methylene chloride, a suspected carcinogen, is commonly used for stripping of organic coatings. The CAA90 identified methylene chloride as a HAP and as such, it is subject to regulation under the Aerospace NESHAP. The Aerospace NESHAP requires elimination of organic HAP emissions from depainting operations by September 1998.

Over the past several years, various companies have developed paint strippers to replace methylene chloride. The majority of these strippers contain benzyl alcohol. Both alkaline/amine and acid activated strippers have been formulated. The acid activated strippers have been successfully used in the commercial sector. However, these strippers are not considered to be acceptable for military applications because of their potential to induce hydrogen embrittlement in high strength steel.

Several benzyl alcohol based strippers have been used for military applications, with varying degrees of success. Examples of these strippers are Turco 6813 (polyurethane), McGean Rohco E1058 (polysufide), Eldorado SR-145 (polyurethane/polysufide), and Eldorado PR-3133 (polyurethane). Many other products have been tested and used for military applications. In formulating environmentally preferred strippers, a key point that must be considered is the stripper's ability to attack the various types of coating systems that are present on military aircraft. A fair degree of success has been achieved with epoxy primers, polysulfide coatings, and polyurethane topcoats.

A more difficult problem has surfaced when stripping aged Koroflex primer (TT-P-2760). The Koroflex primer is a polyurethane coating that is applied to larger aircraft (e.g. transport aircraft) to improve the flexibility of the coating system, thereby increasing its resistance to cracking and adhesion loss due to flexing of the structure during flight. The Koroflex primer also provides a barrier, thus lending an increased level of protection to the substrate. In many cases, the Koroflex primer is applied directly to the metal and overcoated with MIL-C-85285 or MIL-C-83286 topcoat. This coating system has been found to be extremely difficult to remove. Methylene chloride is marginally effective on Koroflex primer, while the environmentally preferred strippers are even less effective on Koroflex. Because many of the weapon systems in the DoD inventory use Koroflex primer, there is a need to develop environmentally preferred strippers that can strip the primer in a reasonable period of time.

In 1993, a contractor initiated a pollution prevention project to replace the methylene chloride based paint stripper that is currently used at the site. A total of eighteen different paint strippers were evaluated. Testing was conducted in the laboratory and field to ensure performance in an operational environment. Testing included: coating removal rates, sandwich corrosion, intergranular attack/end grain pitting and hydrogen embrittlement. Stripping efficiency was evaluated on several different coating schemes: Epoxy Primer (MIL-P-23377TY1CL3) + Polyurethane Topcoat (MIL-C-83286), Epoxy Primer + Polysulfide (MIL-S-81733) + Polyurethane Topcoat, Epoxy Primer + Koroflex (TT-P-2760TY1CL2) + Polyurethane Topcoat.

A summary of the paint stripper evaluation results is presented in Table (1). Of the eighteen strippers tested, several of the strippers met the GSAC requirements. These include McGean Rohco E1058, Turco 6813, Eldorado SR-145 and Eldorado PR-3133.

Table 2.1.1. Environmentally Preferred Paint Stripper Evaluation Results

Paint Stripper	Coating Removal	Sandwich Corrosion (ASTM F1110)	Hydrogen Embrittlement (ASTM F519)	Intergranular Attack (BSS 7219)
Turco 6813	Pass (Marginal)	Pass	Pass	Pass
Turco 6776	Pass	N/A	Fail	Pass
Turco 6840	Pass	Pass	Fail	Pass
B&B 5151M	Fail	Fail	Fail	Fail
Fine Organics 2115	Fail	Pass	Fail	N/A
EZE 542 (Red)	Fail	Pass	Fail	N/A
EZE 542A	Fail	N/A	N/A	N/A
EZE 542 (White)	Pass	Fail	Fail	Fail
EZE 541	Fail	Fail	Fail	Fail
EZE 541A	Fail	N/A	N/A	N/A
McGean Rohco E2000	Fail	N/A	N/A	N/A
McGean Rohco E1092	Fail	Fail	Fail	Fail
McGean Rohco E1058	Pass	Pass	Pass	Pass
McGean Rohco E2002	Fail	N/A	N/A	N/A

Paint Stripper	**Coating Removal**	**Sandwich Corrosion (ASTM F1110)**	**Hydrogen Embrittlement (ASTM F519)**	**Intergranular Attack (BSS 7219)**
Eldorado SR-125A	Fail	N/A	N/A	N/A
Eldorado SR-145	Pass	Pass	Fail	Pass
Eldorado PR-3133	Pass	Pass	Fail	Pass
Eldorado PR-3131	Fail	N/A	N/A	N/A

Stripping Efficiency

Stripping efficiency was a somewhat qualitative test with respect to stripping times. Of the strippers that passed the corrosion tests, the SR-145 was the top performer. This stripper was found to be effective on both polyurethane and polysulfide coatings in relatively cold weather. Eldorado PR-3133 was very effective on polyurethane and less effective on polysulfide coatings. The PR-3133 can be used to strip Koroflex primer.

The McGean Rohco E1058 was formulated specifically for polysulfide coatings and, as such, is effective on polysulfide/polyurethane coating systems. However, in cases where coating thickness' are excessive (> 12 mils), the polyurethane must be stripped before the E1058 can effectively remove the polysulfide. Turco 6813 tends to be more temperature sensitive than the Eldorado SR-145 and PR-3133. However, this stripper will effectively strip epoxy/polyurethane coatings at 70 °F. Additionally, it was found to effectively strip Koroflex primer with somewhat decreased strip rates. Strip times vary according to temperature, type of coatings, overall coating thickness, and age of coatings. In general, the benzyl alcohol based strippers require significantly longer dwell times compared to methylene chloride based strippers. A summary of the recommended stripping guidelines is depicted in Table 2.1.2. The stripping efficiency data clearly indicates that Koroflex with a polyurethane topcoat is extremely difficult to remove. Using the Turco 6813, this coating took four applications of the stripper and 22 hours to strip. Note that the Koroflex strips much more readily when an epoxy primer is used between the base metal and Koroflex.

Hydrogen Embrittlement

Hydrogen embrittlement test results were extremely inconsistent. As previously mentioned, a number of different test methods were used. This test was rerun several times in an effort to obtain consistent data. Of the test methods used, the ASTM F519 1(a) loaded at 75% notch ultimate tensile strength (UTS) and ASTM F519 1(d) loaded at 65% of the predetermined breaking strength are considered to be the most stringent. In general, if a stripper passed either of these tests at least once, it was considered to be an overall passing result. Two of the strippers tested met this criteria: Turco 6813 and McGean Rohco E1058.

SR-145, PR-3133, A-29SCW and Turco 6017 were evaluated using ASTM F519 1(a) at a sustained load of 45% notched tensile strength and step loaded to 90% after 200 hours. All of the specimens exposed to the Turco 6017 failed under 150 hours. The specimens exposed to the Eldorado SR-145, Eldorado PR-3133 and CEE BEE A-29SCW reached the 200-hour mark and failed at various times under the 90% loading (4.8 to 44.9 hours). The failed specimens were then metallurgically analyzed to determine the degree of embrittlement within the specimen. The ranking from best to worst was SR-145 (minimal), PR-3133 (minimal), A-29SCW (slightly higher), and Turco 6017 (significant). The test criteria used here are consistent with the Air Force hydrogen embrittlement test often used for qualification of maintenance chemicals. Therefore, the SR-145 and PR-3133 would be considered acceptable for some programs. A contractor is presently rerunning the hydrogen embrittlement test using ASTM F519 1(a) loaded at 75% UTS.

Table 2.1.2. Stripping Guidelines for Turco 6813 and McGean Rohco E1058

Coating System	Stripper	Application	Dwell Time (hr)	Temp (°F)	Stripping Time (hr)
Epoxy/ Polyurethane	6813	1	2	70	2
Polysulfide/ Epoxy/ Polyurethane	6813	1 2 3	2 2 18	85 85 85	22
Epoxy/ Koroflex/ Polyurethane	6813	1	1.5	70	1.5
Koroflex	6813	1 2 3 4	2 2 2 18	70 70 70 70	24
BMS 10-60 TY1	6813	1 2	4 4	70 70	8
Polysulfide/ Epoxy/ Polyurethane	E1058	1 2 3	2 2 18	75 75 75	22
Polysulfide*	E1058	1	1.5	70	1.5

*Topcoat and Primer previously stripped with Turco 6813.

Background: Mechanical Stripping/*Abrasive Blasting*

Abrasive blasting is an alternative to solvents for depainting. In the blasting process, particulate media is propelled by compressed gases or a liquid to impinge on the contaminated surface. No toxic or hazardous chemicals are used; however, the blasting media can become contaminated with the material being blasted from the surface. There are several different types of blasting media, some multi-purpose and others single purpose. Some of the various types of blasting media are described below:

Mineral Grit/Sand Blasting

Mineral grit and sand are effective blasting media because of their hard, abrasive qualities. However, the media and cleaning residue become mixed and difficult to separate. If the cleaning residue mixture is hazardous, it can be costly to properly dispose of the media/residue mixture.

Steel Shot/Grit

Steel shot is similar to bird shot. It is rough on a substrate but not nearly as rough as sand. Shot and grit can be mixed to achieve the desired performance. Advantages are that it can be magnetically separated from the residue and reused, and it does not create a hazardous dust. Wastes are kept to a minimum. Steel shot stripping is best done in an enclosure/glovebox or with sturdy, full body, personal, protective equipment.

Plastic Media

Plastic media is popular for paint stripping because it is relatively easy on substrates and can be reused. The media can be tailored to a range of paint stripping applications by using plastic beads of varying size and hardness. Systems are relatively inexpensive.

Plastic Foam

Oils, greases, dirt, even paint can be removed from parts by blasting with small bits of urethane foam. If the soil is moist (i.e. oil and grease), the foam bits will absorb it. The foam can then be washed, dried and reused. Waste streams are similar to a parts washer with the advantage that the part itself does not get wet. For paint or scale removal, the foam can be wet to reduce dust generation.

Dry Ice (CO_2)

Developed for aircraft paint stripping, this system has some interesting characteristics. First, there is no excess waste generated. The CO_2 pellets sublime after contact with the part, dissipating as CO_2 gas; paint and soil falls to the ground. Second, the sublimation of pellets on impact helps to lift paint from the surrounding substrate. First generation systems were slow but recent modifications have improved the speed. Once optimized, paint stripping proceeds at 1 sq. ft/min.

Contractors have developed a process that combines CO_2 pellets with a flashlamp. The flashlamp provides heat to destroy a coating's cohesive bonds; the pellets cool and clean the surface. The process has been successfully applied to aluminum and composite materials used in aircraft.

The limitation of large-scale CO_2 blasting is high cost. A capital investment of $170,000 to $250,000 is necessary for the pelletizer. More sophisticated models may cost upwards of $400,000. These costs do not include expenses for auxiliary equipment or installation.

Wheat Starch

This relatively inexpensive media was also developed for aircraft paint stripping. The crystalline wheat starch used in this system can be reused and actually becomes more aggressive as it breaks down. Wheat starch is very forgiving of error and is easy on substrates. Crystalline wheat starch molecules are different from the naturally occurring polymer so explosion potential is not a problem.

Walnut Shells and Other Food By-Products

These unusual media are used, among other things, to clean carbon deposits from engine parts. Ground walnut shells are gentle on the substrate and inexpensive. Peanut shells and ground corncobs are also used as blast media.

Bicarbonate of Sodium Stripping (BOSS)

BOSS eliminates the toxic stripping solvents such as toluene, xylene, MEK, and acetone from the stripping process. One disadvantage is grit entrapment behind panels and in cracks that contributes to corrosion, particularly of aluminum structures. Even when no corrosion is yet present, the entrapped powder gives a false impression of corrosion. This can be disturbing to system users. The media is not recyclable and disposal (usually into the sewer) requires large amounts of water. Care must be taken to keep contaminants (e.g. heavy metals) out of the waste stream.

Vacuum Blasting

This is actually a blast system that can use a variety of media such as some of those described above. A special vacuum head is held against the substrate. The media is accelerated to the head using a vacuum instead of compressed air. After impact the vacuum pulls the media back to the holding bin where it is continuously reused. This reduces environmental impact and worker exposure to hazardous substances and allows other nearby operations to continue uninterrupted.

Needle Guns (Chipping)

This system uses multiple, reciprocating needles, to pummel paint, dirt and scale from surfaces. The needles are contained in a vacuum head that is held up against the part during cleaning. The vacuum system captures the removed soil, thus eliminating worker and environmental exposure. A major advantage is that no excess wastes are generated. The technique is popular in applications such as removing lead-based paint from bridges.

Brush Removal

A contractor developed a machine with rotating brushes that mechanically cleans copper metal sheets with pumice. The machine replaced an existing chemical surface preparation process that used sequential spraying with ammonium persulphate, phosphoric acid and sulfuric acid. The chemical process generated 40,000 lbs./yr. of hazardous liquid waste. With the mechanical cleaning machine, the fine abrasive pumice generates a nonhazardous sludge that can be sent to a conventional landfill.

The following tables compare depainting technologies and are excerpts from a study conducted by the Air Force and a contractor. The study was funded by the US Air Force. This information is an average of data collected from various airframes at several Air Logistic Centers.

Table 2.1.3. Relative Life-Cycle Cost: Normalized Operating Costs ($/ft^2), Production Rates (ft^2/hr), and Capital Conversion Costs ($)

Paint Stripping Method	**$/ft^2**	**ft^2/hr**	**$**
Methylene Chloride	3.0	25	($10,000,000)***
Two-Component Benzyl Alcohol	3.7	29	$50,000+
Plastic Media Blasting	1.8	50	$1,500,000
Medium Pressure Water with Bicarbonate of Soda Stripping	1.9	56	$1,000,000
Wheat Starch	2**	45	$1,500,000++
Large Area Robotic Paint Stripper (LARPS)	1.1	150	$4,000,000 to $10,000,000
FLASHJET®	3.2**	100	<$4,000,000+++
Laser*	1.2	60	<$4,000,000

*Projection from prototype test data.
**Vendor estimate. May include life-cycle costs
***Emission control costs
+Assuming no VOC control cost
++Assumed equivalent to PMB
+++Assumed equivalent to laser

Note that these were results from certain airframes at particular locations. Costs vary widely between weapon systems. For example, the cost for wheat starch and plastic media blasting on some weapon systems has been reported at ten times the cost presented in table 2.1.3. Therefore it is important to obtain information which corresponds to a particular weapon system. Costs may also vary to some extent between sites. Therefore, when looking at costs from another site, even though it is your type of weapon system, determine if location specific costs will be different. Also, when comparing calculated numbers, such as cost per square foot, from different sources, determine what factors went into the calculations.

Table 2.1.4. Stripping Technology Comparison

Depainting Technology	**MC-Based Stripping**	**Alternative Chemical Stripping**	**PMB**	**MPW/BOSS after presoftening with BA**	**LARPS/HPW**	**Laser Stripping**	**Wheat Starch Blasting**	**FLASHJET® with CO_2 Pellet Blasting**
Stripping Rate	Medium	Medium	Med-High	Low-Med.	Med.-High	High	Low-Med.	High
Level of required PPE	High	High	Med.-High, Low for automated	High	Low	Low	Low	Low
Labor hour requirement	High	High	High, Low for automated	High	Low	Low	High	Low
Compatibility	Medium	Medium	Med.-High	Medium	High	High	High	High
Corrosion Potential	Low	Low-Med.	Low	Med.-High	High	Low	High	Low
Intrusion Potential	High	High	Medium	High	High	Low	High	Low
Pre-stripping preparation requirements	High	High	High	High	High	Low	High	Low
Post-stripping cleanup requirements	High	High	Medium	High	Low	Low	Medium	Low
Residue Volume	High	High	High	High	High	Low	High	Low
Residue demands on IWTP	High	High	High	High	High	Low	High	Low
Air Pollution Control Rqmt.	High	Low-Med.	Medium	Medium	Low	Low	Low	Low
Current Status of technology in Air Force	Wide use since 1940's	Components only, under testing for frames	Wide use since 1989	Aircraft frames since 1994	Aircraft frames since 1997	Radomes, under investigation for frames	Demo-stage, under testing	Under testing for military use
Initial capital costs for conversion from MC stripping	None	Low	Medium	Low	High	High	Medium	High

2.2 Research and Development

Research: Eliminate Stripping of Primer Coatings

One alternative to stripping and reapplication of a chromate primer is to consider implementation of a coating system that does not require stripping of the coating to the metal surface. For instance, the weapon system manufacturer would be required to spray the corrosion inhibiting primer (chromium, or non-chromium) followed by a coating system that is designed to be stripped. The coating system would be an intermediate coat that is readily attacked by a specific type of solvent (such as alcohol) and a polyurethane topcoat. In most cases, the rework activity would then be limited to stripping and reapplication of the nonchromate coatings. This would eliminate the chromium in the paint stripper residue and waste associated with painting operations in addition to airborne emissions of hexavalent chromium.

The rationale behind removal of organic coatings has been to expose the bare metal in order to facilitate evaluation of the health of the metal substrate. As an alternate, a contractor has developed a process that will allow for non-destructive inspection (NDI) of critical structures without removal of the coating. The technique that has been developed will comprehensively evaluate the residual strength of critical structures and determine the location of cracks and/or corrosion. This will further allow for the continued monitoring of the health of the vehicle by detecting changes such as crack growth, corrosion depth and microstructural changes.

The NDI technique involves the use of two technologies, which are sensitive to the condition of metallic structures: eddy current measurements and ultrasonic sensing. These evaluation techniques can be computer automated for data acquisition, analysis and archiving. Ultrasound, which is sensitive to discontinuities in elastic structures, and electromagnetic eddy-currents, which are sensitive to the conductivity or magnetic permeability in the local of the probe, represents complementary means of detecting anomalous conditions in metals. The sensing probes used in both techniques can be tailored for specific structure and defect geometries.

P2 Option: FLASHJET®

Planned: FLASHJET® uses a high energy xenon discharge lamp coupled with surface cooling and cleaning provided by pelletized carbon dioxide (“dry ice”) that depaints and cleans surfaces with a robotically controlled motion over the coated surface. The thickness of coating removed can be controlled by the voltage delivered to the xenon lamp. FLASHJET® uses a vacuum particulate removal substrate system that is run through various filters. Periodic changeout of the system generates the only waste from the system. A contractor currently has a $2.7 million, fully operational system. FLASHJET® eliminates all VOCs, significantly reduces strip time (6 to 3.5 days), has the lowest operating cost/ft^2 for aircraft paint removal, has significantly reduced health hazards, and is safe on metallic and composite aircraft structures. FLASHJET® does have problems in removing paint from curved surfaces, it works well however on completely flat surfaces. The system has high capital costs (robotics and CO_2 support facilities) and there are questionable thermal shock effects under application of the system.

The Navy is in the planning stages for using FLASHJET® as a paint removal system. They plan on having the system installed FY99.

Research: FLASHJET®

The Army is preparing to test the FLASHJET® over the next two years. In the first year the system will be tried on helicopters and components, and in the second year on tanks and other ground equipment. How the FLASHJET® will perform on the irregular surfaces of many of the Army vehicles will be investigated.

Research: Paintless Airplanes (Appliqués)

Appliqués are thin polymer films backed by a pressure-sensitive adhesive that can be peeled off in sheets, eliminating the need for abrasive blasting, chemical coating removal, or other techniques. Contractors have been demonstrating the feasibility of replacing most, if not all painting of an aircraft with this technology. The work is being performed as part of a Technology Maturation contract from the Joint Strike Fighter (JSF) Paintless Airplane Program (JPAP). This technology involves films backed by adhesives.

Research: A Faster Acting Stripper for Koroflex

The Air Force initiated a project to develop a faster acting stripper for Koroflex primer. The project is a collaborative effort between the US EPA, the US Air Force, and industry. The project was completed in 1996 and a production version of the alternate stripper(s) will be available in 1998.

The first phase of the project involved identifying potential candidate strippers for Koroflex. During this phase of the program, the chemical mechanism for degradation of the polymeric bonds was used as a basis for identifying alternative solvents. Six different types of solvents systems were identified as potential replacements for methylene chloride in paint stripping: benzyl alcohol, n-methyl-2-pyrrolidinone, dibasic ester mixtures, propylene carbonate, n-amyl acetate, and methyl isoamyl ketone. Several commercially available strippers were identified. Thirteen strippers were selected as candidate for further evaluation.

The evaluation phase of the project is currently underway. Each candidate stripper will be evaluated based on several performance parameters. These include: appearance, biodegradability, toxicity, pH, evaporation, viscosity, flash point, cold stability, consistency, flow, removal power/rinsability, corrosion, hydrogen embrittlement, storage stability, and density. Once this testing is complete, the Air Force will select three stripper candidates that will undergo full scale testing in field operations. After completion of this phase, the strippers will be evaluated for effectiveness in removing other coatings such as epoxy primers (BMS 10-11, MIL-P-23377) or self-priming topcoats (TT-P-2760).

3. SURFACE COATING

## 3.1 Paint Gun Washers	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP

P2 Option: Paint Gun Washer

Success: Automatic paint gun washers are similar in operation to dishwashing machines. Within the sealed unit, the paint gun is attached to a nozzle, which circulates solvent throughout the interior of the gun. Meanwhile, the exterior of the gun is cleaned by paint thinner using conventional dishwater action. The cleaning solvents are then collected in a reservoir, where they are filtered. The filtered solvent can then be reused avoiding disposal costs. Solvent use was reduced by 33%, labor costs are also reduced.

## 3.2 Primers	Ozone NAAQS (measured in VOCs and NO_x) Chromium compounds (HAP) Aerospace NESHAP

P2 Option: Water Reducible Epoxy Primer

Success: At one time MIL-P-23377 epoxy-polyamide primer was used on virtually everything. This primer contained 25% strontium chromate. This primer has been successfully replaced for most applications by MIL-P-53030 epoxy, water reducible, lead and chromate-free primer, eliminating chromate and VOCs. Painters using water reducible coatings for the first time will require training and practice. The water reducible coatings require more careful surface preparation to avoid blistering and lifting. This type of primer is thinned with water. Because of its cohesive properties it does not tend to run.

P2 Option: Nonchromated Primer

Success: The Tie Coat nonchromated primer is going through the TO change process and tentatively will be approved in mid-spring 1998. It is expected to be approved for use on planes during their midlife cycle painting. These paintings occur when the bare metal is not exposed and the chromated primer (corrosion resistance) is still intact but the adhesion property is lost.

Research: Non-Chromated Flexible Primer

The Koroflex primer is a polyurethane coating that is applied to larger aircraft (e.g. transport aircraft) to improve the flexibility of the coating system, thereby increasing its resistance to cracking and adhesion loss due to flexing of the structure during flight. The Koroflex primer also provides a barrier, thus lending an increased level of protection to the substrate. In many cases, the Koroflex primer is applied directly to the metal and overcoated with MIL-C-85285 or MIL-C-83286 topcoat.

To date, a nonchromated version of the Koroflex primer has not been developed and qualified.

The Koroflex primer would be considered a low usage item compared to the epoxy primers. Once the nonchromated coating technology matures, the nonchromated corrosion inhibiting pigments can be formulated into a polyurethane resins system. Currently, there are two qualified suppliers of Koroflex. These companies would be in the best position to reformulate the Koroflex primer using nonchromated corrosion inhibitors. However, since neither of these companies has successfully formulated a nonchromated primer capable of meeting 2000-hour salt spray resistance, it will be some time before a nonchromated Koroflex primer will be available. Presently, one contractor is in a good position to accomplish this, however, Koroflex is not included in their present product line.

Research: Development of Non-chromate Corrosion Inhibitors for Coatings on Aluminum

Non-chromate substitutes equivalent to the chromate corrosion inhibitors formulated in primers and/or paints for the protection of high-strength aluminum alloys were studied. Quaternary ammonium dimolybdate salts (Q-Mo) were found to prevent ocean-water salt-spray corrosion for 2000 hours, equivalent to the strontium chromate-filled epoxy-polyamide primer, MIL-P-23377. Quaternary ammonium nitrate, phosphate, and borates were included in the evaluations. However, the Q-Mo was superior in every regard. The dimolybdate quaternary ammonium salt is a developmental inhibitor of high purity containing less than 1,000 ppm sulfate and 100 ppm chloride. Optimization of the molybdate in the primer was successful in achieving the physical, corrosion, and fluid resistance, and working properties required for demonstration testing and evaluation.

3.3 CARC Painting

Ozone NAAQS (measured in VOCs and NO_x)
Aerospace NESHAP

Each Chemical Agent Resistant Coating (CARC) camouflage topcoat color and primer used has a different VOC concentration. CARC paint is extensively used on many different types of equipment including all tactical helicopters, ground equipment, tanks, trucks, generators, and radar sets. CARC paints typically contain high VOCs, isocyanates, and chromium. Paint guns applying CARC typically require methyl ethyl ketone for clean up.

P2 Option: Waterborne CARC

Success: A Joint Service effort is underway to improve the formulation, application, and depainting of waterborne CARC. The Army has been working on a reformulated CARC, MIL-P-64159. Two installations have been using the waterborne CARC for testing, and it is expected to be approved and fielded by May 1998.

P2 Option: Waterborne Camouflage Coating

Success: Two Marine Corps bases have switched to waterborne camouflage coatings as a temporary measure until waterborne CARC is available, in order to comply with VOC limits. This non-CARC coating, MIL-C-29475, is not for use in combat. With N-Methylpyrrolidinone (NMP) as the solvating agent, this coating has reduced isocyanate emissions from 5-7 lb./gallon to 2-3 LB/gallon. These coatings have a VOC content of less than 1.8 LB/gallon. They have been satisfied with these topcoats. Results of a two-year study show:

1. a 50% reduction in VOC
2. reduction in Personal Protective Equipment (PPE) for brush and roll applications
3. increased production throughput
4. better flexibility, cleanability, mar and abrasion resistance
5. easier cleanup, i.e. can use water
6. reduction in generated waste

The topcoats have passed the adhesion, infrared and gloss requirements. They have not yet done extensive field testing and have not tested for chemical agents. Consequently the waterborne camouflage coating meets the established camouflage requirements but not the chemical agent resistance requirements. However, the Marine Corps has authorized interim use of this current formulation. Paint guns applying CARC typically require methyl ethyl ketone for clean-up but the current coating is waterborne so the paint guns can be cleaned with just water. The Marine Corps has developed a plain language guide, User's Guide For Application of Waterborne Camouflage Coating, Code 88-4.

Research: Waterborne Coatings

Despite the fact that waterborne coatings are relatively common, research continues to address limitations in application and improve performance and durability as well as further reducing VOC and HAP content. The following are examples of some of this research.

An Air Force laboratory researches polyurethane paints under the High Performance Aerospace Coating System Program. Waterborne polyurethane systems are being examined under a test program. It is reported that the isocyanates in waterborne (as opposed to the usual solvent-borne) systems are blocked from reacting, which may reduce the exposure potential for workers spraying the paint.

Background: *Waterborne Coatings*

Waterborne paints differ from conventional coatings in that water has been substituted for certain organic solvents in the coating that are used as the dispersal medium for synthetic resins and pigments in the coatings. These coatings may still contain between 5 and 20 percent organic solvents for wetting, viscosity control, and pigment dispersion. Coalescing solvents allow the particles of resin to fuse together as the water evaporates to form a continuous coating. A wide variety of waterborne coatings are commercially available such as emulsions (latex), colloidal dispersions, or solutions. Many of these coatings have performance characteristics similar to the more traditional organic solvent-based coatings and can be applied using a variety of proven methods.

VOC Content

Waterborne coatings may still contain organic solvents, with typical ranges between 5 percent and 20 percent.

HAP Content

The HAPs content tends to be lower due to reduced concentrations of solvents. Concentrations of metals and other HAPs are specific to the coating.

Benefits

Waterborne coatings tend to have these benefits when compared to conventional coatings:

- VOC and HAPs emissions are significantly reduced.
- A wide variety of coatings are available.
- Waterborne paints are generally easier to apply and clean up.
- Waterborne coatings tend to display good to excellent surface properties including gloss, rub resistance, anti-sealing effect, and non-yellowing film.
- The overspray from some waterborne paints can be recovered and recycled, effectively increasing transfer.
- Waste disposal requirements for waterborne paint waste are less restrictive. Depending on local requirements and/or waste quantities, dried waterborne paint waste may be sent to landfills as non-hazardous waste.
- Health and safety requirements for workers are significantly reduced or eliminated due to the reduced presence of solvents in the workplace.

Limitations

There are certain limitations that are common to waterborne coatings:

- Some waterborne coatings have a shorter shelf life, depending on the coating's composition.
- Waterborne coatings can react with other materials (e.g. cause steel to rust).
- Waterborne coatings can have a lower chemical and solvent resistance than solvent borne coatings.
- These coatings tend to be more sensitive to temperature.
- Humidity controls may be needed because waterborne coatings are sensitive to humidity; low humidity can cause coatings to dry extremely fast, creating craters in the final film, while high humidity can delay dryings, resulting in sagging.
- The quality of the application is dependent on surface cleanliness; the water's high surface tension prevents the wetting of some surfaces and causes poor coating flow characteristics. Surfaces with grease and other contaminants are especially a problem.

- Emulsion coatings have poor penetration and adhesion properties on porous surfaces, e.g. wood. This prevents good adhesions to old, chalky surfaces.
- Lower abrasive resistance may translate into more frequent painting cycles.

Applications

Existing coating delivery systems can usually be adapted to handle waterborne coatings. Waterborne coatings can be applied using a variety of methods, including air or airless spraying, auto deposition, curtain coating, electrostatic spraying, flow coating, or fluidized bed. When using waterborne paints, the application system must be electrically isolated from the factory structure, not just grounded.

Economics

In general, the price of waterborne paints is comparable to the price of solvent-based paints. Solvent-based paint systems can usually be converted to waterborne paint systems with a limited capital investment. However, if it is found that painting is required more frequently the life cycle costs may be greater.

Examples

- MIL-P-85582 is a Waterborne Epoxy Primer Coating that is corrosion inhibitive, and chemical and solvent resistant. Formulated primarily for spray application, these primers are compatible with polyurethane and epoxy topcoats. The maximum VOC content of the admixed primer coating is 340 g/L. The product is available in two types and classes:
    - Type 1 = Standard pigments
    - Type 2 = Low infrared reflective pigments
    - Class C1 = Barium chromate based corrosion inhibitors
    - Class C2 = Strontium chromate based corrosion inhibitors
- The Air Force currently uses a latex paint to paint the interiors of its KC-135. Only the floors and removable parts are painted with other materials. Floors are painted with epoxy paint and removable parts are still painted with a solvent-based polyurethane paint. Diluted liquid paint waste is treated in the wastewater treatment plant and solid paint waste is fed to the base's waste-to-energy plant.

3.4 Touch-Up Painting	Ozone NAAQS (measured in VOCs and NO_x) Aerospace Manufacturing and Rework Facilities NESHAP

P2 Option: Disposable Paint Applicator Pen *SEMPEN PEN™*

Success: Touch up painting of aircraft has been successful using a disposable pen. This touch up kit is designed for the storage, mixing and application of touch-up paints. It holds a small quantity of two-component material (base and curing agent). The attached brush is used to dispense and apply paint in areas up to 2 square feet. It eliminates airborne concentrations of toxic compounds caused by spray atomization.

P2 Option: Reusable Spray Cans

Success: Use of solvent based paint results in VOC emissions. When using spray cans there may be an additional ODS or VOC used as the propellant. Use of reusable spray cans may reduce the emissions of VOCs, EPA-17 chemicals, and ODSs by using air as the propellant. Use of reusable spray cans also eliminates the waste of empty spray cans.

Issue: The Aerospace NESHAP carries a surprising disincentive to using reusable, refillable spray cans. While disposable spray cans are exempt from the rule, reusable ones are not.

P2 Option: Plural Component Dispensing of Aircraft Primer

Success: Aircraft rework typically involves the substantial use of primer for touch-up applications. To minimize the waste from touch-up operations, a contractor has significantly reduced the quantity of primer used in touch-up operations and the resulting waste stream and air emissions. The system proportionally mixes and dispenses a small quantity (1-ounce) of primer on demand. The primer is dispensed into a small container and used shortly thereafter. This allows the individual to mix only the quantity of primer required.

### 3.5 General Painting	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP

P2 Option: Latex Painting of Vehicles

Success: Latex paints (water-based paints) have been successfully used on unique vehicles such as LARKs and (non-combat) HMMWVs . They have been having some problems with the aesthetics of the applications, however. They have also been using latex orange base paint on target boats, i.e. tow drones.

### 3.6 Architectural Coatings	Architectural Coating NSPS Ozone NAAQS (measured in VOCs and NO_x)

P2 Option: Latex paints.

Success: Latex paints have been successfully used as architectural coatings. Painters prefer using latex because clean up is a lot easier with water. This eliminates the need for and emissions from paint thinner. Unless they have to specifically use an oil-based paint for sealing or matching, from a performance standpoint Latex is the best choice.

### 3.7 Cadmium Plating	Cadmium Compounds HAP

P2 Option: Ion Vapor Deposition

Success: Aluminum Ion Vapor Deposition on aircraft parts is used within a vacuum chamber to plate parts instead of plating with cadmium. This has had significant paybacks during stripping as cadmium is not emitted during blasting of aircraft parts.

3.8 Chromic Acid Anodizing

Chromium Compounds HAP

Research: Thin Film Sulfuric Acid Anodizing (TFSAA)

A contractor has identified and partially qualified an alternate anodizing process that does not use EPA 17 chemicals. The process is Thin Film Sulfuric Acid Anodizing (TFSAA). The Air Force is funding the construction of a pilot scale TFSAA line.

3.9 Chromate Conversion Coating

Chromium Compounds HAP

Research: Metasilicate and Organofunctional Silane Substitute for CCC

A contractor developed a nonchromated surface treatment process for aluminum that greatly enhances the adhesion of applied paints and coatings. The process consists of a metasilicate and organofunctional silane that provides a covalent chemical bond with the paint or coating. An evaluation for NASA (Space Shuttle) determined this process to be equivalent to unpainted chromate chemical conversion coating (CCC) in corrosion resistance. This process still needs military qualification. The pretreatment process is a two-step process that is applicable to immersion applications and, potentially, spray applications.

3.10 Hard Chrome Plating

Chromium Compounds HAP

Research: Hard Chromium Plating Options

The Air Force directed a contractor to research viable alternatives to two surface-finishing processes that use hexavalent chromium. The resulting research identified alternative processes or material substitutions involving less use and fewer emissions of chromium. The two processes were hard chrome plating of steel and chromate conversion coating of aluminum. Each process was addressed in a separate report. The hard chromium plating report presents the results of the engineering study conducted by an Air Force contractor.

3.11 Coating Technology

Background: Powder Coatings

Powder Coating is the application of finely ground plastic powders by electrostatic means followed by curing to melt and fuse the powder into a continuous coating. It provides a durable, corrosion resistant surface and emits no VOCs and HAPs. Powder coats can be either thermosetting powders or thermoplastic powders. Thermosetting powders melt and flow to coat the substrate and then cross-link with other particles in the powder formulation to form high molecular weight polymers. Examples include acrylic, epoxy/polyester hybrid, functional epoxy, thin film epoxy, and urethane polyester. Because thermoplastic powders do not undergo chemical change, cured thermoplastic coatings will melt when heated. Examples include cellulose ester, polyamides (such as Nylon-11) polyester, and polyvinyl chloride (PVC).

P2 Option: Powder Coatings

Success: Powder coatings are being developed for use on Ground Support Equipment (GSE). They expect to have a tougher, more durable finish on the GSE and the operations will not need air permits. The facility is currently being built and results from tests under a Navy program are expected in the first half of 1998.

Success: Navy torpedoes are operationally tested on a range after which they are disassembled, refurbished, and then reassembled. As part of the refurbishment process, external torpedo components must be stripped and repainted. A Navy facility implemented P2 beginning in 1989. P2 evolved from air spray of lead based paint to powder coatings of plastic epoxy. The results of implementing powder coatings are reduced air emissions and liability, increased worker and efficiency, and a better quality coating. VOCs decreased by approximately 260 tons from about 270 tons in 1991 to about 10 tons in 1995.

VOC Content

The VOC content from powder coatings is always less than 10 percent.

HAP Content

The HAP content is considerably reduced due to the lack of solvent in the coatings. The presence of any HAPs in the coating is dependent upon the specific formulation of the coating.

Benefits

There are a number of advantages to using powder coats in lieu of conventional coatings:

- Powder coatings are very durable and corrosion resistant.
- There are no problems with running, sagging, and bubbles.
- An air permit is not required; powder coating is a clean technology, virtually without air emissions.
- Transfer efficiencies are nearly 100 percent and any overspray can be recycled for reuse.
- Worker health and safety conditions are improved, leading to increased productivity.
- There is no liquid mixing or pumping, or need for liquid viscosity monitoring.
- Reduced use of hazardous materials in paint; however, there may be environmental issues associated with pretreatment (surface preparation).
- May be used to coat a variety of substrates, including aluminum and steel.

Limitations

Discussed below are some of the limitations to using powder coatings instead of conventional solvent-based coatings:

- Coatings cannot be <1 mil thickness.
- A uniform film thickness is difficult to maintain.
- Coatings are subject to powder handing (e.g., changing colors during the process).
- Surfaces must be totally clean and dry before powder is applied. No cleansing action is available as the coating is applied to the part because powder contains no organic solvents.
- Powder coating may not be practical for repainting vehicles, aircraft, and ships because curing requires elevated temperatures.
- Cured thermoplastic coatings may soften when heated but will not melt.
- The system must be reconfigured for each application.

Applications

At this time, powder coating is generally limited to small parts. The coating thickness can range from 1.5 to 60 mils.

Economics

Key economic considerations when evaluating powder coating as an alternative to conventional coating systems include:

- Capital cost for equipment and the cost of some powders are comparatively expensive.
- Costs for labor, energy, and environmental and safety compliance are lower.

Research

- The Air Force Advanced Aircraft Coating Program is investigating powder coating for large parts. Tasks are being undertaken to develop, optimize and produce powders that will provide the desired improvements in coating systems, improve aircraft coating performance and increase environmental acceptability. An Air Force laboratory has programs designed to develop environmentally compliant paint systems, such as: high performance aerospace coatings; advanced aircraft paint systems; low temperature plasma coatings and surface treatment; zero VOC coatings; large area powder coatings; durable, cleanable coatings; and high velocity thermal spray coatings.
- An Air Force base recently installed a prototype epoxy powder coating system. They will begin using this process in the near future.

- The Army has been developing a Powder Coating Technology for Small Arms Bullet Tip Identification. The dry paint is applied using a spray or fluidized bed after the projectile surface has been heated to between 250° and 350°F. In addition to coating projectiles, this technology may be applicable to commercial small caliber, cannon caliber, and large caliber ammunition.
- A contractor has reportedly developed a powder coat "torpedo paint" that may meet all required characteristics. Questions remain regarding depainting.
- A DoD demonstration/training center for E-coat and powder coat technologies is researching feasibility testing, process optimization, and process validation. It will provide system design, installation and start-up support, training, and follow-up support as needed. A second task focuses on demonstrating the applicability and technical and economic feasibility of powder coating for small businesses.

Background: Low VOC, High-Solids Coatings

High-solids coatings and primers contain higher concentrations (40 to nearly 100 percent) of non-volatiles than conventional paints (which typically contain 8-30 percent solids). Because these formulations use low-molecular weight resins, they require less solvent to attain the viscosity needed for the application. The resins have highly reactive sites to promote polymerization. High solids coatings may be one or two component systems based on acrylic, alkyd, epoxy, polyester, or urethane resins and can be cured at ambient air or in high temperature bake ovens.

VOC Content

The VOC content of high-solids coatings is lower than conventional coatings. VOC concentrations typically range between 0 percent and 60 percent, depending on the coating formulation.

HAP Content

The emission of HAPs from the application of high solids coatings tends to be less than with conventional coatings due to reduced concentrations of solvent. Emissions of other HAPs such as isocyanates and chromates are dependent on the specific coating formulation.

Benefits

In general, high-solids coatings have certain advantages over conventional coatings:

- VOC emissions are significantly reduced.
- Coatings can often be applied using existing equipment.
- Less paint is needed to achieve desired film thickness.
- Curing can take place at both ambient temperatures or in high-energy bake ovens.

Limitations

High-solids coatings tend to have the following limitations:

- To ensure paint adhesion the surface must be especially clean of oils, greases, and other surface contaminants that would otherwise be dissolved in solvents.
- These coatings may be difficult to atomize; special equipment may be required for some coatings, particularly those approaching 100 percent solids.
- May be necessary to heat paint to maintain a workable paint consistency.
- Color matching may be difficult because of difficulty to blend.
- Cleanup may be more difficult.
- Pressure may have to be increased in spray applications or 2-component formulations and plural component equipment that meters and mixes the materials at the spray gun.

Examples

Some of the high-solids coatings that are listed on the Qualified Products List include:

- MIL-C-85285 High Solids Content Polyurethane Coatings (Type I for aircraft and Type II for ground equipment) are an alternative to MIL-C-22750 and MIL-C-83286. QPL-85285-6 provides more than 28 products that meet the performance specifications.
- MIL-C-4168 Type IV: This Chemical Agent Resistant Polyurethane Coating (CARC) is an alternative to MIL-C-4618 Type II coatings. Type IV coatings are formulated to meet the South Coast Air Quality Management District VOC requirements. QPL-46168-6 lists at least 55 Type IV coatings with 13 colors listed.
- MIL-P-553022B Type II. This Lead- and Chromate-Free Corrosion Inhibiting Primer is an alternative to MIL-P-23377. QPL-53022-11 lists at least 12 primers that meet the performance specifications.

Background: Self-Priming Topcoat

UNICOAT is a one coat painting system for aircraft that replaces the traditional two coat primer and topcoat systems. It has been successfully demonstrated on both Air Force and Navy Aircraft and has been issued a Federal specification, TT-P-2756. Originally developed at a Navy center in 1990, UNICOAT provides the adhesion and corrosion resistance of a primer and the chemical resistance, durability, and flexibility of the original topcoat. UNICOAT is lead-free and chromate-free and is a blend of non-toxic organic and inorganic zinc compounds. UNICOAT is a polyurethane with corrosion inhibitors and adhesion promoters added to the formula.

VOC Content

UNICOAT is VOC compliant with VOC levels of $\leq$420 g/L. By eliminating the need to spray a separate coat of primer, the coating system reduces emissions of VOCs.

HAP Content

Most UNICOAT contains no toxic pigments (i.e. chromate, lead, etc.); however some free isocyanates may be released during mixing and spraying.

Benefits

UNICOAT offers certain advantages over the conventional 2-step primer/coating systems:

- VOC emissions and hazardous waste generation are reduced by 50 - 70%.
- The paint weight is reduced, increasing aircraft fuel efficiency.
- Because UNICOAT is a one coat painting system, it requires less operator-time to apply.
- The Navy reports that UNICOAT:
    - Exhibits good durability and cleanability.
    - Reduces the amount of corrosion control maintenance required.
    - Cleans more easily than MIL-C-85285.

Limitations

There are some cases where UNICOAT is not as good as traditional primer coating systems:

- An Air Force laboratory reports that corrosion protection may not be comparable to two coat coatings.
- A Naval facility reports that UNICOAT may fail the pot test.
- An Air Force base reports substandard corrosion protection on aluminum and magnesium substrates, inadequate adhesion when applied directly to leading edge tape, and insufficient Skydol resistance on K-10 aircraft.
- There have been complaints by rework facilities that adhesion to the metal surface is poor. To alleviate this problem, the rework facilities use an epoxy primer (chromated) under the UNICOAT. Obviously, this defeats the purpose of combining the primer and topcoat into a single system.
- Frequent color changes are not practical.

Applications

UNICOAT is best used as an overcoat on flat coatings and may not be suitable for all coating operations because of high viscosity of formulations. It can be applied directly to metal including aluminum substrates. UNICOAT is already being used at several military installations.

Economics

Costs will vary depending on the specific application. In general, however, savings will be realized due to:

- Fewer gallons of coating purchased.
- Less painting time because only one coat is applied.
- Reduced costs associated with stripping.

Examples

A Federal specification, TT-P-2756: Low VOC Self-Priming Polyurethane Topcoat, has been developed for this technology. This material is intended for use on aircraft, weapons systems, and other applications that require protection for aluminum, steel, magnesium, or polymeric substrates. The GSA offers UNICOAT in full gloss, semi-gloss and flat finishes in more than 30 colors. All coatings are chromate- and lead-free and are low-VOC.

Table 3.11.1. UNICOAT Substitutes for MIL-C-83286

8010 - NIIN Substitute	Item Description	Color	8010 - NIIN	VOC	Chromium compounds
-01-068-3116	Self-Priming Polyurethane	16440	-01-340-7061	420 g/L	0
-01-011-2649	Self-Priming Polyurethane	36320	-01-340-8716	420 g/L	0
-01-017-2480	Self-Priming Polyurethane	36375	-01-340-8717	420 g/L	0
-01-084-6963	Self-Priming Polyurethane	36081	-01-341-0795	420 g/L	0
-00-181-8281	Self-Priming Polyurethane	17925	-01-343-1395	420 g/L	0
-00-181-8254	Self-Priming Polyurethane	16473	-01-344-3220	420 g/L	0
-01-023-4261	Self-Priming Polyurethane	24052	-01-344-3221	420 g/L	0
-01-100-9094	Self-Priming Polyurethane	36118	-01-344-3222	420 g/L	0
-01-117-7692	Self-Priming Polyurethane	36440	-01-353-3694	420 g/L	0
-00-181-8292	Self-Priming Polyurethane	13538	-01-353-3696	420 g/L	0
-00-482-5649	Self-Priming Polyurethane	11136	-01-353-3697	420 g/L	0
-00-181-8283	Self-Priming Polyurethane	15044	-01-353-4950	420 g/L	0
-00-181-8277	Self-Priming Polyurethane	17038	-01-353-4952	420 g/L	0
-00-181-8296	Self-Priming Polyurethane	12197	-01-353-4953	420 g/L	0
-01-068-3115	Self-Priming Polyurethane	16440	-01-354-0959	420 g/L	0
-00-482-5671	Self-Priming Polyurethane	37038	-01-354-0960	420 g/L	0
-01-104-6522	Self-Priming Polyurethane	36375	-01-354-0964	420 g/L	0
-01-122-2134	Self-Priming Polyurethane	36081	-01-354-0965	420 g/L	0
-00-181-8282	Self-Priming Polyurethane	17925	-01-354-0966	420 g/L	0
-00-181-8255	Self-Priming Polyurethane	16473	-01-354-0967	420 g/L	0
-01-023-4260	Self-Priming Polyurethane	24052	-01-354-0968	420 g/L	0
-01-104-6526	Self-Priming Polyurethane	36118	-01-354-0969	420 g/L	0
-01-078-9278	Self-Priming Polyurethane	36440	-01-354-0974	420 g/L	0
-00-181-8287	Self-Priming Polyurethane	13538	-01-354-0976	420 g/L	0
-00-482-5651	Self-Priming Polyurethane	11136	-01-354-0977	420 g/L	0
-00-181-8284	Self-Priming Polyurethane	15044	-01-354-0979	420 g/L	0
-00-181-8276	Self-Priming Polyurethane	17038	-01-354-0981	420 g/L	0
-00-181-8294	Self-Priming Polyurethane	12197	-01-354-0982	420 g/L	0

The preceding table identifies UNICOAT substitutes for MIL-C- 83286 that are VOC compliant and do not contain chromium.

The following tables (Tables 3.11.2 through 3.11.4) are from the Qualified Products List as of 2 September 1997 of self-priming polyurethane coatings that are VOC compliant and do not contain chromium or lead.

Table 3.11.2. Coatings that Dry to a Full Gloss Finish

Red 11136	8010-01-354-0977 KT (2 QT)
Red 11136	8010-01-353-3697 KT (2 GL)
Red 11350	8010-01-358-3421 KT (2 QT)
Red 11350	8010-01-358-3422 KT (2 GL)
Orange 12160	8010-01-358-3424 KT (2 QT)
Orange 12160	8010-01-358-3425 KT (2 GL)
Intl Orange 12197	8010-01-354-0982 KT (2 QT)
Intl Orange 12197	8010-01-353-4953 KT (2 GL)
Orange-Yellow 13538	8010-01-354-0976 KT (2 QT)
Orange-Yellow 13538	8010-01-353-3696 KT (2 GL)
Yellow 13655	8010-01-358-3426 KT (2 QT)
Yellow 13655	8010-01-358-3427 KT (2 GL)
Yellow 13670	8010-01-357-4754 KT (2 QT)
Yellow 13670	8010-01-357-4755 KT (2 GL)
Green 14052	8010-01-362-3200 KT (2 QT)
Green 14052	8010-01-362-3201 KT (2 GL)
Green 14187	8010-01-354-0978 KT (2 QT)
Green 14187	8010-01-353-4949 KT (2 GL)
Blue 15044	8010-01-354-0979 KT (2 QT)
Blue 15044	8010-01-353-4950 KT (2 GL)
Blue 15045	8010-01-357-4752 KT (2 QT)
Blue 15045	8010-01-357-4753 KT (2 GL)
Blue 15180	8010-01-354-0980 KT (2 QT)
Blue 15180	8010-01-353-4951 KT (2 GL)
Blue 15182	8010-01-358-4330 KT (2 QT)
Blue 15182	8010-01-358-3420 KT (2 GL)
Blue 15200	8010-01-354-0971 KT (2 QT)
Blue 15200	8010-01-353-4948 KT (2 GL)
Gray 16251	8010-01-358-3423 KT (2 QT)
Gray 16251	8010-01-358-4331 KT (2 GL)
Gray 16440	8010-01-354-0959 KT (2 QT)
Gray 16440	8010-01-340-7061 KT (2 GL)
Gray 16473	8010-01-354-0967 KT (2 QT)
Gray 16473	8010-01-344-3220 KT (2 GL)
Black 17038	8010-01-354-0981 KT (2 QT)
Black 17038	8010-01-353-4952 KT (2 GL)
White 17925	8010-01-354-0966 KT (2 QT)
White 17925	8010-01-343-1395 KT (2 GL)

Table 3.11.3. Coatings that Dry to a Semi-gloss Finish

Green 24052	8010-01-354-0968 KT (2 QT)
Green 24052	8010-01-344-3221 KT (2 GL)
Green 24064	8010-01-358-3418 KT (2 QT)
Green 24064	8010-01-358-3419 KT (2 GL)
Gray 26231	8010-01-354-0972 KT (2 QT)
Gray 26231	8010-01-353-5756 KT (2 GL)
Haze Gray 26270	8010-01-358-5229 KT (2 QT)
Haze Gray 26270	8010-01-358-5228 KT (2 GL)

Table 3.11.4. Coatings that Dry to a Flat Finish

Brown 30140	8010-01-376-3702 KT (2 QT)
Brown 30140	8010-01-376-3703 KT (2 GL)
Brown 30219	8010-01-376-3708 KT (2 QT)
Brown 30219	8010-01-376-3709 KT (2 GL)
Brown 30279	8010-01-376-3710 KT (2 QT)
Brown 30279	8010-01-376-3711 KT (2 GL)
Tan 30318	8010-01-380-3278 KT (2 QT)
Tan 30318	8010-01-380-3239 KT (2 GL)
Tan 30475	8010-01-376-3704 KT (2 QT)
Tan 30475	8010-01-376-3705 KT (2 GL)
Tan 31667	8010-01-375-4546 KT (2 QT)
Tan 31667	8010-01-375-4547 KT (2 GL)
Peach 31670	8010-01-375-4548 KT (2 QT)
Peach 31670	8010-01-375-5178 KT (2 GL)
Buff 32630	8010-01-375-4549 KT (2 QT)
Buff 32630	8010-01-375-4550 KT (2 GL)
Buff 32648	8010-01-375-4551 KT (2 QT)
Buff 32648	8010-01-375-5179 KT (2 GL)
Tan 33578	8010-01-375-4552 KT (2 QT)
Tan 33578	8010-01-375-4553 KT (2 GL)
Tan 33613	8010-01-375-4554 KT (2 QT)
Tan 33613	8010-01-375-4555 KT (2 GL)
Tan 33711	8010-01-375-4556 KT (2 QT)
Tan 33711	8010-01-375-4557 KT (2 GL)
Tan 33717	8010-01-375-4558 KT (2 QT)
Tan 33717	8010-01-375-4559 KT (2 GL)
Green 34086	8010-01-354-0970 KT (2 QT)
Green 34086	8010-01-345-6534 KT (2 GL)
Field Green 34095	8010-01-354-0962 KT (2 QT)
Field Green 34095	8010-01-340-8715 KT (2 GL)
Green 34097	8010-01-354-0973 KT (2 QT)
Green 34097	8010-01-353-3693 KT (2 GL)
Blue 35109	8010-01-376-3706 KT (2 QT)
Blue 35109	8010-01-376-3707 KT (2 GL)
Blue Gray 35164	8010-01-375-4560 KT (2 QT)
Blue Gray 35164	8010-01-375-5180 KT (2 GL)
Blue 35190	8010-01-376-3700 KT (2 QT)
Blue 35190	8010-01-376-3701 KT (2 GL)
Blue Gray 35237	8010-01-354-0961 KT (2 QT)
Blue Gray 35237	8010-01-340-8714 KT (2 GL)
Blue 35450	8010-01-423-3635 KT (2 QT)
Blue 35450	8010-01-423-3638 KT (2 GL)
Gray 36081	8010-01-354-0965 KT (2 QT)
Gray 36081	8010-01-341-0795 KT (2 GL)
Gray 36118	8010-01-354-0969 KT (2 QT)
Gray 36118	8010-01-344-3222 KT (2 GL)
Gray 36173	8010-01-354-0983 KT (2 QT)
Gray 36173	8010-01-353-4947 KT (2 GL)
Gray 36231	8010-01-372-3960 KT (2 QT)

Gray 36231	8010-01-368-8515 KT (2 GL)
Gray 36251	8010-01-374-3392 KT (2 QT)
Gray 36251	8010-01-374-3393 KT (2 GL)
Gray 36307	8010-01-374-3395 KT (2 QT)
Gray 36307	8010-01-374-3394 KT (2 GL)
Gray 36320	8010-01-354-0963 KT (2 QT)
Gray 36320	8010-01-340-8716 KT (2 GL)
Gray 36375	8010-01-354-0964 KT (2 QT)
Gray 36375	8010-01-340-8717 KT (2 GL)
Gray 36440	8010-01-354-0974 KT (2 QT)
Gray 36440	8010-01-353-3694 KT (2 GL)
Gray 36495	8010-01-354-0975 KT (2 QT)
Gray 36495	8010-01-353-3695 KT (2 GL)
Gray 36555	8010-01-380-3268 KT (2 QT)
Gray 36555	8010-01-380-3281 KT (2 GL)
Black 37038	8010-01-354-0960 KT (2 QT)
Black 37038	8010-01-340-8713 KT (2 GL)
Beige 37855	8010-01-375-4544 KT (2 QT)
Beige 37855	8010-01-375-4545 KT (2 GL)

Background: Radiation Curable Coatings

Radiation-Curable Coatings are formulated to cure quickly by exposure to ultraviolet (UV), electron beam (EB), infrared (IR), or microwave radiation. Radiation-Curable Coatings have a higher solids content and consist of a low-molecular weight olefin resin (with carbon-carbon double bonds), a reactive solvent containing unsaturated groups, and a photointiator. Radiation-Curable Coatings are usually clear, but can be pigmented and tend to exhibit good resistance to abrasion, heat staining, and weathering.

VOC Content

Recently VOC compliant radiation curable coatings have been developed with VOC contents as low as 360 g/L.

HAP Content

The HAP content of these coatings is dependent on the composition of the specific coating. Some monomer emissions may be in the exhaust. In most cases, however, the HAP content should be less than that found in conventional coatings.

Benefits

- Production rates tend to be higher because the coated items cure faster than other methods.
- Radiation Ovens require 50-75 percent less floor space than conventional curing ovens.

Limitations

- Certain parts cannot be coated because of their shape and geometry.
- Coatings must be blanketed by an inert gas to prevent tacky surface (air retards polymerization).

- Vapors from the coatings are an eye and skin irritant.
- Some radiation curable coatings are oncogenic or carcinogenic.

Applications

- These coatings can be applied using air or airless spraying, autodeposition, curtain coating, electrostatic spraying, flow coating, or roller/coil coating.
- Radiation curable coatings can be used on weather-sensitive substrates.

Economics

- These coatings tend to have high capital costs, but low energy costs when compared to thermally cured coatings. Production rates tend to be higher because of the decreased time needed for curing.

Background: Supercritical CO_2 Spraying

Supercritical CO_2 Spraying is a paint spraying process that substitutes supercritical (above its critical temperature and pressure) carbon dioxide (CO_2) for as much as 80 percent of the solvents that are used in other coating formulations. Supercritical CO_2 reduces paint viscosity and produces a vigorous atomization and a quality finish. The technology is commercially available.

VOC Content

VOC content and emissions may be reduced up to 80 percent.

HAP Content

Emissions of HAPs may be reduced up to 90 percent.

Benefits

- Existing spray equipment may be retrofitted in some cases.
- Transfer efficiencies approach 60 percent, reducing the amount of coating used and emission rates.
- This technology can produce a higher quality finish than other applications.
- Because less solvent is present, fire/explosion hazards are reduced.
- Because most of the remaining solvents in the coatings are slower evaporating, solvent that evaporates in a bake line or curing oven can be recovered or incinerated.

Limitations

- The availability of coatings is limited: conventional coatings need to be reformulated.
- Frequent color changes are not practical.

Applications

This technology is especially applicable where a high quality finish is needed.

Economics

- Capital costs are higher.
- Expenditures on coatings may be reduced because the unit cost of coatings may be lower, and the transfer efficiencies tend to be slightly higher.

Background: Non-Chromated Primers

Many companies have committed substantial resources to the development of nonchromated primers. Several contractors have formulated nonchromated primers that are currently under evaluation at a naval facility. At this time, however, only one company has a qualified a mil-spec non-chrome primer. Another contractor has developed a nonchromated primer that was originally intended for composite surfaces contacting with metal. This primer (DLP-131) is a solvent based, high solids primer and was tested in accordance with MIL-P-23377G. Scale-up efforts will be complete during the 2nd Quarter 1996. Because of the excellent corrosion resistance achieved with this primer (3000 hour salt spray resistance), it is being considered as a candidate for qualification under MIL-P-23377.

MIL-P-23377 Class N: This primer is corrosion inhibitive, chemical resistive, and able to be stripped. Class 2 versions of both Type I (standard pigment) and Type II (low infrared reflective pigment) primers do not contain chromium. Two contractors produce this type of primer.

MIL-P-53030: This water reducible epoxy primer is intended for use on ferrous and non-ferrous substrates. It is a lead- and chromate-free primer that may be used to replace MIL-P-52192 and MIL-P-23377 in some cases. The Army has replaced use of MIL-P-23377 with MIL-P-53030 in many applications. The primer is compatible with chemical agent resistant and other aliphatic polyurethane topcoats. The primer contains no more than 340 grams per liter (2.8 pounds per gallon) of volatile organic compounds (VOC). The primer described in this specification is intended for use on clean, chemically pretreated metal surfaces. It is compatible with MIL-C-46168, MIL-C-83286, MIL-C-85285 and MIL-C22750 topcoats.

The Air Force Advanced Aircraft Coating Program's work on advanced corrosion resistant aircraft coatings includes qualifying a near-term coating system that will meet Aerospace NESHAP requirements and a long-term, totally "green" system. The near-term system includes non-chromated conversion coatings, non-chromated and low VOC primers and topcoats. The long-term solution will utilize sol-gel, a ceramic technology, to replace conversion coatings and interface coatings, and low VOC, non-isocyanate topcoats. This project is targeted toward tanker/transport coatings systems but the technologies will be applicable to all conventional (non-Low Observable) aircraft. The C/KC-135 aircraft has been selected as a test-bed.

An Air Force laboratory is working on qualifying non-chromated primers for use during scuff sanding and over-coating of aircraft (i.e., the aircraft is repainted without stripping to bare metal).

Research: Ceramic Based Coating

CERAM-KOTE 54 is a multi-use, single coat, spray applied, air-dried, flexible, self-priming, ceramic-based coating that was applied on several Air National Guard aircraft with favorable results. It was also applied on the following:

- F-4 Phantom nose cone
- F-15 Eagle leading wing edges, vertical and horizontal stabilizers, and jet intakes
- B-1 Bomber leading edges including slats
- F-16 leading edges, horizontal and vertical stabilizers
- Jet engine lips

Benefits

An Air Force laboratory engineers tested the product on a Whirley Arm Tester at an Air Force base. The standard polyurethane coating lasted only eight minutes while CERAM-KOTE 54 lasted 15 minutes.

Limitations

CERAM-KOTE has two noted drawbacks. It is not covered by a military specification, and it is reported to be difficult to remove. While the proponents of CERAM-KOTE question the need to remove the material, some Air Force units want to be able to strip an aircraft's leading edge down to bare metal. Concerns also exist about colorfastness and infrared invisibility of the material.

The Navy has conducted some IR tests on the material.

Research: Non-Chromate Primers on Aircraft

An Air Force base recently tested non-chromate surface conversion coatings as replacements for alodine, which contains large amounts of chromate. As chromate is being phased out of the aircraft painting process, X-IT Prekote, and SOL GEL Primer were tested as potential replacements for alodine. These new surface conversion coatings are chromate free and non-hazardous. They have the potential to change a large and costly waste stream from hazardous to non-hazardous.

The new surface conversion coatings were applied to two T-38A and two T-37B aircraft. All tests were conducted by Flying Training Wing (FTW) personnel under the supervision of the manufacturers. The X-IT worked very well and is going to be advanced for testing on three more aircraft (T-38s). If those tests are successful it may be approved. SOL GEL Primer did not work as it caused problems with adhesion and magnesium coating. It was dropped from further testing.

A non-chromated formulation of MIL-P-85582 by a contractor has been approved. Field-testing is in progress. Other formulations are under evaluation by the Navy.

Research: Metasilicate and Organofunctional Silane Substitute for CCC

A contractor developed a nonchromated surface treatment process for aluminum that greatly enhances the adhesion of applied paints and coatings. The process consists of a metasilicate and organofunctional silane that provides a covalent chemical bond with the paint or coating. An evaluation for NASA (Space Shuttle) determined this process to be equivalent to unpainted chromate chemical conversion coating (CCC) in corrosion resistance. This process still needs military qualification. The pretreatment process is a two-step process that is applicable to immersion applications and, potentially, spray applications.

Research: *Vapor Deposition*

Vapor Deposition is a group of technologies that is used in decorative coating, tool coating and other equipment coating applications. It is fundamentally an evaporative process where there is an atom-by-atom transfer from the solid phase to the vapor phase and back to the solid phase with a gradual build-up of a film on the surface to be coated. It is mainly considered an alternative to electroplating, but may have some painting applications as well. An Army laboratory is investigating ion vapor deposition (IVD), also known as ion vapor plating.

The laboratory is continuing research by using ion vapor deposition to coat anodes in cathodic protection systems and gaskets in communication shelters. It holds the patent for "Mixed Metal Oxide Coated Substrates".

VOC Content

There are essentially no VOC emissions associated with this process because the process is conducted in a vacuum.

HAP Content

No HAPs are emitted by IVD.

Benefits of IVD

- Can be used with virtually any type of coating
- Can be applied to most metals and some plastics
- Coatings are typically soft, ductile, adherent, and corrosion resistant
- Generates limited quantities of non-hazardous waste

Limitations of IVD

- Limited to small parts applications
- Cannot be used where fine tolerances are required or there is a small diameter opening
- Requires a cooling water system
- Typically does not work well where lubrication occurs (e.g., on fasteners)

Applications

Vapor deposition technologies can be used on most metals and some plastics.

Economics

The capital costs of this option are high (as much as $500,000 or more).

Research: Appliqués

Through the Joint Strike Fighter (JSF) Paintless Airplane Program (JPAP), private contractors have been demonstrating feasibility of replacing paint with appliqués, an adhesive sheet.

Extensive material testing and a series of flight test were performed prior to full-coverage application of an F/A-18B supersonic aircraft at a naval center. The JPAP's will be quantifying the reduction in aircraft support costs associated with appliqués by estimating the total life-cycle costs for fleet use of appliqués and comparing them to paint. Other JPAP objectives include demonstrating the suitability of appliqués for maritime and carrier environments, and for supersonic aircraft.

To accomplish these objectives, the private contractors have conducted materials, environmental, wind tunnel and flight tests. The flight tests were broken into a series of progressively more difficult demonstrations beginning with a small patch of appliqués placed on the surfaces of a chase plane. In September 1996, most surfaces of another plane were covered with an appliqué, and in October a one-year flight test began. Material flight-qualification testing and chase plane flight tests were conducted, along with development of application, cutting and removal techniques.

VOC Content

There are no volatile emissions.

HAP Content

There are no HAP emissions.

Benefits

Appliqués have the following benefits in addition to zero emissions:

- There would be no need for stripping and repainting of aircraft.
- Hazardous waste generation would decrease significantly.
- Because old appliqués are peeled off, there will be no “weight growth”.
- Appliqués can be applied concurrently with other maintenance operations.

Limitations

Listed below are some of the current limitations with appliqués that need to be addressed:

- A chromate primer is still needed to prevent corrosion.
- Appliqués are difficult to apply to panel edges and fasteners.
- Improvements are needed in linking the adhesive to the film.
- It is suspected that chromates in the primer may leach into the appliqué.

Applications

While this technology is promising, it is still in the research phase, and so not yet ready for the field.

Economics

This technology has the potential to cut maintenance and environmental costs.

Research: Non-Isocyanates Paints

Isocyanates are used as hardeners in polyurethane paint systems. The Air Force, other military services, and commercial aircraft manufacturers use polyurethane paint systems almost exclusively on their aircraft exterior surfaces. These paints are two-part paint systems, in which the isocyanate groups in Part 1 react with the hydroxyl groups in Part 2 to generate a urethane cross-link, which hardens or "cures" the paint.

The advantages of isocyanate based paint systems include rapid curing time, low curing temperature, and excellent abrasion and impact resistance. Unfortunately, isocyanates have both health and environmental hazards, prompting the Air Force Air Logistic Centers (ALCs) to request research resources for the investigation of a replacement for isocyanates in polyurethane paint systems.

Vapors or mists of isocyanates can be generated during paint spraying. Even brief exposure can be irritating to the nose, throat, and lungs. Sensitization may result from excessive exposure. Subsequent exposure to low concentrations has been known to provoke allergic reactions with asthma-type symptoms. Repeated or prolonged skin contact may cause irritation, blistering, dermatitis, or skin sensitization. The Air Force protects Corrosion Control personnel by requiring the use of coveralls, supplied air respirators, and in many cases, mechanical ventilation.

Some isocyanates are also considered environmental hazards. A few have been added to EPA's Aerospace Industry NESHAP list of HAPs. The list now includes hexamethylene 1,6-diisocyanate, methyl isocyanate, methylene diphenyl diisocyanate, and 2,4 toluene diisocyanate.

The potential for exposure to isocyanates is increased when the personal protective equipment (respirators, etc.), engineering controls (paint booths), and administrative controls (prohibiting occupancy of painting areas for hours after painting) are bypassed. These protective controls are not always followed by the painters, or those who work near painting areas.

In recent years, chemical substitution within polyurethane paint systems has been the topic of industrial research. But these efforts have focused on the elimination of chromium, and the reduction of volatile organic compounds (VOCs) in the paint, and not on the elimination of isocyanates. To date, no replacement for isocyanate-containing polyurethane paints has been developed for use in the aerospace industry.

- A private contractor has developed substitutes for polyurethane paints for use in general industry (cycloaliphatic epoxy systems). However, these paints reportedly will not meet the specifications required by the aerospace industry (flexibility tests, etc.). Since present research is focused in other areas the company predicts that the coatings industry will not develop a suitable substitute for isocyanate-containing polyurethane paint for the aerospace industry for at least 10 to 20 years.

- A contractor’s paint research has focused on ridding the paint of metals and VOCs. Isocyanate-substitution is a long-range research issue, with some testing. The contractor is experimenting with one-component polyurethane systems. These systems contain isocyanates that are pre-reacted, which is believed to be less hazardous to workers applying the paints. But the company reports that these systems do not offer the characteristics required by the aerospace industry. They are currently used inside some aircraft, but not on the exterior skin of the aircraft.

- A private contractor specializes in Navy aircraft coatings and materials development. They have an active R&D department that has proprietary coating systems in development that may be applicable to aircraft in five to ten years. The competitive nature of the commercial coatings industry prevents this and most companies from sharing details of the research.

- An Air Force laboratory is conducting research on waterborne polyurethane paints under its High Performance Aerospace Coating System Program. The isocyanates in waterborne (as opposed to the usual solvent-borne) systems are blocked from reacting, which may reduce the exposure potential for workers spraying the paint. This may be a promising alternative to the system currently in use.

- The Air Force's Advanced Aircraft Coating Program and a contractor are working to develop advanced corrosion resistant aircraft coatings for aluminum alloys which are environmentally benign and meet DoD performance demands. The program employs a two-part parallel effort to develop a near-term coating system that will meet Aerospace NESHAP requirements and a long-term, totally "green" system that will include low VOC, non-isocyanate topcoats. It is targeted toward tanker/transport coatings systems but the technologies will be applicable to all conventional (non-Low Observable) aircraft. The C/KC-135 aircraft has been selected as a test-bed.

- Aircraft Film Technology has been studied by the Air Force. Although the film is an isocyanate-containing polyurethane, it is a hand-applied film material, and not sprayed onto the surface of the aircraft. Therefore, the film would have a lower potential for isocyanate exposure to workers. Various types of film are currently used on portions of military aircraft. Examples include polyurethane radome boots on the F-14, F-15, and F-16; polyurethane rotor boots on Army helicopters; and polyurethane leading edge tape. Concerns exist for both the Air Force and the commercial aircraft industry regarding corrosion, adhesion, and resistance to service fluids.

- The Naval Center that investigates the surface coatings used on Navy aircraft, reported that the Navy uses MIL-C 85285 and MIL-C 83286 polyurethane topcoats. The office suggests that a one-component polyurethane system may be used for touch up painting of aircraft.

Research: Zero VOC Coatings

Industry continues to develop lower VOC coatings. A private contractor is currently in the process of field testing a zero VOC polyurethane topcoat. The coating is a two-component polyurethane that utilizes water as a carrier. Typical properties of a zero VOC gloss polyurethane coating include the following:

Table 3.11.5. Typical Properties of Zero VOC Gloss Polyurethane

Property	Specified Value
VOC	Zero
Flash Point	None
Hazardous Air Pollutants	None
Resin Type	Polyester Urethane
Pencil Hardness	2H-3H
Flexibility (Gardner Impact)	60%
20 ° Gloss	87
20 ° Gloss	85
Hy Jet IV Resistance	30 Day F Pencil Hardness
Water Immersion	4 Days @ 37°C
Fluid Resistance	Resistance To Hydraulic Fluids, Lubrication Oils & Fuels
Humidity	30 Days
Freeze Thaw Stability	5 Cycles

Based on the performance properties outlined above, it appears that zero VOC topcoats will offer comparable performance to the polyurethane topcoats currently used for military applications (MIL-C-85285 and MIL-C-83286). However, the application process for this technology may be more sensitive than polyurethane topcoats to environmental conditions. Because the carrier used in these coatings is water, temperature and humidity conditions will have a greater effect on the cure. Temperature or humidity controls for paint booths or hangars may be necessary when using this product in some climates.

P2 Option: *Convergent Spray Technologies™*
Spray Process For Environmentally Friendly Coatings

Success: A major contributor to the Space Shuttle Program, the NASA contractor responsible for the non-motor segments of the solid rocket boosters, was tasked with the challenge of developing a new material and process to replace a coating with toxic constituents. A new coating and applicator was developed, tested and implemented in March 1996. This new material and process eliminated air emissions and reduced hazardous wastes by 99% compared to the previous process. The process is now used for other aerospace and commercial applications and has potential for numerous other uses.

To protect the Space Shuttle Solid Rocket Boosters (SRBs) from the extremely high temperature environments generated during ascent and descent, the forward and rear sections are coated with a highly specialized insulating material. From 1984 until the spring of 1996, Marshall Sprayable Ablative-2 (MSA-2) was used for insulating the SRBs, which contained methylene chloride and perchloroethylene. Air emissions from the application of MSA-2 were the greatest single source of hazardous air emissions associated with the processing of SRBs (>10 tons/year). Unused MSA-2 and methylene chloride, used to flush the spray system and in mixing coating components, produced over 16 tons of hazardous waste annually. MSA-2 was a unique material used only on the SRBs and substitute materials did not exist to meet the stringent requirements. An independent research and development program was initiated with a goal of creating an environmentally friendly process and material.

Criteria for the new ablative material included: non-toxic components, heat dissipation characteristics equal or superior to MSA-2, improved application process, improved transfer efficiencies, and easy clean-up.

Five years of testing culminated in only one candidate material and process, Marshall Convergent Coating-1 (MCC-1) applied using Convergent Spray Technologies™ (CST ™) spray process and end effector. MCC-1 uses very little toxic material (a two part adhesive, ground cork and glass eccospheres). These materials are nonvolatile, therefore eliminating air emissions. In addition to the chlorinated solvent carriers, MSA-2 consisted of a two part adhesive and was filled with a mixture of five solid components. The complexity of the formulation provided greater opportunities for error during storage and mixing operations.

The MSA-2 application was a batch process involving as much as 50% waste. In contrast the MCC-1 is applied using a CST ™ coating process which generates very little waste. The CST ™ spray process mixes the components in the resin stream, external to the spray nozzle. This method eliminates the use of mixing pots and their clean-up after each mix. This is a spray-on-demand system. MCC-1 is a very high solids material and there is much less overspray compared to MSA-2. The CST™ spray process therefore uses less material during application.

In March 1996, the contractor replaced MSA-2 with MCC-1. Toxic air emissions were eliminated as there are no volatile organic compounds in MCC-1. An additional benefit is the elimination of air permitting requirements and the associated record keeping. Hazardous waste generation from insulating operations was reduced by 99%. The only hazardous waste produced by MCC-1 operations is from the cleaning of the nozzle upon completion of a spray. About one quart of solvent is used to clean this part. This compares to the 30 gallons of methylene chloride formerly used to clean the MSA-2 mix pots and associated hoses. The CST ™ spray process only mixes what is sprayed, therefore, there is no unused material requiring disposal. Each MSA-2 mix generated a significant amount of hazardous waste. Waste disposal costs for MSA-2 related operations exceeded $12,000 in 1995. Disposal costs for MCC-1 using the CST ™ spray processes are projected to be less than $500/year.

Spin Off Technology

The CST ™ spray processes provide environmental solutions for other applications. Space vehicles in addition to the Shuttle SRBs are now using this technology. This technology has also been used for a trial road coating. The process to effectively spray material with high solids content makes this a useful process for applying a non-skid surface coating on bridges where ice may easily form.

CST ™ spray processes are being evaluated for use in applying a coating on HVAC systems, applying an insulator to aircraft fuselages, and for coating the interior of rocket motors as well as for applying a magnetic radar absorption material on helicopters and other aircraft. There are potential applications for the chemical and petroleum industries where impact, chemical, and weather resistant coatings are required. The CST™ spray processes are being evaluated as part of a National Defense Center for Environmental Excellence program by the Army.

4. COMBUSTION

## 4.1 Medical Waste Incinerators	Hospital/Medical/Infectious Waste Incinerator (HMIWI) New Source Performance Standard (NSPS) Existing Source Emission Guideline (EG)

The new medical waste incinerator rules will increase the cost of compliance of military medical waste incinerators. The DoD is researching alternatives to incineration.

P2 Option: Out-source medical waste for disposal off post

Success: A contract to ship medical waste off post proved to be less expensive than running the medical waste incinerator. By shipping medical waste off post at $0.28 per pound, $107,000 was saved in the first year.

Success: An Air Force medical group operates a 28 bed/two operating room hospital. They out-sourced 15,000 lbs. of red bag waste at a cost of approximately $10,000. Cost estimates for maintaining and running an incinerator exceeded these values.

P2 Option: Effective Red Bag Waste Pollution Prevention Program

Success: An Air Force base medical group implemented a red bag waste program to minimize red bag waste being sent off-site. The program reduced the amount of brown bag waste put in the red bags and vice versa.

Option: Reclassify the HMIWI as a “Pathological” Incinerator

Success: A pathological incinerator burns solely pathological wastes. “Pathological” waste is defined as: waste material consisting of only human or animal remains, anatomical parts and/or tissue, the bags/containers used to collect and transport the waste material, and animal bedding (if applicable). In a recent situation, an Air Force base faced with installing monitoring devices on its medical waste incinerator received a Standard Exemption upon agreeing to combust only pathological wastes. By definition if an incinerator burns less than 10% medical waste it does not qualify as a medical waste incinerator

Option: Reclassify Incinerator Size Category

Success: Reclassifying the HMIWI to a smaller size designation can reduce the cost of add-on controls due to less stringent emissions guidelines. A source may, during its most recent performance test, change its size designation by establishing a “maximum charge rate” lower than its design capacity. Before seeking other reclassification the incinerator should first be classified as "rural" if it meets the criteria described below.

Option: Reclassify Incinerator Category as “Rural”

Note: Before seeking other reclassification the incinerator should first be classified as "rural" if it is located at least 50 miles from the nearest Standard Metropolitan Statistical Area (SMSA) boundary and burns no more than 2,000 pounds of hospital waste and medical/infectious waste per week. The “rural criteria” stipulates that an HMIWI is allowed to meet alternative emission limits.

For purposes of these emission guidelines, the list of areas comprising each SMSA as of 30 June 1993 will be used to determine whether a small HMIWI meets the “rural criteria.” The SMSA is defined by the Office of Management and Budget (OMB). The list of areas comprising each SMSA is presented in OMB Bulletin No. 93-17 entitled “Revised Statistical Definitions for Metropolitan Areas.” This document is available for public inspection and copying at EPA's Air and Radiation Docket and Information Center (Docket A-91-61, item IV-J-125).

4.2 Classified Waste Incinerators	Industrial Combustion Coordinated Rulemaking (ICCR)

Option: Replace Incinerator with a Disintegrator.

Success: A classified waste incinerator was replaced with a disintegrator. The process has no air emissions. The disintegrator is adequate for paper and cardboard, but not for microfiche. Payback estimated in 20 months and annual savings of $26,321. Paper from the disintegrator can be recycled.

4.3 Municipal Waste Combustors	Municipal Waste Combustor NSPS/EG

P2 Option: Remove batteries from the waste stream.

Planned: A machine that removes batteries from the waste stream is planned as an upgrade to the recycling facility. Removing batteries before incineration will reduce emissions of heavy metals.

4.4 Treatment, Storage, Disposal Facility	Hazardous Waste Combustor NESHAP

Research: Molten Salt Oxidation Technology

The Navy is conducting a demonstration study that uses molten salt oxidation (MSO) technology to treat and destroy hazardous and non-hazardous waste materials. Tests are being conducted on both energetic and inert materials. The Navy has installed, and is operating a remote small scale energetic molten salt oxidation unit. It has also designed and built the first energetic solid feed system to meter dry energetics into a MSO system.

Molten salt oxidation (MSO) is an innovative technology that can efficiently and effectively dispose of a wide variety of materials, and can be an alternative to open burning/open detonation. MSO is a process for treating wastes via reacting the material with an excess of air by injecting them into a molten salt bed. Sodium carbonate (Na2CO3) is the salt used in the molten bed.

Molten salt oxidation is ideal for demilitarization of waste materials, because the organic composition of the material is oxidized to carbon dioxide and water. Any halogens present in the feed, such as chlorine and fluorine, will form an acidic gas; however, the acidic gas will quickly be neutralized by the molten sodium carbonate salt to form its corresponding benign salt, e.g., sodium chloride or sodium fluoride. Dioxins will not form in the stack gases since the halogen has reacted, creating a salt. The remaining inorganic materials will collect in the molten salt bed, thus preventing them from entering the environment. The inorganic material can later be separated and than reclaimed or resold. The molten salt in essence oxidizes and scrubs the material in one stage. Molten salt oxidation has the advantage over conventional thermal treatment processes, because aqueous scrubbers used to remove corrosive acidic gases from the off-gas are not necessary for a MSO system. Furthermore, molten salt has excellent retention for metallic elements, which is of particular importance for hazardous metals such as cadmium, lead, and chromium. The salt, which retains these components, can be removed from the MSO unit and handled as a solid salt matrix; compared to handling of an ash or slag in the case of incineration.

At the Naval facility, the demonstration program thus far has successfully treated composite and doublebase propellants, oils, carbohydrates, paints, cellulose, solvents and fuel oils. In addition, process equipment is being designed and tested to allow the commercialization of this technology. The facility is working with government laboratories, private industry, academia and DoD facilities to continue the advancement of molten salt oxidation technology.

4.5 Boilers	Executive Order 12902 Section 305 Sulfur Dioxide (SO_2) NAAQS Nitrogen Dioxide (NO_2) NAAQS Particulate Matter (PM) NAAQS

P2 Option: Switch From Using Fuel #6 To Fuel#2

Success: This has been extremely effective in reducing a Marine Corps base’s total air pollution emissions since 80% of total emissions at the installation are from boilers.

P2 Option: Control Operating Procedures (NO_x Optimization)

Success: A Naval shipyard operates four steam boilers fired with No. 6 fuel oil. Typically, if a facility is a major source and located in a nonattainment area reasonably available control technology (RACT) would be required, such as retrofit with low NO_x burners and flue gas recirculation. Instead the shipyard was able to control their operating procedures as an alternative to an expensive retrofit and permitting protocol. The shipyard submitted a NO_x control operating procedure as an alternative to expensive continuous emission monitors (CEMs) to satisfy the compliance assurance monitoring requirements of EPA'S Title V Operating Permit Program. Simple combustion modifications reduced emissions from above 0.5 pounds per million BTU of heat input to below 0.3 pounds per million BTU of heat input. The program focuses on two NO_x reduction techniques: fuel biasing and low excess air firing. Each boiler requires its own fuel biasing and air firing procedure relative to firing capacity. For example, for boiler one, carbon monoxide (CO) and opacity were monitored to determine the impact of fuel biasing on complete combustion. Elevated levels of CO or opacity were not observed during this test condition. Ten percent fuel biasing had the effect of reducing the NO_x emission rate to 0.35 pounds per million BTU of heat input. This iterative procedure was continued until the emission rate had been reduced to under 0.3 pounds per million BTU of heat input with acceptable CO and opacity levels. NO_x optimization involves only the cost of implementing the program and maintaining the demonstrated adjustments.

P2 Option: Convert Coal-Fired Steam Plant to Natural Gas

Success: A Naval shipyard steam generating facility was fired with coal. Conversion of the plant to natural gas reduced criteria air pollutants by 286 tons, eliminated 7,400 tons of coal ash (solid waste), eliminated stack monitoring, and saved approximately $2,500,000 annually.

Success: An Air Force base's coal-fired heating plant was converted to natural gas and retrofitted with low NO_x burners. Conversion of the plant to natural gas reduced air quality compliance requirements, National Pollutant Discharge Elimination System (NPDES) requirements, as well as air emissions.

P2 Option: Retrofit to low NO_x burners reduced sizing.

Success: Reduce sizing of boilers and use of low NO_x burners reduced air emissions. Many boilers and generators at DoD installations are oversized. The larger combustion sources are less efficient and potential emissions are greater than smaller sources. Operating levels of external combustion units on installations should be scrutinized to determine if they have been oversized.

Problem: An Air Force Base recently installed low NO_x boilers to reduce criteria pollutant emissions. Unfortunately, the contract for installation of the boiler went to an inexperienced group. The boilers were repeatedly stack sampled, but never complied with the local standards. Reinstalling the boilers will be an expensive task and add to the costs of P2. The old saying "you pay for what you get" certainly applies in this case.

Problem: An Air Force Center has source sampled many types of P2 emission reduction technologies. Some of these technologies have not passed the emissions criteria claimed in the manufacturer literature. As a lesson, it is important to ensure that the manufacturers of P2 technologies are responsible for their products' performance. This dilemma should be resolved before the technology is purchased and a contract mechanism should be established to provide for the case when the technology does not meet the stated criteria.

P2 Option: Replace Oil Hot Water Heaters with Propane Units

Success: As oil fired hot water heaters in a mobile facility reached the end of their useful life, they were replaced with propane units. There is not enough propane stored to cross the risk management thresholds of Section 112(r).

P2 Option: Convert from Oil to Natural Gas

Success: Buildings with old oil-fired boilers and furnaces are being converted to natural gas. At an Army facility, fuel conversion can yield a significant reduction in both cost and pollution. This is an area of the country with an average of 7,601 heating degree days, a design temperature of -7 degrees, and with actual temperatures expected to reach -20 degrees each year and occasionally dipping as low as -40 degrees. Of the approximately 1,200 older buildings on post, which are generally small and all oil fueled, approximately 100 were converted in the first round completed in fiscal year 1997. There were several motivations for this project:

1. Cleaner fuel. Most notably SO_2 emissions are eliminated.

2. Cheaper fuel. Gas is purchased through a broker directly from the source. This is generally much cheaper than buying from the utility. However, the utility transports the fuel and is paid for this service.

3. Compliance. Executive Order 12902 Section 305 directs Federal agencies to take steps to reduce the use of petroleum in their buildings and facilities by switching to less polluting and non-petroleum based energy sources such as natural gas or solar energy.

4. Elimination of the delivery problem. Oil tanks were too often running dry, as the various contractors did not keep up with the demand.

5. Removal of underground storage tanks (USTs). This achieves compliance with regulations governing USTs and eliminates their associated liability.

6. Timing. Oil fired units are aging, with some as old as 20 years. When an oil furnace or boiler wears out before the building is retrofitted for gas, instead of installing new oil equipment, propane units are installed which can then be easily converted to natural gas when the gas lines get that far.

7. Efficiency. Replacing old oil units with new natural gas units increases the combustion efficiency from 75% to 90%. At the same time, automatic setback thermostats and zoned heating systems are being installed for further reductions in heating requirements. This adds up to lower fuel consumption, which means lower fuel costs and lower emission levels.

This first round of building conversions included 96 buildings, completed with about $2 million of P2 funds. The buildings selected for the change are those that meet three criteria. They are occupied year round, they have been retrofitted with insulation and energy efficient lighting, and they have been refurnished. It is hoped that about $1 million per year may be obtained to continue the conversion project. Funding sources are being explored such as construction, P2 and the Federal Energy Management Program (FEMP).

P2 Option: Efficient Energy Use Reduces Boiler Emissions

Success: The Air Force has instituted energy saving programs that reduce heating and electricity needs on base. The reduction in heating reduces boiler emissions.

P2 Option: Geothermal Energy

Success: Geothermal energy is not an option for every installation, but a few have made good use of it. A Naval facility is running large electricity generating turbines off of a geothermal field that is expected to last for 30 years. This was a public/private venture, which will allow the facility to sell electricity back to the power company when produced in excess of needs.

P2 Option: Geothermal Energy

Success: An Army facility installed residential geothermal heat pumps (GHPs) that provide space heating, cooling, and humidity control. They may also provide water heating either to supplement or replace conventional water heaters. These systems work by moving heat, rather than by converting chemical energy to heat like in a boiler or furnace. In heating mode, a GHP extracts heat from the earth and distributes it to the building, or uses it to heat water. Cooler air from the building is returned to the geothermal heat pump, where it cools the fluid flowing to the ground. The fluid is then re-warmed as it flows through the heat exchanger buried deep in the ground. In cooling mode, the process is reversed. The relatively cool fluid from the earth connection absorbs heat from the building and transfers it to the ground.

The facility Training Center has some 23,000 military personnel and family members living in on-post housing. The housing stock consists of 4,003 units in 1,296 buildings. About 80 percent of the units had air-source heat pumps and electric water heaters. The remainder were cooled by central air conditioning and heated by natural gas forced-air furnaces. Cooling is the main requirement in this area.

About half of the base's energy bill has been for housing energy consumption. This project, including building envelope improvements, is expected to save about a third of residential energy costs. That translates into about $3.3 million annually in utility bills and maintenance over the 20-year life of the contract.

P2 Option: Cogeneration: Compressed Natural Gas Fuel Cell

Success: A Naval hospital is almost completely powered by a compressed natural gas fuel cell which converts natural gas to electricity and heat. The system uses a cathodic system that reduces natural gas to water. The byproduct is a small amount of steam. In one year the facility has saved the base $60,000 in energy consumption not counting the added value of drastically reducing emissions. The fuel cell is extremely inexpensive to operate, and is expected to have a 5-6 year payback period.

Problem: The unit senses the air that comes into the unit and if the air is too dirty, the equipment shuts down. They located the fuel cell near emergency diesel generators, and when the emergency generators kick on, the fuel cell shuts down because of the amount of NO_x in the air from the generators. This demonstrates the importance of considering emission sources when locating fuel cells.

4.6 Vehicles	PM and Ozone NAAQS Executive Order 13031

Executive Order 13031 and the Energy Policy Act of 1992 direct Federal agencies to incorporate alternative fuel vehicles (AFVs) into their fleets. Typically, the biggest challenge of incorporating AFVs into the fleet is establishing a convenient source of alternative fuel. Natural gas is cleaner burning than most other alternative fuels. There are two types of natural gas fueling stations: rapid fill stations are much more expensive than slow fill ones, but there is also a difference in fueling times between minutes and hours. Slow fill is practical if the vehicles can be filled over night.

P2 Option: Install Compressed Natural Gas Station

Success: A Rapid Fill Compressed Natural Gas Station has been installed that has significantly reduced ozone precursors and PM. Residents and businesses also use the station. This promotes a "good neighbor" image to the community. The facility is open 24 hours and is maintained by a private contractor, which funded and built the facility. The Marine Corps provided the real estate for the facility, which is significant to the overall partnering success.

P2 Option: Alternative Fueled Vehicles - Compressed Natural Gas

Success: So far 80 Compressed Natural Gas bifuel vehicles have been added to an Army facility's GSA fleet of 500. Most of the CNG vehicles are light duty trucks at this time, with a couple of passenger vehicles. The GSA vehicles average 1000 miles per vehicle per month, bringing the annual total up to around 6 million miles. If 15 percent of these miles are powered by natural gas, expected emission reductions would be 2.3 tons of carbon monoxide, 0.6 tons of nitrogen oxides, and 1.2 tons of non-methane hydrocarbons. The fueling station was put into service in 1996.

P2 Option: Alternative Fueled Vehicles: Compressed Natural Gas

Success: To make a significant contribution to reducing local air pollution levels, an Air Force base has embarked on an ambitious program to reduce the use of gasoline and reduce the emission of VOCs from base vehicles. The base has already converted 40 fleet vehicles from gasoline to a bi-fuel compressed natural gas (CNG) system.

The base has recently obtained funding from the Advanced Research Project Agency (ARPA), through the base Alternative Fueled Vehicle Systems Program

Office (AFVSPO) to assist in converting 27 diesel powered vehicles to dual fuel use. This will enable the vehicles to use 80% CNG and 20% diesel fuel. The contract for the conversion was awarded with an estimated completion date of May 1996. Finally, the base is currently working to convert an additional 76 vehicles to CNG.

P2 Option: Alternative Fueled Vehicles - Solar charged electric vehicle

Success: An electric powered six-passenger Chrysler van was purchased in 1997. This vehicle has a maximum speed of 80 miles per hour and a range of 80 miles per charge. This range figure is somewhat diminished when air conditioning is required. The white color of the vehicle minimizes solar gain and thus air conditioning requirements.

P2 Option: Alternative Fueled Vehicles - Electric Bicycles for intrabase travel

Success: Electric bicycles are being introduced in the base in a partnership with a private contractor to stimulate alternate forms of transportation. This contributes to NO_x reduction. Unfortunately, these do not count as AFVs in the official tally.

4.7 Aerospace Ground Equipment

Carbon Monoxide (CO) NAAQS
Nitrogen Dioxide (NO_2) NAAQS
Particulate Matter (PM) NAAQS

P2 Option: Reduce emissions from Aerospace Ground Equipment (AGE), a.k.a. Aerospace Ground Support Equipment (AGSE), Ground Support Equipment (GSE)

Success: An Air Reserve Base is in an extreme nonattainment area for ozone with NO_x being the prime air quality offender. AGE accounts for almost one-half of all NO_x emissions at the base. Not knowing exactly how the equipment would be regulated, they wanted to proactively pursue ways to reduce emissions. They conducted a study and have published the following recommendations:

- <u>Develop a procedure to encourage the users to minimize AGE use.</u> Users are to be made aware of how much they use the equipment in a quarterly memo to encourage buy-in from operators to use the equipment only when necessary. Estimated NO_x reduction using this method is 10%.
- <u>Switch from diesel to JP-8 fuel.</u> Both NO_x and SO_x are slightly reduced when using JP-8. Even though emission reductions are small, JP-8 is desirable from a logistical standpoint. It is no longer necessary to stock multiple fuels. Estimated NO_x reduction using this method is 2%.
- <u>Plan emission tests.</u> Use the results of emission tests to determine the optimum combination of fuel injector type and timing. Request a Technical Order (TO) waiver and implement. Testing is underway to change both the fuel injector type and the timing and comparing NO_x emissions and modifying TOs accordingly. Estimated NO_x reduction using this method range from 10 to 30%.

- Experiment with powering two aircraft off a single AGE engine. The users are not in favor of this option because cables are heavy and bulky and aircraft parking and maintenance schedules would have to be adjusted, however there is potential for significant reductions. No near-term reduction of NO_x is associated with this option.
- Supply users with 20 sets of battery powered explosive-proof lights. Much of the AGE use was to power aircraft lighting at night. Users should be encouraged to use rechargeable lanterns instead of AGE for night lighting. A product such as Eveready No. 459 Lantern (NSN: 6230-01-102-7999) is recommended. The NO_x reduction using this method is estimated at 20%.
- Supply the users with two of the Army's 15kW skid mounted generators for evaluation. There are many advantages of these smaller generators including reduced fuel consumption and quieter operation. However concerns over compatibility, deployability, user acceptance and cost must be evaluated before recommending full base-wide implementation. No near-term reduction of NO_x is associated with this option.

P2 Option: Install Low Emissions Injectors And Retarded Injector Timing (RIT).

Success: The Air Force is currently field testing different injectors and timing settings for A/M 32 AD-86 AGE. The modifications have shown an 80% reduction in NO_x and other criteria air pollutants. This technology will be used at several different Air Force bases to determine if any side effects or performance limitations occur.

PC Option: Emission-Control Technologies for Aerospace Ground Support Equipment

Success: The Air Force is currently field testing additional NO_x reduction strategies along with the retarded-injector timing mentioned above. These technologies include selective-catalytic reduction (SCR) and exhaust-gas recirculation. The technologies are going through a final stage of development with hopes of significantly decreasing NO_x emissions. This is pollution control (PC) rather than prevention.

4.8 Generators

Carbon Monoxide (CO) NAAQS
Nitrogen Dioxide (NO_2) NAAQS

P2 Option: Solar Photovoltaic Electricity Generation

Source: Photovoltaics and batteries provide 2 kW to a meteorological station that is off the grid out in the desert. A 112 kW photovoltaic system is under construction at another off-grid site. Photovoltaics and batteries were obtained from elsewhere in the Army where a solar project was canceled. Some of the donated materials were traded for the construction of a facility with a power conditioning unit. Note that batteries used for this type of application are deep cycle (e.g. marine) batteries. In this case, because materials were donated for this site and because of the distance from the grid, installing solar power is cheaper than extending the grid.

P2 Option: Solar Power

Success: One third of the base's NO_x emissions comes from two 450 HP engines. These diesel generators run 24 hr/day. They are used to power moving targets at the tank firing range. In December 1997, installation of solar power to replace the generators was completed. Energy generation uses a 1 acre solar array of photovoltaic panels. It is an uninteruptable power supply with an inverter that converts DC power to AC. So far the project has proved to be highly successful.

P2 Option: Solar and Wind Energy

Success: The Mobile Power Center (MPC) is a prototype unit designed to test the feasibility of using solar and wind energy to supply electrical power to mobile Marine Corps units. The MPC was successfully demonstrated recently by the Marine Corps. Performance data has been provided to representatives of the Combat Service Support Enterprise element of the Special Purpose Marine Air Ground Task Force for further correlation with user logs. An objective final report is expected from the Marine Corps.

The system is constructed on a base, which houses the main battery, DC/AC inverter, and control and monitoring equipment. The main source of power is a 3.42 kW solar panel array. The array is comprised of 3 banks of 6 solar panels, which are supported by metal frames. A collapsible mast attached to the base supports a 1 kW wind generator.

4.9 Jet Engine Testing	Engine Test Facilities NESHAP CO, NO_2, PM NAAQS

P2 Option: Reduce Engine Tests

Success: A Navy facility has 22 jet engine test cells. The engines come from all branches of the Armed Forces to undergo performance testing and rework. Since emissions from test cells are significant, the facility looked for P2 opportunities to reduce emissions. The goal was to reduce emissions and improve jet engine test cell operations with a corresponding reduction in jet engine test cell fuel usage, labor, and operation costs. The facility considered applying P2 to test cells by decreasing the test cell reject rate. A reject occurs when a jet engine does not meet certain criteria of a test or fails mechanically. When a jet engine is rejected, it must be re-tested and pass a performance test before it can be reintroduced into production.

Achievements from the years 1991 to 1994 were reviewed. Significant improvements had been made to reduce engine-inherent test rejects as a result of regular wear and tear on a particular engine type. Reduction of rejects was accomplished by running the test cell through a series of maintenance checks that included such actions as vibration analysis, casing examination to restore clearances to "as new" conditions, and oil testing. They also adopted a

Reliability-Centered Maintenance (RCM) philosophy that emphasized safety and operational goals in addition to the minimization of maintenance man-hours, material usage, and costs. They estimated that approximately 40 percent of the rejects were eliminated through the combination of these rigorous pretest checkouts and the RCM program.

In 1995, another review of operations was conducted, and a strategy to reduce emissions from test cells was considered for the overall P2 plan. The pollution prevention team considered letting a contract to collect data to further reduce the reject rate. The teams found that they did not need to let this contract because the Engineering Department continued to make improvements in reducing the reject rate. Improvements made since 1995 are as follows for a few of the engine types:

F402: Rejects over three years since 1995 revealed the main causes to be excessive vibration and low performance (high jet pipe temperature or low thrust). The reject rate was approximately 21 percent. In 1995, the facility established a research project with North Carolina State University to develop an engine diagnostic method to better identify the causes of excessive F402 engine vibration. This resulted in the establishment of the computer based "Diagnostic Engine Vibration System" now operational in the F402 test cell and the installation of an additional vibration transducer on the engine during the test. Results of the use of this system have been positive, allowing better isolation of the discrepant component causing the excessive vibration. The reject rate is anticipated to decrease in the future with the use of this system and the accumulation of historical vibration reject data. Low performance has been addressed by the introduction of improved rework and assembly procedures required by a Local Engineering Specification.

T58: Efforts have focused on elimination of the primary degraders including low power, oil leaks, and oil consumption. There have been dramatic results. Rejects were reduced by 75 percent. There is also a new Data Reduction Program for each test cell installed. This provides the tools to isolate problem components in reject engines.

Auxiliary Power Units (APUs): Efforts have been made to reduce test cell time and reject rate for all models of APUs. Although the test cell reject rate is higher than the ideal, it is about 30 percent lower than it was in 1994. Data on test cell rejects, corrective actions, and resolution of problems (statistical process control data being collected in the shop) is currently being kept. They are working with shop and Quality Evaluation personnel to try and organize the information better to assist with further reducing the reject rate.

As of early 1998, fuel usage records have been fully automated for 6 of the 22 test cells. It is anticipated that all test cells will be fully automated by the end of 1998. Software tracks the type of engine, duration of each engine run and the amount of fuel used.

Technical directives to the shop have cut the rejections to a minimal level. Test cell rejects of engines will continue although significant reductions in the reject rate have been achieved. Emission control devices may have to be considered to further decrease emissions.

5. STORAGE

5.1 Listed Substance Storage	Accidental Release Prevention Program (Risk Management Programs and Plans)

P2 Option: Eliminate the Use and Storage of Substances Listed under the Accidental Release Prevention Program

Success: Chlorine and sulfur dioxide were eliminated. Eight one ton cylinders of chlorine and four one ton cylinders of sulfur dioxide were used in treating water at a Sewage Treatment Plant. These quantities of materials trigger the threshold for the Risk Management Program. They have changed their system to use ultraviolet light and sand filters to process wastewater at the sewage treatment plant.

Success: Chlorine used to treat wastewater was eliminated by using ultraviolet light and advanced oxidation at the oily wastewater treatment plant.

P2 Option: Reduce or Divide the Storage of Chlorine (or other listed substances)

Success: A number of installations are reducing the risk of harm to people and the environment by reducing the amount of listed substances stored in one place. Alternately, the same benefit can be achieved by dividing up storage so that only an amount below the threshold is located in one place or in such a way that it could be involved in a single catastrophic event. This both reduces the risk and eliminates the need to develop a Risk Management Program and Plan.

6. TRAINING

6.1 Fire Fighting Training

Particulate Matter (PM) NAAQS - Fugitive Emissions

P2 Option: Reduce the Amount of Soot Emitted during Fire Fighting Training

Success: PM contributors are being reduced at a fire fighting training facility. Fuel additives allow a 90% decrease in the amount of soot emissions. This technology was originally developed in Kuwait during Operation Desert Storm where soot suppressant contributed to the success of the war. The Marine Corps is doing additional testing at the installation. The fires still burn hot and dark which is necessary for training purposes, but yet show drastic reductions in the amount of soot emitted.

6.2 Field Training Exercises

Particulate Matter (PM) NAAQS – Fugitive Emissions

P2 Option: Reduce the Amount of Dust during Field Training

Success: Particulate matter (PM) contributors are being reduced during off road vehicular travel in a number of ways. Tank travel has been narrowed using railroad ties. Native vegetation has been planted in rutted areas to help stabilize the soil. Soil stabilization projects are in place to prevent PM. Soil stabilizers are used on roadways, roadway access points, edges of roadways, parking lots, and turnouts. The stabilizers work better and are cheaper than asphalt (stabilizers cost approximately 4 cents/square foot). They have found soil penetration as deep as 10 inches when using the correct mixture of water. Stabilizers seem to work best where there are 20% fines existing within the soil.

Research: Use Dust Control Agents

Findings: Five dust control agents were chosen to study at three installations. These dust control agents ranged in price from $0.28 to $0.70 per square yard applied.

Agent	Composition
Dust-Fyghter	38% CaCl (absorbs moisture from the air)
Lignin	calcium lignosulfonate
SoilSement	polyvinyl acrylic polymer emulsion
SoyaSeal6	soybean feedstock processing by-products
Top Seal	polyvinyl acrylic polymer emulsion

Results of dust deposition and dust obscuration tests are included in a report called *Dust Control Material Performance on Unsurfaced Roadways and Tank*

Trails published by the U.S. Army Environmental Center and the US Army Corps of Engineers, September 1996.

P2 Option: Helicopter Rotor Washout Control

Success: A soil conservationist at an Army facility developed an effective way to turn a patch of flying dirt into a stable landing pad. Large crush rock is spread in the washout area. This holds everything in place. The rocks must be large enough so they will not get caught up in the air currents. After a while, vegetation will begin to grow through the rocks, increasing the stability of the soil.

6.3 Weapons Training at Firing Ranges

Lead NAAQS

P2 Option: Reduce the Amount of Lead Dust during Weapons Training

Success: Bullets (lead) fired from weapons impact a dirt berm. Lead emitted during firing and other lead already embedded within the berm stirred up on impact cause significant lead dust emissions. Typically installations clean up berms after extended periods of time (often as long as 30 years). This also contributes to significant atmospheric loading of lead. Backloaders and other heavy equipment dig up the berms for removal, which contributes to lead emissions and excessive worker exposure to lead. The Marine Corps is in the process of incorporating a range management plan where berms are serviced at the maximum of every three years. A system is being installed to capture lead after they are fired into collection facilities located behind the target after penetration of the target. A water mister is being sprayed across targets to knock down lead dust as the lead impacts collectors. Berms are being constructed in a concrete basin and painted with an epoxy paint to ensure runoff does not pollute groundwater. What is essentially a baghouse is also being installed over targets to draw in lead contaminated air.

Research: "Green Bullets"

The Department of Defense is addressing the issue of hazardous materials in the manufacture and use of small caliber ammunition. The Army is looking for ways to reduce or eliminate ODSs, VOCs, and heavy metals in the manufacture of primers and projectiles in small-caliber ammunition.

Research: P2 on Ranges

The Army conducts demonstration and evaluation projects through the Range XXI program, which is the environmental component of Force XXI, designed to bring war fighting into the 21st century. Pollution prevention, maintenance, and remediation technologies and techniques are being demonstrated and evaluated in 5 thrust areas:

1. Small Arms Range Technology (soil washing; bullet traps; Range Management Manual; Range Evaluation Software Tool; Army Sampling and Analysis Plan)

2. Impact Area Design and Management (preventing erosion and lead migration; unexploded ordnance (UXO) management)

3. Training Area Sustainment (dust control; land based carrying capacity; tactical concealment areas; VegSpec computer-based tool)

4. Acquisition Support (non-toxic ammunition, such as a non-toxic, tungsten-based alternative to the current 556 round)

5. Training and Test Emissions Management

7. MISCELLANEOUS

7.1 Ethylene Oxide Sterilizing

State-Specific Regulations

P2 Option: Plasma Sterilization Technologies

Success: Ethylene oxide (EtO) has been used extensively as a medical equipment sterilant. However, EtO is highly explosive in nature and therefore it has traditionally been mixed with a carrier agent, CFC-12 (Freon), which is an ODS. Because of the carcinogenicity of ethylene oxide and ODS phaseout required under the Montreal Protocol, researchers sought alternatives. In 1994 the Food and Drug Administration (FDA) approved the process known as "Hydrogen Peroxide Plasma Sterilization", which is marketed under the trade name STERRAD^{TM}. In 1995 the FDA approved Peracetic Acid Gas/Plasma technology which is marketed under the trade name PLAZLYTE^{TM}. There are a number of STERRAD^{TM} units in use throughout the Services. The cost for either of these safe, effective units is \$100,000. The Navy is looking for a way to phase out all existing medical ethylene oxide sterilizers.

References:

1. Fire Hazard from Carbon Adsorption Deodorizing Systems, EPA 550-F-97-002E, May 1997.
2. EPA Memorandum from John Seitz to Regional Air Toxics Coordinators, Subpart O-Ethylene Oxide Commercial Sterilization Plant Explosions, 29 July 1997.

P2 Option: Out-Source

Success: STERRAD^{TM} units have their advantages, but are not able to sterilize all the items that an ethylene oxide sterilizer is capable of sterilizing. A medical center is out-sourcing the items its STERRAD^{TM} and its steam units are not able to handle. Unfortunately this is not the greatest example because they are out-sourcing the items to another Army medical center. The STERRAD^{TM} design is improving. Newer models are expected to handle more items. Its newer version is pending FDA approval. Until then, any items needing sterilization may need to be out-sourced.

P2 Option: Steam Sterilization

Success: A medical center is using steam as an alternative for items that need to be disinfected but not fully sterilized. This reduces the amount of items needing to be sent through the ethylene oxide sterilizer.

7.2 Fuel Dispensing	VOC and HAP Emissions

P2 Option: Stage II Vapor Recovery System

Success: Fuel dispensing from Government owned facilities and from on-base fueling stations is a large source of VOCs and organic HAPs. Many states in nonattainment regions are already required to use stage II vapor recovery systems because of VOC reduction goals. Eleven pounds of VOCs are emitted for every 1000 gallons of MOGAS dispensed. Stage II vapor recovery can provide a range of control from 88%-99%. Stage II vapor recovery will also provide a reduction in total HAPs from the base. Two Air Force bases used stage II vapor recovery at their fuel dispensing facilities as a means to stay under the HAP major source threshold. By maintaining HAP levels (potential and actual) below major source thresholds, these bases do not fall under the costly Aerospace NESHAP. Installation costs for stage II vapor recovery depends on the fuel dispensing facility.

7.3 Pesticides	VOC and HAP Emissions

Background: Pest Management

The Armed Forces Pest Management Board is the DoD group which addresses pest management issues, forms DoD policy, and makes a unified effort to meet the DoD 50% pesticide use reduction goals. The term “pesticide” generally refers to insecticides, rodenticides, herbicides, fungicides, and antimicrobial pesticides. Pest management experts are found within the military community both in engineering and in preventive medicine as pest control issues relate to grounds maintenance as well as disease prevention. There may be certified pesticide applicators employed by the installation as a whole or by the MWR for the golf course. Examples of P2 range from Air Force efforts to avoid the need for pesticides by developing the population of martins (birds which eat mosquitoes) to Army efforts to use alternative pest control methods in food handling facilities.

P2 Option: Alternative Pest Management Methods

Success: The Air Force is using several methods to reduce use of pesticides containing VOCs and HAPs. A reduction in fungicide use was accomplished through use of resistant turf types and proper care. Steam and hot water are being used for weed control (which, by the way, also works for fire ants). Mechanical devices are also being used for weed control. This eliminates VOCs but replaces it with combustion emissions. An Air Force base is using a joint sealant to prevent and reduce weed infestation.

P2 Option: Aqua Heat for Weed Control

Success: An Air Force base is experimenting with heated water treatments to reduce weed growth. The testing is at its beginning stages, but could prove effective.

P2 Option: Biological Control of Noxious Weeds

Success: The Air Force is experimenting with the use of biological controls to reduce the quantity of noxious weeds. The biological controls are a substitute for sprayed herbicides possibly high in VOCs.

P2 Option: Integrated Pest Management (IPM) at Golf Courses

Success: Golf Courses receive from 25% to 65% of pesticide use at an installation in terms of active ingredients. The Army has about 108 golf courses and has an active golf course Integrated Pest Management (IPM) program. IPM uses a variety of materials and methods to control pest populations while minimizing the quantity and toxicity of the active ingredients. Pesticide usage reduction can generally be achieved through product substitution, changes to application schedules (e.g. applying as needed instead of on a schedule), and using innovative physical or biological controls. Golf courses that have taken part in the program have seen significant reductions in pesticide use. Exact reduction amounts have not yet been determined but a preliminary estimate is that typical reductions for the golf courses that have participated so far is about a one-third reduction on average.

7.4 Lubricants

VOC and HAP Emissions

Background: Alternative Chemicals

Lubricants are a vital part of normal maintenance operations and must be available for aircraft maintenance; however, various lubricant products often contain ozone depleting substances (ODS) and Environmental Protection Agency 17 priority pollutants (EPA-17) in product formulations or for use as lubricant propellant and carrier solvents. Lubricants of particular concern are solid film lubricants (MIL-L-46010, MIL-L-23398, MIL-L-46147), release agents (MIL-L-60326), and penetrating oils (A-A-50493).

The Montreal Protocol and subsequent Federal statutes (e.g. Title VI of the Clean Air Act Amendments of 1990) and regulations have resulted in the implementation of a ban on the production and importation of Class I ODSs. In addition, the Aerospace NESHAP requires the reduction of hazardous solvents used at facilities. Solvents covered by the NESHAP include: methylene chloride, toluene, xylene, and MEK.

Due to Federal legislation, Air Force policy, product availability constraints, and air permitting issues, there is a need to identify and/or develop new solid film lubricants, release agents, and penetrating oils which do not contain ODS and EPA-17 constituents. Identification of alternatives will allow the replacement of products, which contain ODSs and minimize EPA-17 chemicals from maintenance and repair activities.

Research: Lubricants

The Air Force has two projects under development. The objectives are: (1) documentation and discussion of *existing* replacements for solid film lubricants (MIL-L-46010, MIL-L-23398, MIL-L-46147), release agents (MIL-L-60326), and penetrating oils (A-A-50493), and (2) documentation and discussion of *potential* replacements.

Existing Replacements for Solid Film Lubricants, Mold Release and Penetrating Oils

Specification changes and the introduction of alternative propellant systems and carrier solvents have eliminated most ODSs from several lubricant products. In addition, product reformulation has eliminated EPA-17 chemicals from certain lubricants. Table 7.4.1 provides a summary of the available products that are ODS/EPA-17 free. Note that there are currently several alternative products available for mold release agents (MIL-L-60326) that do not contain ODS and EPA-17 constituents. However, the military specification continues to contain reference to ODS. The specification needs to be updated to remove this reference and allow alternative products to be used.

Table 7.4.1. Existing Replacements for Lubricant Products

Military Specification	Specification Title	Description
MIL-L-46010, Type III	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting	MIL SPEC compliant; ODS/EPA-17 free
MIL-L-23398	Lubricant, Solid Film, Air Drying, Corrosion Inhibiting	MIL SPEC compliant, ODS/EPA/17 free
MIL-L-60326	Lubricant, Fluorocarbon Telomer Dispersion (for use with ammunition)	ODS/EPA-17 free; Aerosol, Dip, Spray, and Brush / substrate specific products. ODS/EPA-17 free ODS/EPA-17 free
A-A-50493	Penetrating Oils	

Potential Replacements for Solid Film Lubricants (MIL-L-46147 and MIL-L-23398)

A potential replacement product has been identified for solid film lubricants. Currently, the potential replacement products approved for MIL-L-46147 typically contain lead (<10%), methyl ethyl ketone (<10%), xylene (<10%) and methylene chloride (>50%), while the products approved for MIL-L-23398 contain lead, methyl ethyl ketone, xylene, and toluene. Manufacturer claims indicate that the product was designed to meet MIL-L-46147 and MIL-L-23398; however, the product has not been tested and is not accepted for military use. A review of the MSDSs for this product was conducted, and a summary of the hazardous constituents is identified.

Table 7.4.2. Potential Replacement for Solid Film Lubricant (MIL-L-46147 and MIL-L-23398)

Tiodize, 15701 Industry Lane, Huntington Beach, CA 92649, (714) 898-4377		
Material	**Hazardous constituents**	**CAS Number**
Tiolube 75/75	Molybdenum Disulfide Sb203	1317-33-5 1309-64-4

7.5 Adhesives and Sealants	Ozone NAAQS (measured in VOCs and NO_x) Aerospace NESHAP

P2 Option: Alternative Chemicals

The current regulatory drivers governing the use of adhesives and sealants at Federal facilities are: executive orders, DoD policy, Defense Authorization Act Requirements and Service level policy. These documents have (1) removed DoD exemptions from environmental regulation and (2) set goals for elimination or reduction of the use of various classes of materials (ozone depleting substances and the EPA-17 industrial toxics) and the disposal of hazardous waste.

In addition, the EPA has promulgated the Aerospace NESHAP that imposes strict emission limits on a variety of cleaning, coating, and depainting processes. Table 7.5.1 provides definitions and allowable VOC limits for the NESHAP specialty coatings pertaining to adhesives and sealants. A study by the Aerospace Industries Association indicates that a vast majority of commercially available adhesives and sealants currently meet the requirements of the Aerospace NESHAP. Adhesives and sealants in use must be individually examined to determine which products need to be replaced.

A list of adhesives and sealants used at the facility were provided. In general, most of the adhesive systems are currently compliant with all existing and pending regulations. Several adhesives contain EPA-17 materials or HAPs. Of primary concern are the sealants and their continued reliance on solvents (high VOC) and heavy metals, especially chromium as a corrosion inhibitor.

Reformulated MIL-SPEC Sealants

Significant progress has been made to develop less hazardous products for the following MIL-SPEC materials:

- MIL-S-8802 - Scaling Compound, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion. Amendment 4, dated 20 January 1995, canceled Type I (Dichromate Cured) and authorized the use of Type II (Manganese Cured) for all previous uses of Type I.
- MIL-S-81733 replacement - Draft consensus specification, G 990BC, is undergoing evaluation. A private contractor has produced a new sealant, PR-1775, to conform to G 990BC. The Air Force and a private contractor are evaluating the product.
- MIL-S-83430 and its associated qualified product listing (QPL) were canceled 5 October 1994. Future acquisitions of sealant materials will refer to AMS 3276.

- MIL-S-8516 Potting Compounds are now available lead free. However, GSA is depleting stock of lead based potting compound.

Table 7.5.1. Selected Specialty Coatings from the Aerospace NESHAP

Adhesives	RACT VOC Limit	Comments
Commercial Interior Adhesives	6.34 lb./gal, 760 g/l	Materials used in the bonding of passenger cabin interior components. These materials must meet FAA fire worthiness requirements.
Cyanoacrylate Adhesive	8.51 lb./gal, 1020 g/l	A fast setting, single component adhesive that cures at room temperature. Also known as "super glue".
Fuel Tank Adhesive	5.71 lb./gal, 620 g/l	Materials used in the bonding of passenger cabin interior components. These materials must meet FAA fire worthiness requirements.
Non-structural Adhesive	3.00 lb./gal, 360 g/l	A material that bonds non-load bearing aerospace components and is not covered in any other specialty adhesive category.
Rocket Motor Bonding Adhesive	7.43 lb./gal, 890 g/l	Quick setting contact cements that provides a strong, yet flexible bond between two mating surfaces that may be of dissimilar materials.
Rubber Based Adhesive	5.84 lb./gal, 700 g/l	Quick setting contact cements that provide a strong, yet flexible bond between two mating surfaces that may be of dissimilar materials.
Structural Autoclavable Adhesive	0.50 lb./gal, 60 g/l	An adhesive used to bond load carrying aerospace components and is cured by heat and pressure in an autoclave.
Structural Non-autoclavable Adhesive	7.09 lb./gal, 850 g/l	A material that bonds non-load bearing aerospace components and is not covered in any other specialty adhesive category.
Sealants	**RACT VOC Limit**	**Comments**
Extrudable/ Rollable Sealants	1.66 lb./gal, 200 g/l	A material used to prevent the intrusion of water, fuel, air or other liquids or solvents from certain areas of aerospace vehicles or components.
Brushable Sealants	2.00 lb./gal, 240 g/l	
Sprayable Sealants	5.01 lb./gal, 600 g/l	

Waste Minimization Techniques for Adhesives and Sealants

Segregation of Non-hazardous Waste: Currently, 90+% of the sealants used at a private contractor's facility are nonchromated sealants. Recently the company initiated a program to segregate the nonchromated sealants from the hazardous waste stream. This resulted in a 75% reduction in the quantity of sealants disposed of as hazardous waste.

Another contractor facility has initiated a similar program where non-hazardous sealants are identified at the point of issue to allow disposal as a non-regulated waste. Hazardous sealants are now being packaged in colored containers. Each container color corresponds to a specific disposal procedure for the unused material. These simple measures have significantly reduced the volume of hazardous waste from sealant usage.

Minimize Material Usage: Controlling the volume of adhesive/sealant prepared for an application is another way to reduce waste. Proportional dispensing allows the technician to catalyze/mix only the amount required to perform the required task. This technique is currently used for several paste adhesive applications with a reported higher productivity and huge cost savings. Another contractor is currently investigating a similar technique for dispensing of sealants.

One system being considered is Mixpac®, a hand held mixing/dispensing system. A two part adhesive/sealant system is placed in cartridges (cartridges are sized to provide a variety of mix ratios) which are squeezed by the mixing gun. The two parts are then mixed in a static mixing tube and dispensed in the amount needed. The only waste is the residual adhesive/sealant remaining in the mix tube, which after hardening will be disposed of in the appropriate waste stream.

Source: McGinnis, Karen and Gary Benham, "Hand Held Dispensing Equipment Reduces Waste and Saves Cost", Adhesive Age, October 1991

Minimize Issue Quantity: Where possible, reduce the size of the issued product to the minimum quantity needed to accomplish a given task. For example, a contractor used an eight ounce frozen premixed sealant for protecting rivets and fasteners. Typically, 40-80% of the sealant would not be used and would be disposed of as waste since once thawed, it had a limited pot life. The supplier was asked to provide the product in one ounce tubes. Minimizing the issue quantity resulted in a 60% drop in waste produced.

Current Research Efforts

Society of Aerospace Engineering (SAE) Committee: The G9 Sealant committee is working in the following areas: Polythioether fuel tank sealant (Draft G 989BT), integral fuel tank sealing compound (AMS 3276), high strength polysulfide sealant (AMS 3269), access door sealant (AMS 3374a), silicone fire wall sealant (AMS 3374A), windshield sealant (Draft G 990AE), electrically conductive corrosion inhibiting sealant (Draft G 992AH), and low density (specific gravity of 1.3) sealant (Draft G 993BA).

1995 Study to Consolidate Adhesive-Sealant-Coating (Paint) Systems: An Air Force base contracted with a company to produce a prototype expert system to identify and select alternative/superior adhesive-sealant-coating (ACS) systems. The system is designed to address the following: (1) identify materials with environmental and/or health concerns, (2) minimize the number of products in-stock by consolidating similar systems and (3) identify substitutes for out-of-stock products called out in documentation.

The project was performed in three phases. The first phase included collection/categorization of information pertaining to adhesives, sealants and coating systems. In Phase II, the contractor created a database for the selected materials including physical properties and performance characteristics. Using this database, a search engine was used to compare ACS systems and make recommendations for alternative products. These recommendations were then verified by experimentation. The final phase of the project was optimization of system performance to improve the reliability of the recommended replacements.

Sealant Manufacturer's Initiatives: Sealant manufacturers are busy reformulating a number of products that are undergoing evaluation by the aerospace industry.

A private contractor has published a list of less hazardous replacements for several of their products. See Table 7.5.2. Another contractor has reported the results of qualification tests of non-chromated MIL-S-8802 and MIL-S-81733 products. They identified the MIL-S-8802 approved product as PR1422 (chromated). Non-chromated candidates evaluated include: Morton MC237, Flamemaster CS5540, Fiber Resin PS2082, and Morton MC730. The contractor also reported the currently approved MIL-S-81733 products are Morton 665 (contains strontium chromate) and Proseal 870 (contains manganese chromate). A non-chromated alternative, Morton MC730, was reported to have failed the dissimilar metal test.

Table 7.5.2. Product Substitution Reference

PRODUCT	CHEMICAL SYSTEM	REPLACES	APPLICATION	BENEFITS	MIL SPEC	OEM SPEC
PR-1428	MANGANESE DIOXIDE CURED POLYSULFIDE	PR-1321, P/S 706, PR-1403G	FUEL TANK ACCESS DOOR (FORM-IN-PLACE) GASKET	CHROMATE FREE, WORKER/ENVIRONMENTALLY FRIENDLY, FAST CURE, HIGH REMOVABILITY	MIL-S-8784	
PR-1429	MANGANESE DIOXIDE CURED PERMAPOLE P-5	PR-1223, PR-1224, PR-1227	AIRCRAFT INTERIOR FLOOR BOARD GAP/DEPRESSION FILLING & SMOOTHING APPLICATIONS	LEAD FREE, LOW SPECIFIC GRAVITY, HIGH TEMPERATURE CAPABILITY, EXCELLENT REMOVABILITY & REPAIRABILIY		
PR-1758	MANGANESE DIOXIDE CURED PERMAPOLE P-5	P/S 899, PR-1750	AUTOCLAVE COMPATIBLE, BRUSHABLE FAYING SURFACE SEALANT	HIGH SOLID (NVM 99%), HIGH TEMPERATURE RESISTANT (182 C), LOW VISCOSITY (50 PA - S)		
PFI-1758-G	MANGANESE DIOXIDE CURED PERMAPOLE P-5	P/S 870, PR-1436G, PR-1422G	AUTOCLAVE COMPATIBLE, CORROSION INHIBITIVE, BRUSHABLE FAYING SURFACE SEALANT	CORROSION INHIBITIVE, HIGH SOLID (NVM 97%+), LOW VISCOSITY, HIGH TEMPERATURE RESISTANT (182 C)		FMS 3055
PR-1764	MANGANESE DIOXIDE CURED PERMAPOLE P-3	P/S 872	EMI/RFI SHIELDING, CORROSION INHIBITIVE APPLICATIONS	CORROSION INHIBITIVE, HIGH TEMPERATURE RESISTANT (204 C), INSULATION RESISTANT, FUEL RESISTANT	AMS 3266	
PR-1765	MANGANESE DIOXIDE CURED PERMAPOLE P-5		LIGHTNING STRIKE ADVANCED COMPOSITE APPLICATIONS	EXCELLENT ELECTRICAL CONDUCTIVITY, HIGH STRENGTH, FUEL RESISTANT		DAN-1273
PR-1766	MANGANESE DIOXIDE CURED PERMAPOLE P-2		EMI/RFI SHIELDING, CORROSION INHIBITIVE APPLICATIONS	CORROSION INHIBITIVE, GOOD PHYSICAL PROPERTIES, FUEL RESISTANT		

PRODUCT	CHEMICAL SYSTEM	REPLACES	APPLICATION	BENEFITS	MIL SPEC	OEM SPEC
PR-1768	SILICONE ELASTOMERS		EMI/RFI SHIELDING, CORROSION INHIBITIVE APPLICATIONS	CORROSION INHIBITIVE, EXCELLENT RESILIENCE AND COMPRESSION SET (22%)		G472295, MIS-46175
PR-1770	MANGANESE DIOXIDE CURED PERMAPOLE P-5	P/S 899, PR-1750	HIGH TEMPERATURE, HIGH STRENGTH, INTEGRAL FUEL TANK SEALANT	HIGH TEMPERATURE RESISTANT (204 C), HIGH SOLID, EXCELLENT TENSILE/PEEL STRENGTH PROPERTIES	AMS G9-90AG	MS 426
PR-L775	MANGANESE-DIOXIDE CURED PERMAPOLE P-5	P/S 870, PR-1436G	NON-CHROMATE CORROSION INHIBITIVE APPLICATIONS	NON-CHROMATE CORROSION INHIBITIVE ADDITIVE, CRACK-GROWTH INHIBITION, WORKER/ENVIRONMENTALLY FRIENDLY, ENHANCED PHYSICAL PROPERTIES, HIGH TEMPERATURE RESISTANT	AMS G9-9OBC	
PR-1776	MANGANESE DIOXIDE CURED PERMAPOLE P-5	P/S 890, P/S 899, PR-1440, PR-1750	WEIGHT SAVING, INTEGRAL FUEL TANK SEALANT	WEIGHT SAVING (SP. GR.: 1. 30), HIGH STRENGTH PROPERTIES, EXCELLENT FUEL RESISTANCE		BMS 5-45
PR-1778	MANGANESE DIOXIDE CURED PERMAPOLE P-5	PR-1425, PR-380, PR-383	NON-CRAZING WINDSHIELD SEALANT	HIGH SOLID, HIGH STRENGTH, HIGH TEMPERATURE RESISTANT (182 C, 80 HOURS)	MIL-S-11031	
PR-1825	EPOXY CURED PERMAPOLE P-3	PR-1426, P/S 860	QUICK REPAIR OF INTEGRAL FUEL TANK; MILITARY AIRCRAFT BATTLE DAMAGE REPAIR APPLICATIONS	ULTRA-FAST CURE, UNAFFECTED BY RELATIVE HUMIDITY, FAST LOW-TEMPERATURE CURE (12 HOURS @ 4 C; 3 HOURS @ 25 C),		
PR-1826	EPOXY CURED PERMAPOLE P-3	P/S 890, P/S 899, PR-1440, PR-1750, PR-1422	FAST CURE INTEGRAL FUEL TANK SEALANT; CABIN PRESSURE SEALING APPLICATIONS; AVAILABLE IN BRUSH (CL A) AND FILLET (CL B) GRADES	TAST CURE (CURED IN 3 HOURS), HIGH TEMPERATURE RESISTANT (204 C, 10 HOURS), BROADER SERVICE TEMPERATURE RANGE (42 C TO 149 C)	MIL-S-29574 TYPE I	MS 404, FMS 3064, BAC 5504
PR-1826-G	EPOXY CURED PERMAPOLE P-3	PR-1422-GB, PR-1436-GB, P/S 870 B	RAPID CURE, CORROSION INHIBITIVE, FILLET SEALING APPLICATIONS	FAST CURE (TACK FREE IN 1 HOUR), CORROSION INHIBITIVE, LOW TEMPERATURE CURABLE (-51 DEG C)		
PR-1828	EPOXY CURED PERMAPOLE P-3	P/S 890, P/S 899, PR-1440, PR-1750, PR-1422	PRIMERLESS, HIGH TEMPERATURE RESISTANT, QUICK REPAIR, LOW TEMPERATURE APPLICATIONS	SELT-ADHERES TO WIDE RANGE OF SUBSTRATES, FAST CURE (TACK FREE 1 HOUR), HIGH TEMPERATURE RESISTANT (204 C, 10 HOURS), LOW TEMPERATURE CURABLE (-51 C)	MIL-S-29574 TYPE II	FMS 3064 TYPE II
PR-1829	EPOXY CURED PERMAPOLE P-3	PR-1425, PR-1725	NON-CRAZING, UV RESISTANT, WINDSHIELD/CANOPY SEALANT	FAST CURE (TACK FREE IN ONE HOUR @ 25 C), HIGH STRENGTH, LOW TEMPERATURE CURABLE (-40 C), WILL NOT DISCOLOR SUBSTRATES	AMS G9-89BT	
PR-1959	SILICONE ELASTOMERS		NON-CRAZING WINDSHIELD/CANOPY SEALANT	HIGH SOLID CONTENT, NO SHRINKAGE, HIGH TEMPERATURE RESISTANT, EXCELLENT UV RESISTANCE, FLEXIBLE		

PRODUCT	CHEMICAL SYSTEM	REPLACES	APPLICATION	BENEFITS	MIL SPEC	OEM SPEC
PR-1991	SILICONE ELASTOMERS		PRIMERLESS HIGH TEMPERATURE FIREWALL SEALANT; REPAIR OVER AGED FIREWALL SEALANTS	FLAME RESISTANT (TO 1650 C), SKYDROL RESISTANT, PRIMERLESS ADHESION, POLYSULFIDE COMPATIBLE, EXCELLENT REPARABILITY, HIGH SERVICE TEMPERATURE (TO 260 C)		DMS 1799
P/S 875	MANGANESE DIOXIDE CURED PERMAPOLE P-5	P/S 870B, PR-1422G, PR-1436-GB	CORROSION INHIBITIVE, WEIGHT SAVING FILLET SEALANT	LOW SPECIFIC GRAVITY (1.01), CORROSION INHIBITIVE		BMS 5-142, STM 40-107

7.6 Potential to Emit

Criteria and HAP Emissions

Many source definitions and compliance requirements of the CAA are based on thresholds of potential emissions. Potential to emit (PTE) is defined by the CAA as "the maximum capacity of the stationary source to emit a pollutant under its physical and operational design." Any physical or operational limitation on the capacity of the stationary source to emit a pollutant, including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design if the limitation or effect it would have on emissions is Federally enforceable."

Potential to emit is drastically different than many other types of environmental regulations and can be confusing. Traditionally P2 is focused on reducing *actual* emissions. For most practical purposes this is the correct strategy, but if an installation is trying to reduce its PTE, avoid restrictive permits, and achieve minor source status then it is necessary to reduce *potential* emissions.

P2 Option: Federally Enforceable Limits

Success: Several Air Force bases implemented many Federally enforceable limitations on their surface coating, incineration, external combustion, and woodworking operations to maintain their potential HAP emissions below the 25 tons per year threshold. For paint booths some installations used hourly limits and others placed limits on amount of paint/primer (e.g., 25 gallons per months). This strategy exempted many bases from having to comply with the Aerospace NESHAP.

P2 Option: North American Industry Classification System Code Breakouts

Success: An Air Force base was able to separate itself into smaller entities for regulation. The breakout of other services, Federal agencies, contractors, support units, and differing missions allowed the base to become a minor source.

APPENDICES

Appendix A: ACRONYMS

§	Section
ACS	Adhesive Coating Sealant System
AFVSPO	Alternative Fueled Vehicle Systems Program
AFV	Alternative Fuel Vehicle
AGE	Aerospace Ground Equipment
ALC	Air Logistics Center
APU	Auxiliary Power Unit
ARPA	Advanced Research Project Agency
AWACS	Airborne Warning and Control System
BOSS	Bicarbonate of Sodium Stripping
BRAC	Base Realignment And Closure
BTU	British Thermal Unit
CAA	Clean Air Act
CAA90	Clean Air Act Amendments of 1990
CARC	Chemical Agent Resistant Coating
CCC	Chromate Chemical Conversion Coating
CEM	Continuous Emissions Monitor
CEPPO	Chemical Emergency Preparedness and Prevention Office (EPA)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CNG	Compressed Natural Gas
CNO	Chief of Naval Operations
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CTSA	Cleaner Technologies Substitutes Assessment
CWA	Clean Water Act
DENIX	Defense Environmental Network Information eXchange
DfE	Design for the Environment Program
DoD	Department of Defense
DOT	Department of Transportation
EB	Electron Beam
EG	Emission Guideline
EMI/RFI	Electromagnetic Interference / Radio Frequency Interference
EPA	Environmental Protection Agency
EPA-17	EPA's 17 priority pollutants
EPCRA	Emergency Planning and Community Right to Know Act
ERC	Emission Reduction Credits

EtO	Ethylene Oxide
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FEMP	Federal Energy Management Plan
FTW	Flying Training Wing
GACT	Generally Achievable Control Technology
GHP	Geothermal Heat Pump
GOX	Gaseous Oxygen
GSA	Government Services Administration
GSE	Ground Support Equipment
HAP	Hazardous Air Pollutant
HCFC	Dichlorofluoroethane
HFE	Hydrofluoroether
Hg	Mercury
HMIWI	Hospital/Medical/Infectious Waste Incinerator
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HSC	Human Systems Center (Air Force)
HSWA	Hazardous and Solid Waste Amendments
HVAC	Heating, Ventilation, and Air Conditioning Systems
IPA	Isopropyl Alcohol
IPM	Integrated Pest Management
IR	Infrared
ISEA	In-Service Engineer
IVD	Ion Vapor Deposition
IWTP	Industrial Waste Treatment Plant
JSF,JPAP	Joint Strike Fighter, Paintless Airplane Program
LARPS	Large Aircraft Robotic Paint Stripping
LIN	Liquid Nitrogen
LOX	Liquid Oxygen
MACT	Maximum Achievable Control Technology
MC	Methylene Chloride
MEK	Methyl Ethyl Ketone
MIL SPEC	Military Specification
MPC	Mobile Power Center
MRC	Maintenance Requirement Card
MSDS	Material Safety Data Sheet
MSO	Molten Salt Oxidation
MWR	Moral, Welfare, and Recreation
Na_2CO_3	Sodium Carbonate
NAAQS	National Ambient Air Quality Standard
NASA	National Aeronautics and Space Administration
NDI	Non-Destructive Inspection
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NFESC	Naval Facilities Engineering Service Center
NMP	N-Methylpyrrolidinone

NOx	Nitrogen Oxide Compounds
NPDES	National Pollutant Discharge Elimination System
NSN	National Stock Number
NSPS	New Source Performance Standard
ODC	Ozone Depleting Chemical
ODS	Ozone Depleting Substance
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
P2	Pollution Prevention
PC	Pollution Control
PM	Particulate Matter
PMB	Plastic Media Blasting
PPA	Pollution Prevention Act
PPE	Personal Protective Equipment
PPEP	Pollution Prevention Equipment Program (Navy)
PTE	Potential to Emit
PVC	Polyvinyl Chloride
Q-Mo	Quarternary Ammonium Dimolybdate Salts
RACT	Reasonably Available Control Technology
RCM	Reliability Centered Maintenance
RCRA	Resource Conservation and Recovery Act
RECLAIM	Regional Clean Air Incentives Market
RIT	Retarded Injector Timing
SAE	Society of Aerospace Engineering
SCR	Selective Catalytic Reduction
SIP	State Implementation Plan
SMSA	Standard Metropolitan Statistical Area
SNAP	Significant New Alternatives Policy Program
SO_2	Sulfur Dioxide
SRB	Solid Rocket Boosters
SWDA	Solid Waste Disposal Act
TFSAA	Thin Film Sulfuric Acid Anodizing
TO	Technical Order
TRI	Toxic Release Inventory
TWA	Time Weighted Average
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAEC	U.S. Army Environmental Center
UV	Ultraviolet
VOC	Volatile Organic Compound

Appendix B: WEB SITES

Organization	**Content**	**Website**
Air and Waste Management Association	This site provides quality environmental information on publications, meetings, key links, public outreach, news items, education, and certification.	http://www.awma.org
Air Force	Air Force Pollution Prevention Pillar Needs Assessment Report for FY 96. An excellent source for pollution prevention projects in the Air Force. A lot of the AF projects listed above appear in this document.	http://www.wl.wpafb.af.mil/pprevent/
Air Force PRO-ACT	Promotes cross feed of environmental information	http://www.afcee.brooks.af.mil/pro_act/main/proact4.htm
Air Quality Management Using Pollution Prevention: *A Joint Service Approach*	This document makes the connection between air P2 and air regulations, and presents examples of air P2 in the Services.	http://www.denix.osd.mil/denix/DOD/Library/library.html
Army Environmental Center Homepage	The AEC integrates, coordinates and oversees implementation of the Army's environmental programs, and provides technical services and products to HQDA, MACOMs and Commanders.	http://aec-www.apgea.army.mil:8080/
Center for Clean Technology	The Center for Clean Technology WWW Site provides information on the Center's environmental research and associated activities.	http://cct.seas.ucla.edu/

Center for Technology Transfer and Pollution Prevention: CT2P2	The Center provides the tools necessary to transfer technical information about the environment and pollution prevention worldwide. It develops and evaluates new computer-based pollution prevention and technology transfer opportunities.	http://ingis.acn.purdue.edu:9999/cttpp/cttpp.html
Coating Alternatives Guide (CAGE)	An expert system and information base designed to recommend low-emitting alternative coating technologies to coatings users.	http://cage.rti.org/
Defense Environmental Network & Information eXchange (DENIX)	Interesting success stories can be found under "Public Menu", "Environmental Security", "Pollution Prevention", under Accomplishments and Future Directions choose "P2 Success Stories", "P2 Success Story", and scroll down for the interesting ones.	http://denix.cecer.army.mil/denix/denix.html
Defense Standardization Program (DSP)	Acquisition Practices Directorate ODUSD(Industrial Affairs & Installations) Frequently Asked Questions page	http://www.acq.osd.mil/es/std/faq.htm
Defense Supply Center	This site has information on procurement, suppliers, and links to other environmental procurement sites.	http://www.dscr.dla.mil
Department of Defense	The Defense Standardization Program (DSP)	http://www.acq.osd.mil/es/std/
Department of Defense Link	Department of Defense of link is an excellent source for publications and links to other related sites.	http://www.dtic.dla.mil/defenselink/

Environmental Industry Web Site	This site provides information about companies, which provide environmental services and products, opportunities for environmentally oriented businesses, and resources for the environmental industry as a whole.	http://www.doe.ca/
Environmental Security Technology Certification Program	ESTCP's goal is to demonstrate and validate promising, innovative technologies that target DoD environmental needs. These technologies provide a return on investment through cost savings and improved efficiency.	http://estcp.xservices.com/projects/pollutn/index.htm
Environmental Technology Office	The ETO oversees the U.S. Army's pollution prevention environmental technology program and the Department of Defense's National Defense Center for Environmental Excellence (NDCEE).	http://es.inel.gov/program/p2dept/defense/army/dodeto.html
Enviroene	Enviroene, funded by the Strategic Environmental Research and Development Program (SEDRP) and the Environmental Protection Agency (EPA), allows for the dissemination of technical pollution prevention material	http://es.inel.gov/index.html
HAP Status Binder	The purpose of this document is to keep the Services up-to-date on the status of National Emission Standards for Hazardous Air Pollutants, New Source Performance Standards/Emission Guidelines, and Control Technique Guidelines that affect the Military.	http://denix.cecer.army.mil/denix/DOD/Library/HAP/hapindex.html http://www.denix.osd.mil/denix/DOD/Library/HAP/hapindex.html (DoD access only)
Hazardous Technical Information Services	For hazardous material substitutions.	http://www.dgsc.dla.mil/htis/htis.htm

Information Center for the Environment	ICE is a cooperative effort of an interdepartmental team of environmental scientists at the University of California, and collaborators at over thirty private, state, Federal, and international environmental organizations.	http://ice.ucdavis.edu./
Joint Service Pollution Prevention Technical Library	Identifies off the shelf P2 technologies, management practices, and process changes.	http://enviro.nfesc.navy.mil/p2library/
National Defense Center for Environmental Excellence (NDCEE)	The NDCEE was established by the Department of Defense (DoD) to take action in critical areas of environmental concern for the DoD, other government organization, and industry.	http://www.ndcee.ctc.com/
National Pollution Prevention Center for Higher Education	The National Pollution Prevention Center, located at the University of Michigan, was created in 1991 by the U.S. EPA to compile, produce, and distribute educational materials on pollution prevention.	http://www.snre.umich.edu/nppc/
Naval Facilities Engineering Service Center	One of the Navy's leading environmental centers, helping to solve environmental cleanup, compliance, and pollution prevention problems.	http://www.nfesc.navy.mil/enviro/index.html
Navy Environmental Leadership Program	Finding new and innovative ways to manage Navy environmental programs since 1993.	http://www.nasni.navy.mil/~nelp/nelp.htm
Northeast Business Environmental Network (NBEN)	The NBEN provides access to information about pollution prevention and cleaner production, as well as discussion groups for area businesses.	http://www.fedworld.gov

P2 Gems	Developed by the Toxics Use Reduction Institute, P2 Gems is an internet search tool for facility planners, engineers, and managers who are looking for technical and process/materials management information on the Web.	http://www.uml.edu/TURI
SAGE	Solvents Alternative Guide	http://clean.rti.org/
U.S. Environmental Protection Agency	Information is provided under headings including rules, regulations, and legislation; science, research, and technology; and EPA standards.	http://www.epa.gov/
U.S. EPA Atmospheric Pollution Prevention Division	A division of the U.S. EPA Office of Atmospheric Programs, it provides information on CFC/PFC substitutes, improving energy efficiencies, pollution prevention programs and publications.	http://www.epa.gov/docs/GCDOAR/OAR-APPD.html
U.S. EPA's Significant New Alternatives Policy Program (SNAP)	Information on alternatives to Class I and Class II ODSs.	http://www.epa.gov/ozone/title6/snap/
U.S. EPA - Office of Pollution Prevention	Information on pollution prevention.	http://www.epa.gov/opptintr/index.html

Appendix C: REGULATORY INFORMATION

Clean Air Act and Toxic Release Inventory Reporting Requirements Applicability to Painting and Depainting Solvents

Solvent	**Process Area**			**Clean Air Act Applicability**		
Category/Example	**Paint**	**Depaint**	**VOC**	**HAP**	**ODC**	**TRI**
HALOGENATED SOLVENTS						
Methyl Chloroform (1,1,1-Trichloroethane)	X			X	Class I	X
Methylene Chloride	X	X		X		X
KETONES						
Methyl Ethyl Ketone	X	X	X	X		X
Methyl Isobutyl Ketone	X		X	X		X
Acetone	X	X				
ALCOHOLS						
Methanol	X	X	X			X
Ethanol	X		X			
Isopropanol	X		X			
AROMATIC HYDROCARBONS						
Toluene	X	X	X	X		X
Xylene	X	X	X	X		X
ALIPHATIC HYDROCARBONS						
Mineral Spirits	X	X	X			
Naphtha	X	X	X			
OTHER CATEGORIES AND COMPOUNDS						
N-Methyl Pyrrolidone		X	X			
Glycol Ethers	X	X	X	X		X[1]
Terpenes	X		X			

From Pollution Prevention and the Clean Air Act: Benefits and Opportunities for Federal Facilities, Volume II (EPA 300-B-96-009B, May 1996)

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[1] Both the HAP and TRI lists identify Glycol Ethers as a chemical category for those Glycol Ethers which are derivatives of Mono-, Di-, or Tri- Ethylene Glycol. Ethylene Glycol is also listed as an individual compound on both lists.

Governing Department Of Defense and Service Regulations for Pollution Prevention

Department of Defense (DoD)

1. DoD Directive 4210.15 *Hazardous Material Pollution Prevention* (27 July 1989)
2. DoD Regulation 5000.2-R *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs* (4 November 1996)

Air Force

1. Air Force Instruction 32-7080 *Pollution Prevention Program*
2. Air Force Instruction 32-7001 *Environmental Budgeting*
3. Air Force Instruction 63-188 *Engineering, Research, Development, and Acquisition*

Army

1. Army Regulation 200-1 *Environmental Protection and Enhancement* (21 February 1997)

Marine Corps

1. MCO P5090.2 *Environmental Compliance and Protection Manual* (26 September 1991)
2. MCBUL 4440 *Hazardous Material Consolidation Program* (22 May 1997)

Navy

1. OPNAVINST 5090.1B *Environmental and Natural Resources Program Manual* (1 November 1994)
2. OPNAVINST 4110.2 *Hazardous Material Control and Management* (20 June 1989)

Initiatives to Reauthorize the PPA

The National Pollution Prevention Roundtable is the largest membership organization in the country devoted solely to promoting P2, i.e. source reduction. The P2 Roundtable is working on initiatives to reauthorize the Pollution Prevention Act (PPA). There are a number of problems they seek to address, many of which have been experienced within DoD:

- Multi-media, prevention-based environmental protection approaches are not routinely considered.
- The current Federal environmental framework is not designed to adequately foster pollution prevention, provide flexibility for innovation within industry and within state and local governments. The current laws also do not send appropriate environmental cost signals to consumers and industry, resulting in an inefficient use of resources and pollution.
- Even with conventional and costly end-of-pipe control and treatment technologies, the nation's air, land and water resources are still being impacted--often by small difficult to manage pollution from dispersed and persistent sources.
- Funding is a major problem. Prevention-based programs are competing for resources with traditional well-funded end-of-pipe environmental management programs.

The P2 Roundtable seeks to assess and strengthen the PPA of 1990. The PPA has been considered to be fairly ineffective. The Act has a limited mandate and competes with major end-of-pipe environmental statutes such as the Clean Air Act (CAA), the Clean Water Act (CWA), and the Resource Conservation and Recovery Act (RCRA), which all contain strong requirements and enforcement provisions.

The P2 Roundtable further recommends amending the PPA to create a multi-media prevention based unified statute, to link or supersede the other single media environmental management laws.

Appendix D: EPA PROGRAMS & RESOURCES

Significant New Alternatives Policy Program (SNAP)

The list created and maintained by the EPA suggests alternatives to Class I and Class II Ozone Depleting substances. The list includes substitutes for applications such as aerosols, adhesives, coatings, inks, foam blowing, fire suppression, refrigeration, solvents, sterilants, and tobacco expansion. A copy of the list can be obtained from http://www.epa.gov/ozone/title6/snap/.

POC: US EPA, Office of Stratospheric Ozone Protection (202) 233-9152

Design for the Environment

The Design for the Environment (DfE) program works with several industry sectors to identify cost-effective alternatives to existing products and processes that reduce risks to workers and the environment while maintaining or improving performance and product quality. A typical DfE industry project includes developing a Cleaner Technologies Substitutes Assessment (CTSA) and a communication and implementation strategy. CTSAs provide detailed environmental, economic, and performance information on traditional and alternative manufacturing methods and technologies. To help industry implement some of the new technologies identified during CTSA development, DfE provides a variety of outreach tools, including fact sheets, bulletins, pollution prevention case studies, software, videos, and training materials. There are five DfE projects of potential interest to DoD:

- Printed Wiring Board Project
- Screen Printing Project
- Lithography Project
- Flexography Project
- Garment and Textile Care Program (note: EPA desires to prototype “Wet Cleaning” and other types of non-solvent based cleaning within the DoD. Currently there is only 2% market penetration of alternatives to dry cleaning. If DoD were to successfully implement these alternatives, it would be a great boon to the emerging technologies.)
- Metal Finishing Project

http://www.epa.gov/dfe/

EPA Publications

EPA Pollution Prevention Directory (EPA 742-B-94-005)
USEPA, (202) 260-7751
401 M Street, SW (3404), Washington, DC 20460

Contains information on Federal, state, and local resources, as well as university centers that are conducting pollution prevention research and training.

Pollution Prevention and the Clean Air Act: Benefits and Opportunities for Federal Facilities Volumes I and II
(EPA 300-B-96-009A and EPA 300-B-96-009B)
USEPA, (202) 260-1023
401 M Street, SW (7409), Washington, DC 20460

Guides to Pollution Prevention:

Document	EPA Document Number
The Paint Manufacturing Industry	625/7-90/005
Organic Coating Removal	625/R-93/015
Alternatives to Chlorinated Solvents for Cleaning and Degreasing	625/R-93/016
Cleaning and Degreasing Process Change	625/R-93/017
Organic Coating Replacements	625/R-94/006
Alternative Metal Finishes	625/R-94/007

ACCESS EPA (GPO Stock #: 055-000-00509-5)
A comprehensive directory to major information and services and collections of EPA and other public sector organizations. ACCESS EPA includes many online information resources such as bulletin boards, databases, and EPA scientific models.

Sources of EPA documents:

ORD Publications (G-72), (513) 569-7562
26 W. Martin Luther King Drive
Cincinnati, OH 45268-1072

Government Printing Office
710 North Capitol Street, NW
Washington, DC 20401

Pollution Prevention Information Clearinghouse
USEPA, (202) 260-1023
401 M Street, SW (7409), Washington, DC 20460
home page: http://www.epa.gov/opptintr/p2home
The clearinghouse is a distribution center for EPA documents and fact sheets dealing with source reduction and pollution prevention. It also provides a reference and referral service for pollution prevention questions.