

Reducing Use of Ozone-Depleting Substances and Chlorinated Solvents at McClellan AFB

James E. Thom, CH2M HILL, Corvallis, Oregon, and
Lance Lankford, McClellan AFB, California

Abstract

The Sacramento Air Logistics Command (McClellan AFB) has a long-established program of source emission control designed to reduce air emissions and waste discharges, in turn reducing the overall potential for environmental impact and public health risks. As part of this program and in response to continuously tightening regulations dealing with ozone-depleting substances (ODS) and chlorinated solvents, McClellan AFB, in conjunction with CH2M HILL, recently conducted a facility-wide project to: 1) inventory ODS and a few target chlorinated solvents, and 2) identify and evaluate alternatives for reducing the use of these compounds. Target chlorinated solvents included methylene chloride (METH), perchloroethylene (PERC), and trichloroethylene (TCE). This paper will present the findings of the project associated with solvent-cleaning operations conducted at McClellan AFB. The alternatives identified and evaluated included: solvent substitution, operational improvements, equipment modifications, equipment replacement, workload consolidation, and alternative processes.

Introduction

Global environmental awareness has been on the uprise for the past several years. International scientific conferences and world congresses are recognizing and attempting to minimize the environmental impact of industrial processes on our global environment.

The Montreal Protocol on Substances that Deplete the Ozone Layer, ratified by the United States in 1987, began the deluge of regulations, executive orders, and treaties aimed at reducing and soon eliminating production of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and methyl chloroform (1,1,1-trichloroethane-TCA), all of which are of interest to the electroplating and surface finishing industry.

This paper describes how one large military installation is complying with the regulations that call for phaseout of ozone-depleting substances and minimizing use of chlorinated solvents. The paper presents the results of McClellan AFB's study,

describes the processes that use ODS and chlorinated solvents, the evaluation of alternatives to reduce or eliminate use of ODS and chlorinated solvents, and the installations current program for implementation of selected recommendations.

Background

McClellan AFB is one of five Air Logistics Command Centers in the United States providing maintenance of and support to defense aircraft, surveillance and warning systems, radar sites, and space systems. The base employs approximately 17,000 people, 13,000 of whom are civilians.

CFCs, TCA, and other chlorinated solvents are critical to the degreasing, electronics cleaning, and aircraft maintenance activities conducted at McClellan AFB. Environmental managers at the base began programs to reduce and eliminate use of many solvents and ozone-depleting substances in the early 1980s. In 1991, McClellan AFB conducted a study in conjunction with CH2M HILL to identify and evaluate alternatives to reduce or eliminate use of ozone depleting substances at the base. Study phases included:

- Inventory of ozone-depleting substances used at McClellan AFB in 1990
- Review of international, federal, state, and local regulations and timelines for phaseout of substances currently in use
- Evaluation of alternatives to reduce or eliminate use
- Recommendations for implementation

The evaluation of alternatives and identification of recommendations were made within the requirements of California's waste minimization law, Senate Bill 14 (SB 14).

1990 use rates of ozone-depleting substances and selected solvents for solvent-cleaning applications are summarized in Table 1. These rates are considered to represent the baseline, from which reductions will occur as recommendations are implemented.

Table 1 Ozone-Depleting Substances and Solvents Used for Solvent Cleaning at McClellan AFB in 1990		
Process	Compound	1990 Use (kg)
Vapor Degreasing (VDG)	CFC-113	424 (935 lbs)
	TCA	20,593 (45,400 lbs)
	PERC	35,290 (77,800 lbs)
Cold Cleaning	TCA	5,470 (12,059 lbs)
	CFC-113	907 (2,000 lbs)
Ultrasonic/VDG	TCA	499 (1,100 lbs)
Precision Cleaning	CFC-11	2,359 (5,200 lbs)
	CFC-113	87 (192 lbs)
Wipe Cleaning	CFC-113	953 (2,100 lbs)
	METH	91 (200 lbs)

ODS and Chlorinated Solvent Cleaning Use at McClellan AFB

Approximately 90 percent of all solvents used at McClellan AFB for cleaning procedures are used in degreasing applications. Nine vapor degreasers, eleven ultrasonic degreasers, and one cold degreaser use TCA, CFC-113, CFC-11, and PERC in degreasing operations. Each type of degreasing operation has unique operational characteristics that needed to be evaluated before any equipment or process changes could be recommended.

Vapor Degreasing. All vapor degreasers operate on the same general principle. The cleaning action results from the condensation of hot solvent vapors onto cooler parts, flushing away contamination from the article being cleaned. The cleaning continues until the temperature of the vapor equalizes with the temperature of the part and condensation ceases. A typical vapor degreaser is an open-top tank with a heat source at the base of the tank to boil the solvent. The height of the solvent vapors is controlled by cooling/condenser coils that encircle the top of the tank and condense vapors back into their liquid state. To minimize solvent loss, the tank height above the vapor zone is extended. This area is referred to as the "freeboard" area. Lids or covers are used to prevent solvent evaporation

when the tanks are not in operation. Efficient tank design, together with proper operation and maintenance procedures, results in a very effective cleaning system.

Cold Cleaning. Degreasers that do not rely on condensation of the vapors for cleaning action are classified as cold degreasers. Cold degreasers may or may not be heated. Parts are cleaned by spraying solvent directly onto the surface or by immersing them in a tank that can be agitated. Cold cleaning is also accomplished by wiping soiled surfaces with solvent-coated rags or cloths. The absence of heat results in increased cleaning times for many contaminants. This is the simplest form of degreasing; however, unlike vapor degreasing, the parts need to be suspended on a rack for a short drying period after cleaning is completed.

Ultrasonic Vapor Degreasing. At McClellan AFB ultrasonic vapor degreasing is accomplished in a two-step cleaning procedure that starts with the more aggressive ultrasonic exposure and ends with typical vapor degreasing. The aggressive precleaning is a result of ultrasonic vibrations being transmitted through the solvent medium to the part that is immersed in the degreasing unit. High-frequency sound is used to induce vibrations that cause the rapid formation and collapse of gas bubbles in the solvent medium, a phenomenon known as cavitation. Cavitation bubbles implode

during compression, resulting in the production of small shock waves that radiate from the point of implosion. The energy released from these implosions provides the cleaning action. At McClellan AFB, the part, following immersion in the ultrasonic unit, is vapor degreased to ensure that cleanliness requirements are met.

Precision Cleaning. There are two operations that McClellan AFB refers to as precision cleaning. Both operations actually employ ultrasonic vapor degreasers using high-purity CFC-11 and CFC-113. CFC-11 is used to clean hydraulic actuators, and CFC-113 is used to clean oxygen regulators.

Wipe Cleaning. Wipe cleaning is conducted in a variety of locations throughout McClellan AFB. CFC-113 is used for electrical contact cleaning and METH is used for spot cleaning, paint removal, and removal of conformal coatings.

Evaluation of Alternatives

Short- and long-term alternatives have been identified for reducing the use of ozone-depleting substances and the target solvents at McClellan AFB. These alternatives include substitution of materials, alternative processes, operational improvements, recycling, and equipment modifications. These alternatives were evaluated using the criteria mandated in the State of California's Source Reduction and Hazardous Waste Management Review Act (SB 14). The alternatives were evaluated using these criteria to allow them to be incorporated into future revisions of McClellan AFB's Waste Minimization Plan. The evaluation criteria used included the following:

- Change in hazardous waste. How does the alternative affect the volume, concentration, or type of waste generated?
- Technical feasibility. Is the alternative technologically feasible for implementation? Is it commercially available and demonstrated?
- Economic feasibility. What are the capital, operating, and waste manage-

ment costs of the alternative? Does the option have an acceptable return on investment or other comparison?

- Effects on product quality. How will the quality of the product being produced be affected by the change with this alternative?
- Employee health and safety implications. How would the alternative affect the health and safety of workers?
- Regulatory acceptance. Are permits, variances, or compliance schedules of any state, local, and federal agencies required for this alternative?
- Cross-media effects. Are there any releases or discharges to other media as a result of the waste minimization alternative?

Short-term (1-year) and long-term (3- to 8-year) alternatives were evaluated and discussed for the processes and operations described previously. In the short term, most of the alternatives are not feasible, either because the alternatives are not developed and tested to a point of commercial availability, or because specific applications need additional evaluation and specific testing before a recommendation can be made. In the long term, several options appear viable.

Short- and long-term alternatives for solvent cleaning processes that were not rejected during the evaluation phase included:

- Consolidation of workloads. Many of the vapor degreasers were underutilized and more a matter of convenience for the operators than a necessity for operations. Two standard vapor degreasers and two ultrasonic vapor degreasers were identified for consolidation.
- Substitute aqueous cleaning. The following cleaners were recommended for further testing to be used for metal

surface cleaning and plating shop use prior to plating processes:

- Turco Sprayze
- Daraclean 283
- Enbond 4798 & 5910
- Oakite 220 NP
- Blue Gold
- Brulin 815 GD

- Substitute semi-aqueous cleaning. The following cleaners were recommended for further testing to be used for wipe or immersion cleaning:
 - Voltkut 30 GW
 - Key Chem 01386

- Substitute HCFC cleaning. The following HCFCs were identified as potential substitutes for solvent cleaning applications:
 - HCFC 141b
 - HCFC 225cb

- Improvements in operational practices
 - Add automated hoist to vapor degreasers to minimize loading and unloading losses
 - Add solvent recycling capabilities
 - Test vapor degreasers regularly for water buildup, inhibitor concentrations, and contaminant buildup to extend the life and effectiveness of solvent

- Equipment modification. Vapor degreaser modifications included:
 - Increasing freeboard ratio to a minimum of 100 percent
 - Add refrigerated chillers
 - Eliminate lip vents
 - Eliminate hand spray wands and replace with fixed spray systems

- Replace liftoff covers with biparting or roll-top type

- Equipment replacement
 - Replace traditional vapor degreasers with hermetically sealed units.
 - A TCA vapor degreaser was used in a photoetching process. An alternative photodeveloping process called Fotofoil M, which did not require TCA solvent vapor degreasing was identified as an alternative to the old vapor degreasing process.

Many of the equipment modifications (e.g., improve cover, raise freeboard) could be performed in the short term, resulting in both reduced emissions and reduced use of the solvents. Equipment replacement is also potentially feasible in the short term.

In the long term, a combination of solvent substitution, consolidation of processes, process changes, equipment replacement, and design modifications could potentially eliminate all chlorinated solvent usage at McClellan AFB. Some solvent usage may always be necessary in some applications, but as new equipment becomes available, the consumption and emission of solvents should be close to zero.

Implementation of Alternatives

Based on the evaluation of alternatives and ongoing pollution prevention activities, several modifications have been made at McClellan AFB or are in the process of being made to accomplish the goal of reducing use of ODS and target solvents. These modifications included employing alternative processes that do not use ODS or chlorinated solvents, improving operational practices, pursuing military specification changes, and replacing equipment with hermetically sealed units.

Aqueous Cleaning. McClellan AFB has replaced a few solvent cleaning operations with aqueous cleaners. An automated closed-loop aqueous

ous defluxing and cleaning process replaced two existing vapor degreasers. The aqueous cleaning systems will be used for circuit board defluxing in the printed wireboard facility. This change resulted in a reduction of 499 kg (1,100 pounds) of CFC-113 emissions in 1991. In addition, in 1991, a sphere wash rack solvent cleaning system was converted to a steam-cleaning process. Approximately 907 kg (2,000 pounds) per year of CFC-113 emissions were eliminated as a result of this change.

While some applications lend themselves nicely to aqueous cleaning, McClellan AFB does not view this alternative as a panacea for all of their solvent-cleaning applications. Some of the aqueous cleaners remove heavy metals like chromium and cadmium from the parts being cleaned during the cleaning process. The heavy metal-laden wastewater requires extensive post treatment that can drive up the cost of the entire system. This post treatment requirement, coupled with concerns over worker health and safety, wastewater toxicity, hydrogen embrittlement, and requalification and technical order change requirements, precludes a mass exodus to aqueous cleaning for all the solvent-cleaning applications.

Electrical Contact Cleaner Specification Revision. McClellan AFB has identified some likely reductions that can be made if military specifications are revised. One of the more feasible alternatives, if military specification MIL-C-81302 can be revised, is the replacement of CFC-113 for electrical contact cleaning and lubrication by either a PERC-based cleaner or HCFC 225cb. This change could be accomplished without sacrificing cleanliness objectives and would result in a reduction of 953 kg (2,100 pounds) per year or CFC-113 emissions.

Honeycomb Cell Structure Cleaning. TCA is used in a specific application at McClellan AFB to clean aircraft parts with bonded honeycomb cell structure. Other available solvents, such as PERC, would dissolve the adhesive forming the honeycomb structure, so substitute solvent cleaners are not an option at this time. Corrosion concerns over aqueous and semiaqueous cleaners preclude their use. It appeared inevitable that with the new

state-of-the-art vapor degreaser McClellan AFB built for this cleaning application, that this was one source of emissions that could not be reduced or eliminated. However, evaluation of the entire process revealed that the parts being cleaned had the potential to not require cleaning if properly cared for. Through proper handling and protection during storage, the parts may not become soiled, thus eliminating or at least minimizing the need for cleaning.

Hermetically Sealed Vapor Degreasing. Another alternative given careful consideration at McClellan AFB is the installation of hermetically sealed equipment for some solvent cleaning applications. Potentially 18,144 kg (40,000 pounds) per year of TCA use could be eliminated through the purchase and installation of hermetically sealed units. Hermetically sealed equipment and the use of alternative precision-cleaning solvents could further eliminate approximately 2,268 kg (5,000 pounds) per year of CFC-11 used in hydraulic actuator cleaning.

Hermetically sealed vapor degreasers can minimize emissions by well over 90 percent. In fact, enclosed solvent cleaning equipment from DURR Industries and Tiyoda, Inc. have shown that 99.9 percent containment is possible. Recent tests conducted by Battelle¹ reported a DURR hermetically sealed vapor degreaser to have losses of less than or equal to 1 gram per hour. This resulted in worker exposure of less than or equal to 3 ppm solvent.

With worker exposure and risk minimized, the previous aversion to using TCE in solvent-cleaning applications may be overcome. The use of TCE would avoid costly and time-consuming Technical Order changes and requalification testing, because it is already allowed as an alternative solvent under many of the military specifications calling for PERC or TCA.

McClellan AFB estimates that the workload from all of the vapor degreasers could be accomplished in hermetically sealed units with losses minimized to approximately 45 kg (100 pounds) of TCA per year. This option does require stockpiling and recycling of TCA on the base, but mini-

mizes the impact of production ban on the processes until alternatives are further developed and military specifications have been revised to incorporate changes. As older equipment is retired and new weapon systems are procured that do not require the use of ODS for maintenance of the systems, the dependence on ODS will subside.

Conclusions

McClellan AFB has a long-established program of source emission control designed to reduce air emissions and waste discharges and in turn to reduce the overall potential for environmental impacts or public health risks. McClellan AFB operates extensive data bases to track chemical use and estimate emissions of CFCs and toxic air contaminants. Between 1990 and 1991 CFC-113 use dropped 59% from 2,439 kg (5,377 pounds) to 1,012 kg (2,231 pounds), TCA usage was reduced 30% from 26,565 kg (58,559 pounds) to 18,450 kg (40,676 pounds), and CFC-11 usage was eliminated from the 2,359 kg (5,200 pounds) used in 1990. Each year, similar reductions will be monitored as McClellan AFB moves forward with its goals to reduce and eliminate use of ozone-depleting substances.

Military specifications and qualifications testing requirements are being revised to include non-ODS processes, but this is a slow, time-consuming, and expensive process. In an effort to maintain competitiveness and capabilities, McClellan AFB has proposed to purchase hermetically sealed vapor degreasers in parallel with efforts to continue testing and evaluating other promising alternatives. Purchase of the ultra-tight solvent-cleaning machines will not only allow for continued operation under current military specifications and technical orders, but is cost effective when the value of the solvents saved is considered. This option not only minimizes worker exposure to solvents and minimizes reliance on the solvents planned for production bans, but also maintains current capabilities while operating under existing technical orders and military specifications.

Reference

¹Gavaskar, Arun, Olsenbuttel, Robert, Hernon-Kenny, Laura, Jones, Jody, Salem, Mona, Becker, John R., *Onsite Solvent Recovery Study. Draft Technology Evaluation Report*, Battelle Memorial Institute Columbus, Ohio for Risk Reduction Engineering Laboratory Office of Research and Development for the USEPA, Cincinnati, Ohio, Contract No. 68/CO 0003, Work Assignment 0-06, 1992.

Bibliography

Environmental Effects of Ozone Depletion: 1991 Update, United Nations Environment Programme, November 1991.

Evanhoff, Steve, *Evaluation of Water Based, Terpene, and Freon Degreasers*, Third Annual Aerospace Hazardous Waste Minimization Conference, May 1988.

Gribble, Gordon W., "Naturally Occurring Organohalogen Compounds--A Survey," *Journal of Natural Products*, Vol. 55, No. 10, pp. 1353-1395, October 1992.

Law, Paul, *Alternatives for the Replacement of Chlorinated Solvent Degreasing*, Fifth Annual Aerospace Hazardous Waste Minimization Conference, May 1990.

Synthesis of the Reports of the Ozone Scientific Assessment Panel, Environmental Effects Assessment Panel, United Nations Environment Programme, November 1991.

Wolf, K., Yazdani, A., and Yates, P., "Chlorinated Solvents: Will the Alternatives Be Safer?" *Journal of the Air and Waste Management Association*, 1991.

World Meteorological Organization, "Scientific Assessment of Stratospheric Ozone: 1989," *Global Ozone Research and Monitoring Project Report No. 20*, Vol. II, Appendix: AFEAS Report, 1989.