POLLUTION PREVENTION SUCCESS STORIES AT TINKER AIR FORCE BASE, OKLAHOMA

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ABSTRACT

The Oklahoma City Air Logistics Center's [OC-ALC] Pollution Prevention Program is simple, direct, and fundamental: reduce the purchase and use of targeted toxic chemicals. OC-ALC has become the Air Force leader in introducing new prototype technologies into all maintenance processes and quantifying their environmental benefits. The innovative technologies are reducing the handling of hazardous materials and eliminating hazardous waste. The success of the program lies in coordinating efforts, promoting awareness, transferring technology, obtaining funds, and executing the projects. The OC-ALC pollution prevention program involves efforts to reduce the use of wastes through a hierarchy of actions. The actions are as follows: source reduction, chemical substitution, recycle and reuse, treatment, and disposal. Pollution prevention first seeks to change processes to eliminate purchase and generation of undesirable *targeted* materials [source reduction]. Where source reduction is not feasible, environmentally-complaint materials may be substituted for the non-complaint materials. The next P^2 action is to recycle and reuse the hazardous materials. The following P^2 actions include the treatment of wastes and emissions control [VOC abatement control] to reduce environmental impacts prior to disposal and only when source reduction and chemical substitution actions are not feasible [cost-prohibitive, immature technology, etc.]. At the root of the program is a compliance site assessment that identified four major processes in aircraft depot maintenance activities [painting, depainting, cleaning, and electroplating] that generates the majority of the center's hazardous waste streams. Purchase and use of hazardous chemicals are tracked to verify the validity of implemented technologies and monitor trends. The objective of this paper is to highlight technologies that have reduced targeted hazardous chemical purchases by 1,500,000 pounds, reduced the generation of hazardous industrial waste by 8,000,000 pounds, and reduced the use of ozone depleting substances [ODSs] by 330,000 pounds, annually. This paper will discuss the following technologies: abrasive carbon dioxide blasting, environmentally-acceptable chemical depainting agents, radome chemical depainting, medium pressure water jet knife, high pressure aircraft component subsystem, advanced vapor degreaser, NESHAP-compliant wipe solvents, powder coatings, and alternative electroplating technologies *[i.e., ion vapor deposition, ion vapor* high velocity oxygen fuel, electromagnetic particle deposition, etc].

PAST SUCCESSES

• Tinker AFB single managers have led the DoD in reducing toxic releases. Since the 1994 baseline year established by EPA, OC-ALC has reduced toxic emissions by over 82% or 1.5-million pounds.

• Qualified a less toxic and environmentally acceptable chemical depainting agent to replace methylene chloride / phenol strippers. This reduced methylene chloride / phenol by over 800,000

pounds per year and resulted in an estmiated cost savings of over \$245,000, annually.

• Eliminated more than 330,000 pounds of ozone depleting substances from our baseline and digitized over 7,000 technical order files to ensure reduction goals were met.

• Replaced over 14 vapor degreasers in the cleaning of aircraft parts that has eliminated over 108,000 pounds of hazardous waste and 131,000 pounds of air emissions, translating to a cost savings in waste disposal costs and avoided compliance costs of roughly \$450,000, annually.

• Implemented Electromechanical Devices Cleaning system that uses high quality aliphatic hydrocarbon solvents instead of chlorinated solvents such as Trichloroethane and CFC 113, thereby eliminating more than 12,000 pounds of hazardous waste and 14,000 pounds of hazardous air pollutants [HAPs] per year.

• Pressure Spray washing has been implemented base-wide to reduce the use of vapor degreasers and eliminate over 45,000 pounds of ODCs and hazardous material.

• New more efficient degreasers have been implemented to reduce percholoethylene solvent consumption, eliminating over 15,000 pounds of Perchloroethylene.

• OC-ALC engineers have reduced the amount of hazardous waste sludge disposal by 3,745,600 pounds annually [80.2 percent], translating to a savings of \$750,000 in hazardous waste disposal costs [82 percent]. In CY1995, the industrial wastewater treatment facility [IWTF] disposed of 4.66-million pounds of wet industrial hazardous waste at a cost of \$916,000. In CY2002, the IWTF had reduced the amount of hazardous waste disposed off-site by 3.75-million pounds [80 percent reduction]. Hazardous waste disposal costs for CY2002 totaled \$165,000, saving over \$750,000, annually.

• 24-million pounds of metals, glass, paper, wood, tires and plastics were recycled, and 100 million pounds of concrete were reused in the concrete recycling program. Solid waste disposal was reduced by 53% in 1994 and 59% in 1995, exceeding Air Force reduction goals by three years.

• OC-ALC/EMPD engineers were instrumental in evaluating alternative chemical strippers for depainting aircraft. OC-ALC is pursuing the testing and prototyping of alternative, environmentally acceptable, chemical strippers, in addition to investigating compatibility with industrial wastewater treatment facility. The benefits include mission enhancement by reducing occupational health exposures, decreasing hazardous air pollutants, reducing flow time per aircraft, and improving product quality. Past chemical strippers were not in compliance with current environmental regulations. Alternative stripper will eliminate over 500,000 pounds of hazardous chemicals annually. Alternative chemical stripper reduces chemical usage by 60 percent with a four-fold reduction in personnel health risks. New chemical depainting agent will save OC-ALC from investing \$6M in pollution control / abatement equipment.

• OC-ALC/EMPD engineers are evaluating the use of renewable energy fuels such as solar and wind. EMPD was the recipient of the 1996 DOE Renewable Energy Award for our efforts in promoting renewable energy technologies. A 6.8-kW photovoltaic array, which converts solar radiation to electricity, and a 10-kW wind turbine, which transforms wind power to electricity, have been installed on base. The photovoltaic array consists of 128 fixed, flat plate modules

generating approximately 13,350 kW-hrs per year, which amounts to 29,000 pounds per year of reduced air emissions from the utility plant and a cost savings of around \$1,050, annually. The wind turbine is 80 feet tall generates approximately 18,000 kW-hrs per year, which amounts to 38,800 pounds per year of reduced air emissions from the utility plant and a cost savings of around \$1,450, annually.

• OC-ALC/EMPD engineers are investigating water and energy conservation technologies for potential applicability at Tinker AFB. Engineers are evaluating the potential reuse of industrial and ground water with the potential to reuse 50% of the water that is currently discharged off-site.

• OC-ALC/EMPD engineers are aggressively involved in recycling of municipal solid waste with the wood chipper project and upcoming composting project. Engineers are implementing additional recycling equipment to recycle solvents, anti-freeze, engine oil, machine coolant, and hydraulic fluid.

• OC-ALC/EMPD engineers are investigating alternative electroplating technologies including Electromagnetic Powder Deposition [EPD] and Chemical Vapor Deposition [CVD] technologies, which should minimize / eliminate the use of conventional electroplating processes and their associated hazardous waste products.

• OC-ALC/EMPD was the first to implement carbon dioxide [CO₂] blasting technology as a replacement for abrasive grit blasting and chemical depainting. CO₂ blasting used to remove carbon, corrosion, and coatings from jet engine components, which were historically, accomplished using solvents, acids, and caustics [soaking hours to days]. CO₂ has replaced traditional grit blasting [*i.e.*, sand blasting], thereby eliminating the need for masking since solid CO₂ sublimes to a gas upon impact. CO₂ blasting technology reduces chemical usage, minimizes amount of hazardous waste generated, increases worker safety, and shortens processing times. CO₂ blasting has eliminated a total of 1,700 gallons of chemical [methylene chloride, *o*-dichlorobenzene, cresylic acid, caustic solutions, etc.] per year.

• OC-ALC/EMPD was the first facility to implement water jet knife technology with a robotically controlled arm. The water jet knife is capable of stripping abradable thermal spray coatings, fiberglass, paint, sealants, adhesives, and aluminum vane wraps. Historically, these operations were accomplished using methylene chloride [soaking days] and were manually scrapped away using a putty knife. Water jet knife technology reduces chemical usage, minimizes amount of hazardous waste generated, minimizes the use of water, increases worker safety, and shortens processing times. The water jet knife operates at 20,000 psi with a flow rate of 20 gallons per minute. The Water Jets have eliminated the use of 2,360 gallons per year of methylene chloride. They have also resulted in quicker processing times [from days to minutes] and increased worker safety.

• OC-ALC/EMPD implemented a chemical cleaning facility for cleaning jet engine components. Chemical cleaning is done to remove contaminants from engine components, which might otherwise interfere with other repair processes [*i.e.*, electroplating, welding, painting]. The project to extend the life of alkaline baths by 80% translates into savings of 100,000 pounds of hazardous waste per year.

• OC-ALC/EMPD engineers have placed a number of industrial spray washers throughout the installation. Industrial spray washers replaces perchloroethylene and Freon vapor degreasing operations, PD-680 solvent cleaning operations, and some traditional hand cleaning processes. Industrial spray washer technology has reduced chemical usage, minimized the amount of hazardous waste generated, increased worker safety, and shortened processing times. The processes have eliminated the use of perchloroethylene, 1,1,1-trichloroethane cleaner, PD-680 solvent cleaner, in addition to dramatic reductions in hazardous waste generation.

• OC-ALC/EMPD engineers have implemented a number of alternative electroplating technologies including ion vapor deposition [IVD] for aluminum. IVD is the main process being substituted for conventional cadmium and nickel-cadmium electroplating, thereby improving corrosion inhibition. IVD can withstand temperatures to 950°F as compared to 450°F for traditional cadmium tank electroplating process. IVD can be applied to high-strength steel without associated hydrogen embrittlement problems. IVD has eliminated 50% of cadmium usage in Propulsion Directorate, translating to a savings of 195 pounds, annually. IVD of Aluminum is performed in a vacuum where aluminum wire is fed into a chamber and vaporized. The positively charged Aluminum [AI⁺⁺⁺] vapor is attracted to the negatively charged parts, thereby depositing a uniform coating of aluminum. IVD has been used as a substitute for some previously plated cadmium and nickel-cadmium plated parts such as tie rods and landing gear bolt pins. Before the elimination of cadmium tank plating, OC-ALC used over 400 pounds of cadmium per year. Today only 40 pounds per year are being used in small-scale brush plating operations.

• OC-ALC/EMPD engineers have implemented an alternative electroplating technology called High-Velocity Oxygen Fuel [HVOF] as the newest generation thermal spray process currently approved for the application of wear / erosion coatings and thermal barriers on exhaust nozzles, combustion chambers, and compressor blades, and currently being prototyped as a chrome replacement on a series of aircraft components. HVOF coatings can be applied in approximately 45 minutes compared to over 48 hours for the same thickness of chrome. HVOF improves flexible because one machine is capable of applying over 23 different coatings. HVOF electroplating properties are being compared to the requirements of different parts to determine viable prototype candidates.

• OC-ALC/EMPD engineers are evaluating the use of another alternative electroplating technology Electromagnetic Particle Deposition [EPD] process which applies surface coatings by propelling particles against target surfaces at hyper-velocities for particle deposition. EPD is based on the DoD developed Star Wars *Rail Gun* technology that produces very dense deposit with high bond strengths and minimal part distortion. EPD benefits [*i.e.*, environmental, economic, reduced compliance burden, etc.] include cost avoidance of chemicals, decreased water utilization [environmentally safe], hazardous waste reduction [high-quality fusion bonds], improved productivity [high deposit rates], reduced flow time, and projected cost savings over two million dollars annually, with broad commercial applications.

• OC-ALC/EMPD engineers have implemented another alternative electroplating technology

Twin-Wire Plasma Flame Spray used to deposit metal on jet engine parts and aircraft components, thereby replacing the conventional nickel electroplating operations. Twin-wire flame spray has eliminated 50% of the nickel electroplating workload and its associated hazardous wastes. Plasma flame spray benefits [*i.e.*, environmental, economic, reduced compliance burden costs, etc.] include cost avoidance of chemicals, decreased hazardous waste generation, improved productivity, reduced flow time from days to minutes, and reduced nickel purchases, with broad commercial applications. This process has resulted in reduced chemical usage, reduced waste generation, and quicker processing times. Twin-wire flame spray technology has reduced the purchase of nickel by 11,400 pounds. The hazardous waste disposal associated with nickel plating has also been eliminated. Finally, the new process allows parts to be processed quicker reducing the cost and time of repairs.

• OC-ALC was one of the first DOD installations to implement an aqueous ultrasonic cleaning system as an alternative to chemical cleaning processes. The system utilizes biodegradable aqueous cleaner [low-foam, mild-alkaline, sodium-based detergent] and has eliminated the use of Freon-113, associated hazardous wastes, and air emissions. Ultrasonics is a type of agitation, which is effective at reaching interior surfaces of complex parts. The ultrasonic cleaning system, in conjunction with a high-pressure glove box washer, has replaced an ultrasonic cleaning tank, which used Freon-113 to clean parts. By converting to an aqueous cleaning process a yearly usage of over 4,000 pounds of Freon-113 has been eliminated. Consequently, the waste Freon-113 [approximately 1,800 pounds] and air emissions [approximately 2,000 pounds of VOCs] have been eliminated.

• OC-ALC/EMPD engineers are using computer models to estimate emissions from wastewater treatment processes at the industrial wastewater treatment plant [IWTP]. The efforts have involved estimating volatile organic chemical [VOC] emissions from IWTP process units [*i.e.*, equalization basins, bioreactor, etc.] utilizing computer simulation software developed by the EPA. The magnitude of VOC emissions depends greatly on many factors, such as the physical properties of the pollutants, the temperature of the wastewater, and the design of the individual collection and treatment process units. All of these factors as well as the general scheme used to collect and treat facility wastewater have a major effect on VOC emissions. By inputting process conditions and constraints, the computer simulation determines the waste stream effluent concentrations, air emission releases [*i.e.*, air emission rates], and the amount of biodegradation from each individual process unit. The modeling software was used by EMPD engineers to estimate VOC releases to satisfy the Toxic Release Inventory [TRI] reporting requirement.

SUCCESSFUL / PROVEN TECHNOLOGIES

AIRCRAFT COMPONENT SUBSYSTEM [ACS]: The ACS is a sound-proof enclosed work cell of modular construction containing a 60-inch turntable and a 30-foot linear track. The ACS incorporates medium-pressure water robotic paint strip for component stripping in lieu of chemical strippers. Examples of parts to be stripped in the ACS include inboard and outboard flaps, wheel well doors, engine cowlings, spoilers, rudders, and various other parts. The high-pressure pump is capable of 5.0 gallons per minute at 36,000 psi. The standard water use will be based on the re-circulation of water eight times prior to discharge to the IWTP. The ACS

provides an annual savings of \$1.3 million dollars. The ACS will also eliminate: 140,000 pounds of hazardous air pollutants [methyle ne chloride], 100,000 pounds of facility waste [masking requirements], 8.3 million gallons of wastewater [based on re-circulation of eight times], 76,000 pounds of IWTP hazardous waste sludge, and 330 gallons of ozone depleting chemicals. Perhaps the most impressive benefit of the ACS technology is that it removes personnel from a hazardous work environment, reducing worker turnover by 30 percent.

AQUEOUS IMMERSION FLUSH SYSTEM FOR TUBING: OC-ALC manufactures replacement tubing for air, fuel, hydraulic, and oxygen systems for both engine and aircraft overhaul operations. The manufacturing process leaves a film of forming lubricant inside the tube. This oily film was traditionally removed using a TCA vapor-degreasing unit. In 1996, the system was fabricated, delivered, and installed at OC-ALC for \$150,000. The cleaning process consists of immersing and flushing the tubes with an aqueous cleaning solution and then rinsing the tubes with deionized water. This project has reduced TCA usage by a total of over 14,000 pounds from a 1994 baseline and has saved \$55,000 in annual material costs. Furthermore, it eliminated the use of ozone depleting compounds and the compliance requirements associated with the halogenated solvents NESHAP.

HIGH PRESSURE SPRAY WASHER FOR WHEEL BEARINGS: OC-ALC is the home of the only LEVEL 2 bearing overhaul unit in the USAF. Wheel bearings are repaired here and arrive from the user coated with a thick layer of grease and grime. These soils were traditionally removed in a 1,1,1-trichloroethane vapor degreaser. With pollution prevention funding and procurement assistance, a highly effective high-pressure spray washer was procured. The system was delivered, installed, and made fully operational January 1997. This system was well received by shop personnel and is cleaning the wheel bearings in the same time it took for vapor degreaser cleaning and sometimes half the time depending on the level of soil. Project eliminated over 2,400 pounds of TCA from 1994 baseline and reduced yearly material costs by \$9K.

PERCHLOROETHYLENE REDUCTION: In 1990, Tinker AFB's various propulsion shops operated 11 vapor degreasers. By 1994, all the degreasers had been shut down and replaced with aqueous washers except for two located in the plating shop. Those two degreasers consumed more than 70,000 pounds of perchloroethylene [PCE] annually. The primary workload for these last two degreasers was plating wax removal. Secondary workloads included hard-to-clean applications for other propulsion shops that were not adequately cleaned by aqueous means. In 1997, the Propulsion Directorate shut down one of the plating shop degreasers in anticipation of replacing it with a system using more environmentally friendly technologies. In 1998, a closed-loop vacuum vapor PCE degreaser was installed. Operating full-time, this environmentally friendly degreaser uses less than 800 pounds per year of PCE [a 97% reduction over conventional degreasing]. The propulsion shop now operates only one conventional degreaser and one vacuum degreaser and consumes less than 30,000 pounds of PCE on an annual basis. Two other replacement projects are planned and include: (1) development and implementation of a hot oil dip process followed by aqueous parts washing for plating wax removal, (2) implementation of an alternative watersoluble maskant for electroless nickel and borazon plating, and (3) implementation of a second closed-loop vacuum vapor PCE degreaser.

HIGH VELOCITY OXYGEN FUEL: The electroplating of jet engine components has been improved using a robotically-controlled high velocity oxygen fuel [HVOF] coating tool. The process provides the same 85% deposit efficiency as occurs with conventional chrome electroplating, however, it has superior wear and hardness qualities. Each year HVOF technology eliminates over 800,000 pounds of RCRA-regulated waste, including 70,000 pounds of hazardous chromium and chlorinated solvents. Additional savings occur because the purchase of chrome-plating solvents are reduced by 40%. HVOF flame spray is the newest generation high-energy thermal spraying process currently approved for the application of wear / erosion coatings and thermal barriers on exhaust nozzles, combustion chambers, and compressor blades. The main advantage of HVOF over other thermal spray processes is the high impact speed that is obtained by the molten droplets of metal, producing a very dense, hard coating. In addition, HVOF coatings can be applied in approximately 45 minutes compared to over 48 hours for the same thickness of chrome. Wastewater is virtually eliminated because there are no rinse waters involved. Masking waste is also eliminated because the masking will consist of bolt-on sheet metal masks. Finally, HVOF is very flexible because one machine is capable of applying over 23 different coatings.

ENGINE MANIFOLD CLEANING SYSTEM: Before the installation of Engine Manifold Cleaning System [EMCS], fuel manifolds and nozzles were manually cleaned in several large tanks containing either an alkaline permanganate scale remover or an alkaline rust remover. The scale remover contains both sodium hydroxide [NaOH] and potassium permanganate [KMnO₄] while the rust remover contains NaOH and surfactants. Personnel were required to manually transport the parts from one tank to another and were subject to close contact with the above hazardous materials. With the EMCS, parts to be cleaned are introduced into the process by mounting them manually on fixtures placed at four workstations and conveyed automatically into the cleaning line. Once inside the cleaning area, a robotic transporter moves the parts through the process tanks. Feed chemicals are introduced and waste materials are removed via a piping system, which reduces spills and leaks. Parts are removed from the process by automatic conveying and manual removal of fixtures. Control of the process is accomplished by a supervisory computer located outside of the cleaning line in an elevated control room. The EMCS incorporates a permanganate rejuvenation system, where spent solution is back reacted into full-strength potassium permanganate. There are benefits, (1) higher degree of safety to operating personnel as the worker is completely removed from harsh cleaning environment, and (2) through the permanganate rejuvenation system, the generation of hazardous waste from this process has been eliminated while at the same time providing improved cleaning performance.

INDUSTRIAL SPRAY WASHERS: Industrial spray washers have been installed in several shops throughout the Commodities Directorate to replace vapor-degreasing operations. These washers are very much like domestic dishwashers except they are typically larger, the detergent is stronger, and the water is sprayed at a higher pressure [50 *psi*]. The types of parts that are cleaned include Constant Speed Drive [CSD] casings, CSD internals, tail feathers, and cables. The washers have proven themselves as they provide non-corrosive superior cleaning. The cleaning solution used in the washer is prepared with a mild alkaline sodium silicate detergent and is reused for many cleaning cycles. The 140°F solution is pumped into the cleaning chamber at 50 *psi* and attacks parts from all angles as the part is rotated. As the solution is recirculated

from the cleaning chamber to the tank it passes through a series of filters which remove the majority of particle contamination. Following the cleaning cycle, the machines automatically begins a rinse cycle to remove the soapy solution. Once the cleaning and rinsing cycles are complete, parts are removed and much of the residual water flashes off. The remaining water is blown-off using a supply of compressed shop air. Cleaning and rinsing time can be adjusted as needed, typically 10-15 minutes total. Four industrial spray washers have replaced three vapor degreasing cleaning operations and one cold cleaning operation. Yearly usage of over 18,000 pounds of 1,1,1-trichloroethane and 5,000 pounds of Freon-113 is eliminated, as well as 11,500 pounds of waste and five tons of air emissions.

AIRCRAFT RADOME DEPAINTING: This effort was to identify and implement a replacement for methyl ethyl ketone [MEK] in aircraft radome depainting operations. Although MEK is an ideal depainting solvent, it is identified as a hazardous air pollutant [HAP] by the Clean Air Act Amendments of 1990. No alternative method identified has matched the cost and time benefits of MEK stripping. Considered alternatives were destructive to the sensitive structures, or were cost prohibitive, or were not practical, feasible or beneficial to implement. The material goes further, our compliance burden is reduced, and it is safer and less labor intensive to use. Average annual emissions of MEK from the stripping booth exceed 60,000 pounds. In a productive year, the amount topped 78,000 pounds. Considered alternatives included booth modifications to reduce MEK emissions, stripping with alternative media [medium pressure water, wheat starch, carbon dioxide, plastic media, sodium bicarbonate], laser stripping, flashlamp ablation of the coating, and alternative chemical strippers. Achieved stripping times and base rates are provided in TABLE I. Optimized stripping with dimethyl esters provided approximate stripping rates of 60 ft^2 per labor hour [liquid and gel]. This compared to optimum stripping rates of 29 ft^2 per labor hour [B-52] and 38 ft² per labor hour [KC-135] with the baseline MEK. Careful groundwork and patience were the primary keys to success. The optimized stripping process has exceeded expectations.

	LABOR TIME	STRIPPING RATE [minutes per square foot]		
B-52 RADOME [130 Square Feet]				
MEK	975 minutes	7.50 minutes per square foot		
MEK	270 minutes	2.08 minutes per square foot		
Ester-based Solvent	180 minutes	1.38 minutes per square foot		
Ester-based Solvent	130 minutes	1.00 minutes per square foot		
Ester-based Gel	100 minutes	0.77 minutes per square foot		
KC-135 RADOME [48 Square Feet]				
MEK	75 minutes	1.56 minutes per square foot		
Ester-based Solvent	46 minutes	0.96 minutes per square foot		

TABLE I. Comparison of Radome stripping rates and labor requirements

Comparison of cost effectiveness is a factor in acceptance of an alternative. Cost of the dimethyl ester liquid is \$0.90 per pound [\$10 per gallon], compared to \$0.50 per pound [\$3.35 per gallon] for MEK. The gel runs \$16.50 per pound [\$150 per gallon]. For cost analysis [TABLE II], approximations were made for annual workload based upon previous years performance.

PROCESS ELEMENT	CURRENT PROCESS [MEK]	ESTER LIQUID	ESTER GEL
Chemical Cost	\$39,150	\$11,200	\$63,000
Labor Cost	\$14,600	\$8,300	\$8,000
Disposal Cost	\$1,200	\$1,200	\$1,200
Operating Cost	Negligible	Negligible	Negligible
Environmental Compliance	\$700	\$400	\$400
Total Annual Costs	\$55,650	\$21,100	\$72,600

TABLE II. Cost benefit analysis

Based upon a time standard, the sprayable gel application provided best results, but expected costs were unsatisfactory. Reasonably similar performance could be achieved with the blanketing technique developed during optimization. Without MEK, environmental compliance costs of HAPs monitoring, recording and reporting may be eliminated for the site. Projected cost savings are approximately \$30,000 per year. An analysis may also be based upon cost per square foot, and provides the following breakdown in TABLE III. From a functional standpoint, the dimethyl ester solvent is a drop-in replacement for MEK and is effective in removing all three components of the standard B-52 and KC-135 radome coating systems. OC-ALC has reduced VOCs from this one source by 85%. The material goes further, it is less labor intensive, and our compliance burden is reduced. Implementation of the alternative will additionally prevent the potential expenditure of up to \$2,000,000 for VOC emissions controls on the existing stripping booth.

TABLE III. Estimated Total Cost per square foot [ft²]

CHEMICAL	COST PER SQUARE FOOT	
Methyl Ethyl Ketone	\$4.00 per foot ²	
Dimethyl Ester Liquid	\$1.50 per foot ²	
Dimethyl Ester Gel	\$5.20 per foot ²	

FUTURE SUCCESSES

FOUR-DIMENSIONAL REAL-TIME VISUALIZATION OF AIR QUALITY MODELING DATA: Cooperative effort with University of Oklahoma. Project objective is to investigate the use of fourdimensional visualization and analysis of air emission units, controls, emission points, and pollutant plumes released from emission units. The technology can be used to analyze and interpret air quality data, in addition to confirming compliance with current and future environmental regulatory constraints. The objective is to provide a tool for four-dimensional [real-time] visualization and analysis of OC-ALC air emission units, controls, emission points, and pollutant plumes released from those emission units using real-time weather information and user-defined emission rates. These tools shall be implemented as an extension of the existing TAFB geographical information system [GIS] associated with the Air Quality Utility Information System [AQUIS] / Air Information Management System [AIMS] database. Real-time capabilities will enable pro-active scheduling [and increase] of installation workload while insuring emission compliance with federal, state, and local air quality standards. The system will move from a platform that merely presents a static picture [based on annually determined emission statistics using primarily mass-balancing], to a system that is truly real-time and dynamic, providing an up-to-date depiction of pollution emissions based on instantaneous emission monitoring and real-time meteorological information. The new system will use satellite imagery to track certain kinds of pollutants from their sources. The value of such real-time capability is in enabling the scheduling of workload across TAFB such that the cumulative emissions are in continual compliance. Daily air pollution management could result in commodity trading of emissions with other DOD installations or commercial industry sites and an overall increase in the permissible workload on base.

INTERACTIVE WEB-BASED ENVIRONMENTAL TRAINING: Cooperative effort with University of Oklahoma. Project objective is to develop an interactive web-based training program designed to provide air quality training for installation personnel. The training shall include discussion on the environmental requirements specific to Tinker AFB [Clean Air Act, Halogenated NESHAP, Aerospace NESHAP, Chrome NESHAP, Pollution Prevention Requirements, Solid Waste Management Program, Environmental policy overview, Impact card policy, and ISO 14000. etc.]. The training will be in an interactive web-based format accessible to all personnel on the installation. The interactive web-based training will be constructed in modules upon which additional modules / units can be easily added at some future time. Each of the training modules will be designed in a tiered approach depending on the level of responsibility of the user, from shop personnel, shop supervisor, Product Directorate manager, to unit environmental coordinator. The program will track individual personnel interactive training has been successfully completed [dates, time, level of proficiency, etc.]. The system is currently on-line and can be accessed from the Internet [www.tinker.ou.edu].

AIR-SPARGED HYDROCYCLONE TECHNOLOGY: The project objective is to investigate, evaluate, field-test, and design an air-sparged hydrocyclone [ASH] system for application at OC-ALC. The technology has been tested to determine performance at three sites around the installation. To date, the ASH system has been tested at the AFFF pond south of B2121, IWTF D_1-D_2 blending tanks, and IWTF oil-water separator diversionary structure. The objective was to primarily reduce the chemical oxygen demand [COD] of these waste streams and secondarily remove the metal components. The initial test results indicate that the ASH technology has reduced the AFFF COD by 86 percent. The COD reductions for both the IWTP D_1-D_2 blending tanks and IWTP oil-water separator diversionary structure were limited to 15 to 25 percent. The difficulty is thought to be because of the increased solubility of the alcohol-based chemical depainting agents, which limited the COD removal. On a positive note, the ASH technology removed all metal constituents by 90+ percent. OC-ALC engineers are currently investigating the potential to use the ASH technology to pretreat the chemical stripper wastewater to reduce the organic and metals loading on the industrial wastewater treatment facility.

IWTF TOXIC RELEASE INVENTORY MODELING: Cooperative effort with Oklahoma State

University. The project objective is to improve / validate the accuracy, reliability, and repeatability of target pollutant emissions [toxic release inventory or other targeted chemicals, etc.] through monitoring, process unit sampling, and computer modeling of IWTF air emission sources [primary paint chip clarifier, oil-water separators, equalization basins, storage / stabilization tanks, metals treatment basins, solid contact darifiers, lift stations, and gravity thickeners]. In addition, the general fate models [WATER9 and TOXCHEM3] will be validated using pilot plant facilities and the ambient air quality information used to conduct a health risk assessment on the surrounding target population. Current methods need to be improved to satisfy current and future regulatory tracking and reporting requirements and improve compliance with maximum ambient air concentration [MAAC] standards. The intent of this project is to quantify target chemical emissions from the major IWTF emission sources and develop an air emission sampling strategy to improve the accuracy of the air emissions reporting data.

SLUDGE DEWATERING OPERATION: Cooperative effort with Oklahoma State University. The project objective is to improve the current metal hydroxide sludge dewatering operation at the industrial wastewater treatment plant. The current method is inadequate and requires that the hazardous aqueous metal hydroxide sludge be disposed without dewatering, which increases the compliance burden for the installation and Air Force. As part of this effort, the contractor will need to investigate the design capacity and capabilities [limitations, etc.] of the mechanical sludge dewatering equipment [plate-and-frame filter press, pre-coat operation, etc.]. In addition, the effort shall investigate alternative electrolytic flocculants [anionic / cationic polymers, etc.] to improve the sludge settling / separation characteristics of the upstream process units [primary paint-chip clarifier, oil-water separators, solid contact clarifiers, gravity thickener, etc.].

INVESTIGATION OF NEW CHEMICAL DEPAINTING AGENT: EM is evaluating two new aircraft chemical strippers [*Plane Naked* and *PR5020*]. They are both very similar to the Eldorado two-part purple-goop stripper that they currently use. The Aircraft Product Directorate is estimating that it will save \$300,000 annually as well as be safer for the worker. From initial data, the proposed chemicals are a drop-in, environmentally acceptable, cost-effective replacement for the two-part product.

IWTF METALS TREATMENT OPTIMIZATION: Cooperative effort with Oklahoma State University. The objective of this project is to optimize the metals treatment process at the industrial wastewater treatment facility. OC-ALC produces a wide variety of aqueous waste streams, which require significant treatment prior to discharge. These waste streams include oils and greases, heavy metals, volatile organic chemicals, and biodegradable organics. Much of this treatment is performed at the sites industrial waste treatment plant, which includes primary clarification, oilwater separation, flow equalization / stabilization, heavy metals treatment / removal, secondary clarification, and mechanical dewatering activities. The effort was to quantify the pH range to maximize metals precipitation and coagulation / flocculation processes, determine the impact of wastewater temperature on the chemical equilibrium mechanisms, and recommend an optimum feed rate for the ACH, electrolytic cationic / anionic polymers, and caustic.

LONG RANGE TRANSPORT OF OZONE PRECURSORS: Cooperative effort with the University of Oklahoma. The project objective is to conduct an impact assessment of long-range transport of ozone precursors from the Dallas—Ft. Worth area on the local air quality at Tinker AFB. The project focused on the identification of regional weather patterns typically occurring during ozone pollution episodes. Finally a modeling study will be designed aiming at impact quantification of long-range pollutants transport on air quality at Tinker AFB. The final objective was to use the modeling results to formulate emission reductions strategies in order to quantify local and regional scale contributions to the ozone pollution in the OC-ALC / OKC metro area. It is well know that ozone pollution is not a local, but multi-scale problem that extends up to regional, sometimes even continental boundaries. It is necessary to cross-examine pollution plumes at all three scales [local, urban, and regional] to comparatively assess OC-ALCs pollutant contribution and develop strategies for management of those emissions.

COMPUTATIONAL FLUID DYNAMICS MODELING: Cooperative effort with University of Tulsa. The project objective is to identify potential air flow problems associated with siting the aircraft production depaint facility directly north of the engine test cell [B3234]. There is concern that the proximity to B3234 will disrupt the air flow to the test chamber and engine, thereby inducing engine stall conditions that will adversely impact engine performance with the potential for severe engine failure and damage. The objective is to evaluate problems that might be associated with siting the proposed depaint facility. The question is not limited to investigating only air flow problems that may potentially affect the B3234 mission, but includes how the proposed siting may affect the aircraft paint / depaint operations. There might be more concern of how B3234 emissions *[i.e.*, particulates, combustion, JP-8, etc.] will affect downwind paint and depainting activities. In addition, there is concern that volatile organic chemical [VOC] emissions from paint and depaint operations may impact the surrounding region. This effort began by evaluating engine test cell air flow concerns [*i.e.*, fluid flow modeling], followed by discussion of B3234 mission influences to paint / depaint operations [*i.e.*, particulate deposition modeling], discussion of VOC emissions from the proposed paint and depaint facilities *[i.e., VOC air dispersion* modeling], and finish with alternatives for a more detailed investigation.

IWTF HYDRAULIC LOADING: Cooperative effort with Oklahoma State University. Investigate impact of increased hydraulic, solids, and constituent loading on industrial wastewater treatment plant. The project objective was to conduct a hydraulic modeling study, to include a field study, on the IWTF. There is concern that an increase in the flow rate, solids loading, and component concentration [heavy metals and organic constituents] will create future operational problems. The intention of the effort was to determine the impact an increase in wastewater influent and flow parameters will have on plant operations. As part of the effort, the contractor identified process unit weaknesses, bottlenecks, and different operating scenarios for potential increases. For example, will the solid contact clarifier be capable of handling the increase in flow and solids loading, what is the projected limit before we bring on the second unit, can they be operated more efficiently in series configuration.

GEOTHERMAL HEAT PUMP TECHNOLOGY: Cooperative effort with Oklahoma State University. The project objective is to identify and evaluate opportunities for implementation of geothermal heat pump [GHP] technology. The study focused on B3001 Annex 3, B3225, Natural Resources Center, and military family housing. Three of the areas were prime candidates for the technology with amazingly short paybacks, significant energy savings, and considerable environmental savings. Evaluating the payback for a 82.5-ton GHP system in one annex of B3001, total saving is estimated at \$844,260 per year. Energy savings potential for the Depot Corrosion Control Facility [B3225] was approached using a combination of water-to-water GHP units supplying fluid to a radiant floor system to assist in heating and cooling the aircraft and a total energy recovery system. The paint area has conditioned air passing through it on a 100% outside air supply. The total energy recovery wheel will save 70% of the energy, using an energy wheel that transfers both sensible and latent energy. It is projected that a radiant floor system would reduce savings in four ways: (1) the time to acclimate the aircraft by peak load shaving and sensible load transfer, (2) it would also reduce the HVAC load by allowing the supply air temperature to be lower by $4^{\circ}F$, but the radiant floor would maintain the skin temperature at $76^{\circ}F$, (3) reduction in cost would also result from the radiant energy replacing a portion of the current energy supply and associated maintenance, and (4) the final potential savings feature is the reduction of flow rate through the supply registers and still maintains quality painting. The last one needs to be confirmed so the payback is calculated with the first three savings and also with all the savings features. An evaluation of the GHP / radiant / energy recovery system resulted in an annual savings of \$443,488 and a payback of 4.4 years if only three of the savings techniques are incorporated. By using the four techniques, the savings becomes \$510,406 with a payback of 3.8 years.

IWTF LIFECYCLE COST: EM sponsored an Air Force Academy Cadet for the adet summer research program. The objective is to quantify lifecycle costs associated with operating the industrial wastewater treatment plant processes. This effort will require quantifying the IWTF operating costs, *i.e.*, sludge disposal, utility, process unit maintenance, equipment, chemical treatment, labor, etc. This effort will assist the government in quantifying the upstream production costs and enable the process engineer to make better engineering decisions.

GAS PHASE CORONA / PLASMA TECHNOLOGY FOR DESTROYING VOC EMISSIONS: The project objective is to demonstrate gas phase corona / plasma reactor technology capability to destroy VOC and other hazardous air pollutants from paint booth exhausts. The main objective of this demonstration is to obtain design data for a full-scale system that can be compared to alternative technology options. The goals of this demonstration are to (1) identify and correct operational difficulties so as to operate trouble -free and maintain >90% removal of VOCs for continuous two week operation, (2) establish optimum operating conditions, (3) test capacity limits of system components to be used for the design of the full scale equipment and cost estimates, and (4)

collect statistically significant data to verify VOC destruction, and determine operating costs (to include utility / electrical costs). Based upon the results of the demonstration the contractor shall develop full scale capital and operating cost estimates will be prepared using guidelines included in commonly used environmental cost analysis methodology and cost and performance guidelines.

ENVIRONMENTAL DEVELOPMENT PLANNING FUNCTION AT BROOKS AFB: Developed partnership with Environmental Development Planning [EDP] function at Brooks AFB [HSW] and Sam Houston State University investigating the latest wastewater technologies for their Air Force application and commercial development. The intent of the effort is to investigate the latest innovative treatment technologies for industrial wastewater treatment plants.

INDUSTRIAL WASTEWATER CHARACTERIZATION: OC-ALC has placed wastewater flow meters on ten lift stations around the industrial complex in order to develop a better understanding of pollutant and hydraulic loading being discharged from the major processing facilities. This information will be used to develop pollution prevention opportunities. From this information, engineers have determined that roughly 70 percent of the metals loading and 90 percent of the organic loading on the industrial wastewater treatment plant is coming from the aircraft chemical depaint operations. In an effort to minimize the impact from the chemical depaint operation, engineers are addressing the pollution prevention opportunities by investigating the use of alternative chemical depainting agents [*Plane Naked* and *PR5020*] and pretreating the chemical stripper effluent [*i.e.*, air-sparged hydrocyclone, biological digestion, etc.] prior to discharging to the IWTF. From the initial investigation, the rew chemical strippers could save an estimated \$300K annually, while the air-sparged hydrocyclone technology could save roughly \$100K yearly.