

NDCEE

National Defense Center for Environmental Excellence



FY04 TECHNOLOGIES PUBLICATION



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Acronyms & Abbreviations



AAP	Army Ammunition Plant
AFB	Air Force Base
AFIOH	Air Force Institute of Occupational Health
ALC	Air Logistics Center
ARL	Army Research Laboratory
ASTM	American Society for Testing and Materials
ATV	All-terrain vehicle
BOD	Biochemical oxygen demand
BTTN	1,2,4-butanetriol trinitrate
C	Celsius
CARC	Chemical agent resistant coating
CCAD	Corpus Christi Army Depot
CCC	Corrosion Control Center
CEG-A	Combat Equipment Group-Afloat
CERL	Construction Engineering Research Laboratory
CFR	<i>Code of Federal Regulations</i>
CHP	Corn hybrid polymer
CID	Commercial item description
COD	Chemical oxygen demand
CPC	Close proximity containment
CRT	Cathode ray tube
CTC	Concurrent Technologies Corporation
CT/LDC	Commercialization of Technologies to Lower Defense Costs
DC	Direct current
DEER2	Demanufacturing of Electronic Equipment for Reuse and Recycling
DHCC	Deployable HazMat Control Center
DLA	Defense Logistics Agency
DNA	Deoxyribonucleic acid

DOCS™	Drive-On/Through Containment System
DoD	Department of Defense
DODIC	Department of Defense Identification Code
DOE	Department of Energy
DRMS	Defense Reutilization and Marketing Service
DSBR	Dynamic Suspended-Bed Bioreactor
ECAM SM	Economic Cost Analysis Methodology
ECD	Electron capture detector
EDCT	Electronic Data Collection Tool
EDX	Energy dispersive X-ray
EPA	U.S. Environmental Protection Agency
EPP	Electrolytic plasma processing
ERDC	U.S. Army Engineer Research and Development Center
ESOH	Environment, Safety and Occupational Health
F	Fahrenheit
FBG	Fiber Bragg Grating
FBR	Fluidized bed reactor
FC _{Tec}	Fuel Cell Test and Evaluation Center
FEMMS	Facility Environmental Management and Monitoring System
FESEM	Field emission scanning electron microscopy
FY	Fiscal year
GAC	Granular activated carbon
HAP	Hazardous air pollutant
Hazmat	Hazardous material
HEPA	High efficiency particulate air
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HVLP	High-volume low-pressure
HVOC	halogenated volatile organic compound
IAAAP	Iowa Army Ammunition Plant
IBAD	Ion beam assisted deposition

IHDiv	Indian Head Division
IRR	Internal rate of return
IVD	Ion vapor deposition
JMC	Joint Munitions Command
kW	Kilowatt
LADS	Laser Automated Decoating System
LAN	Local area network
LHMEL	Laser Hardened Material Evaluation Center
LSAAP	Lonestar Army Ammunition Plant
MAIM	Magnetically assisted impacting mixing
MANATEE	Managing Army Technologies for Environmental Enhancements
MEK	Methyl ethyl ketone
MIC	Metastable intermolecular composites
NAB	Naval Amphibious Base
NAVAIR	Naval Air Systems Command
NC	Nitrocellulose
NDCEE	National Defense Center for Environmental Excellence
Nd:YAG	Neodymium yttrium aluminum garnet
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NG	Nitroglycerine
Ng	Nanograms
NO _x	Nitrogen oxide
NPDES	National Pollutant Discharge Elimination System
NPV	Net present value
NSWC	Naval Surface Warfare Center
NSWCCD	Naval Surface Warfare Center, Carderock Division
OC-ALC	Oklahoma City Air Logistics Center
OASA (I&E)	Office of the Assistant Secretary of the Army for Installations and Environment

ODASA(ESOH)	Office of the Deputy Assistant Secretary of the Army for Environment, Safety, and Occupational Health
ODS	Ozone-depleting substance
OO-ALC	Ogden Air Logistics Center
PC	Personal computer
PCMS	Passive countermeasure system
PCR	Polymerase chain reaction
PEPS®	Plasma Energy Pyrolysis System
PGDN	Propylene glycol dinitrate
PID	Photoionization detectors
PMB	Plastic media blasting
PMMS	Portable Munitions Monitoring System
POL	Petroleum, oil and lubricant
ppm	Parts per million
psi	Pounds per square inch
RCRA	Resource Conservation and Recovery Act
RFAAP	Radford Army Ammunition Plant
RNA	Ribonucleic acid
SAC	Strong acid cationic
SBA	Strong base anionic
SCR	Selective catalytic reduction
SHT	Special hull treatment
Syngas	Synthesis gas
TACOM	U.S. Army Tank-automotive and Armaments Command
TACOM-ARDEC	U.S. Army TACOM - Armament Research, Development & Engineering Center
TARDEC	U.S. Army Tank Automotive Research Development and Engineering Center
TBP	Thermophilic (Biological) Process
TEGDN	Triethyleneglycol trinitrate
TFLRF	TARDEC Fuels and Lubricants Research Facility

TMETN	1,1,1-trimethylolethane trinitrate
TNT	2,4,6 trinitrotoluene
TYAD	Tobyhanna Army Depot
μl	Microliter
UHPWJ	Ultrahigh-pressure waterjet
U.S.	United States
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center
USAKA/RTS	U.S. Army Kwajalein Atoll/Reagan Test Site
UV	Ultraviolet
UXO	Unexploded ordnance
VOC	Volatile organic compound
W	Watt
WAC	Weak acid cationic
WBA	Weak base anionic
WD-CARC	Water-dispersible chemical agent resistant coating
ZCW	Zinc cut-wire



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Overview



TRANSFERRING TECHNOLOGY SOLUTIONS
Supporting DoD Readiness, Sustainability, and Transformation

NDCEE

National Defense Center for Environmental Excellence

Introduction

In 1991, the U.S. Congress established the National Defense Center for Environmental Excellence (NDCEE) as a national leadership organization to address high-priority environment, safety and occupational health (ESOH) problems for the Department of Defense (DoD), other Government organizations, and the industrial community. The NDCEE is operated by Concurrent Technologies Corporation (CTC), a nonprofit organization. The NDCEE's mission is to:

- Transfer environmentally preferable materials, processes and tools to defense applications and private industry
- Provide training that supports the use of new, environmentally preferable technologies
- Support applied research and development, where appropriate, to transfer new technologies.

The NDCEE is focused on meeting specific end-user needs and emphasizes risk reduction, cost savings, enhanced readiness, and environmental excellence. These outcomes are addressed as an integral part of the NDCEE program by:

- Focusing on sustainable activities that have positive financial impacts
- Transferring technologies that have been demonstrated and validated to meet end-user acceptance criteria
- Leveraging other tasks to eliminate duplication of efforts.

This approach helps to speed technology deployment through integrating environmental decisions into facility and weapon-system life-cycle management decisions. The technology transfer focus at NDCEE complements related transfer activities that are managed by the Joint Services such as those under the Army's Environmental Quality Technology Program.

Technology transfer is the ultimate measure of success for the NDCEE. Since its inception, the NDCEE has provided technology demonstration, validation, implementation and other technical services to a variety of Government organizations, DoD contractors, and other private organizations. More than 330 transfers and/or demonstrations of technology solutions have been completed or scheduled. These technologies include manufacturing materials and processes, environmental treatment and control devices, pollution prevention technologies, and site assessment and clean-up technologies. In addition, nearly 470 technology tools have been developed and transferred through NDCEE activities. Examples of such tools include training, environmental cost analyses, databases, Web sites, geographical information systems, risk analyses, and information exchanges.

This third *NDCEE Annual Technologies Publication* contains the results of the NDCEE's technology demonstration and transfer activities for 33 technologies in fiscal year (FY) 2004. Each technology summary includes a general description along with technology benefits, advantages, and limitations; specific FY04 NDCEE accomplishments; economic analysis findings (if applicable) including capital and operating cost estimates as well as payback periods; suggested implementation applications; points of contact; and applicable NDCEE tasks. To aid readers in identifying technologies that may address their specific challenges, the summaries highlight one or more generic ESOH needs that the technology addresses.

In conjunction with the above technology-related activities, the NDCEE operates a Demonstration Facility. This facility is described on page 95. Immediately following the facility description are summary sheets on each of the facility's technologies.

The Office of the Assistant Secretary of the Army for Installations and Environment (Environment, Safety and Occupational Health) [OASA (I&E) - ESOH] is the designated Executive Agent for the NDCEE Program. Additional information on the NDCEE can be obtained from the NDCEE Web site (<http://www.ndcee.ctc.com/>) and on DENIX (<http://www.denix.osd.mil>).

Collaborative Relationships

Collaborative relationships are an integral component to the NDCEE's success at identifying, demonstrating, validating, and implementing solutions for clients. From the onset of a task, the NDCEE works intimately with the client to understand the client's unique concerns, challenges, and needs. Wherever appropriate, the NDCEE also collaborates with other entities in the quest for a cost-effective, technically viable solution that is most appropriate for each client.

The NDCEE works with a wide variety of organizations within the DoD. The NDCEE also works with other federal agencies, academic institutions, and private industry. More than 50 of these entities, listed below, were involved with the technology activities featured within this document.

Air Force Institute of Occupational Health (AFIOH)

Air Force Munitions Directorate

Army Research Laboratory

Corpus Christi Army Depot (CCAD), Texas

Defense Advanced Research Projects Agency (DARPA)

Defense Logistics Agency (DLA)

Defense Reutilization and Marketing Service (DRMS)

Department of Homeland Security

Edwards Air Force Base (AFB), California

Fort A.P. Hill, Virginia

Fort Bragg, North Carolina

Fort Dix, New Jersey

Fort Eustis, Virginia

Fort Hood, Texas

Fort Shafter, Hawaii

Fort Story, Virginia

Interstate Technology Regulatory Council (ITRC)

Joint Group on Pollution Prevention (JG-PP)

Joint Munitions Command (JMC)

Joint UXO Coordination Office (JUXOCO)

Lake City Army Ammunition Plant (LCAAP), Missouri

Lone Star Army Ammunition Plant (LSAAP), Texas

Marine Corps Munitions Center

Naval Amphibious Base (NAB) Little Creek, Virginia

Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV), Indian Head, Maryland

Naval Surface Warfare Center, Carderock Division (NSWCCD), Maryland

Naval Surface Warfare Center (NSWC), Crane Division, Indiana

Naval Surface Warfare Center, Indian Head Division (IHDiv), Maryland

Navy Ammunition Program Office

New Jersey Institute of Technology (NJIT)

New Mexico State University - Physical Science Laboratory

Office of the Deputy Assistant Secretary of the Army for Environment, Safety and Occupational Health [ODASA (ESOH)], Washington, D.C.

Ogden Air Logistics Center (OO-ALC), Hill AFB, Utah

Oklahoma City Air Logistics Center (OC-ALC), Tinker AFB, Oklahoma

Pearl Harbor Naval Shipyard (PHNSY), Hawaii

Radford Army Ammunition Plant (RFAAP), Virginia

Rock Island Arsenal (RIA), Illinois

Schofield Barracks, Hawaii

Tobyhanna Army Depot (TYAD), Pennsylvania

U.S. Army Combat Equipment Group-Afloat (CEG-A), Goose Creek, South Carolina

U.S. Corps of Engineers (USACE)

U.S. Army Engineers Research Development Center/Construction Engineering Research Laboratory (ERDC/CERL)

U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland

U.S. Army Kwajalein/Regan Test Site, Marshall Islands

U.S. Army Research Laboratory (ARL)

U.S. Army Tank-automotive and Armaments Command - Armament Research, Development & Engineering Center (TACOM-ARDEC)

U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC)

U.S. Environmental Protection Agency (EPA)

TARDEC Fuels and Lubricants Research Facility

Wright-Patterson Air Force Base (WPAFB), Ohio

NDCEE Technical Approach

The primary goal of the NDCEE is to transfer cost-effective, validated technology solutions that meet DoD ESOH requirements, enhance mission readiness, and support sustainability and transformation objectives. NDCEE technology transfer is focused on identifying, evaluating, and implementing technology solutions at installations and for weapon systems to address operational user needs. The NDCEE uses a systematic technical approach to ensure that needs are carefully assessed, candidate technologies are thoroughly evaluated, and attractive solutions are promoted throughout the DoD. This process helps to avoid duplication of efforts and improves the DoD's return on technology investments. The NDCEE approach is also designed to help DoD facilities and weapon system program managers to reduce the technical, cost, schedule, and/or regulatory risks that are commonly associated with implementing new technologies.

As described on the following pages, the NDCEE technical approach has six key phases:

1. Problem Assessment
2. Alternative Solutions
3. Technology Demonstration
4. Technology Justification
5. Technology Implementation
6. Outreach & Follow-up

In practicing this approach, the NDCEE has sharpened the process for evaluating and implementing technologies. Key activities include determining the nature and extent of the issue, engaging stakeholders early in the process, conducting thorough searches for potential technology solutions, and fielding demonstrated technology solutions.

All of the technologies that are featured in this publication have been managed using the NDCEE technical approach. However, because the NDCEE only employs those activities that are necessary to provide effective, validated solutions, some technologies did not need each of the six phases. For instance, some NDCEE tasks do not require a search for alternative solutions or may not need a full technology justification analysis.

Problem Assessment

Each NDCEE task is carried out with careful attention to scope definition, intelligent project planning, and timely interactions with stakeholders. NDCEE staff work closely with clients to fully understand their ESOH requirements and solution preferences. Typical front-end task actions include conducting a baseline analysis of current operations, processes, and materials and then assessing the limitations and advantages of current systems, including consideration of anticipated future environmental requirements.

To accomplish near- or long-term technology transfer objectives, a Technology Transfer Plan is prepared and updated as needed. This plan describes the activities that are necessary to identify, evaluate, and implement an effective technology solution in the field, covering elements such as site identification and needs analysis, technology evaluation and acceptance criteria, financial planning, and stakeholder coordination.

Alternative Solutions

If necessary, the NDCEE identifies a range of technologies with the potential to meet client requirements and then screens their operating features, performance, and cost. Drawing on the baseline analysis and stakeholder input, the NDCEE completes a literature review, database search, and technical interviews to gain a thorough technical, business, and operational understanding of available and emerging solutions. External searching is

supplemented by knowledge and experience that is obtained through the execution of similar NDCEE tasks to extract and apply lessons learned. This initial review, outreach, and search provides the task team with a compilation of pertinent technical references, business information, patent and trademark literature, and ongoing research studies, which forms the basis from which a successful solution may be discovered.

As part of the assessment process, the NDCEE systematically reviews implementation barriers, identifies data gaps, and evaluates risks and benefits associated with technology alternatives. Attractive technology solutions are reviewed against quantifiable criteria that have been established with stakeholders and approved by the Government for down-selection to an optimal list of candidates for further testing and analysis.

Technology Demonstration

This phase can include bench-scale, laboratory, and/or full-scale demonstration testing to evaluate the potential of technology alternatives to meet user requirements. As necessary, it also includes obtaining regulatory permits, developing system designs, identifying operational and maintenance requirements, and other related efforts. The demonstration process can encompass a variety of evaluation requirements including feasibility, optimization, and/or validation testing. Feasibility testing is low-cost, surrogate testing that is used to determine a technology's basic potential for meeting requirements. Bench-scale testing is used to quantitatively define the operating conditions to meet performance requirements. Validation testing is used to determine if the process is statistically robust (i.e., will meet performance requirements under typical service conditions) and to collect data to support cost, performance, and risk analyses. Full-scale validation testing is typically performed either at a client's site under actual field conditions or in the NDCEE Demonstration Facility under simulated service conditions.

Because technologies often benefit multiple users, the NDCEE encourages Government and industry stakeholders to attend demonstrations. This type of planned technology outreach allows interested and varied organizations to obtain a first-hand view of demonstration results as well as encourages technology adoption.

Technology Justification

The NDCEE conducts technical, economic, and regulatory assessments of the candidate technologies to determine their suitability for operational use. To be a viable replacement for the DoD, candidate technologies must meet or exceed existing performance and operational requirements, comply with current and anticipated environmental regulations, enhance readiness, and provide economic benefits.

Compliance with state and federal environmental statutes and regulations as well as Government Executive Orders is a key element of the justification process. In many instances, the driver for technology implementation is improved adherence to regulatory requirements. Examples of potentially applicable environmental statutes and related regulations include the Clean Air Act; Clean Water Act; Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Resource Conservation and Recovery Act (RCRA); and Superfund Amendments and Reauthorization Act (SARA). Failure to comply with these and other environmental regulations can be costly and damaging to the DoD. For instance, exceeding regulatory limits on ozone-depleting substances (ODSs), volatile organic compounds (VOCs), and/or hazardous air pollutants (HAPs) could result in excessive costs, fines, and public outcries against the DoD.

If technical and regulatory requirements are satisfied, an economic analysis is undertaken to compare the cost of a proposed investment against its expected benefits. This assessment

is based on cost and technical data that were systematically collected during the demonstration phase. Using the Environmental Cost Analysis Methodology (ECAMSM) tool, demonstration results, and other relevant information, NDCEE specialists compare the financial aspects of each identified alternative against the baseline process and other candidates. Standard financial indicators such as net present value (NPV), internal rate of return (IRR), and discounted payback period are used in this analysis.

NDCEE specialists use the economic, performance and other technology data to document the business case that is presented to justify the technology investment.

Technology Implementation

A detailed, client-approved site implementation plan is prepared and executed to install the technology for operational use at the selected site. As required, execution of the implementation plan includes activities such as site preparation, technology installation, conversion to operational status, acceptance testing, system startup, and training for operator and maintenance personnel. The NDCEE can also support full-scale site implementation of the selected technology by assisting with technology procurement, approvals from Service authorities, and coordination of related site activities.

A technology transfer data package—typically consisting of design data, operation and maintenance procedures, and training materials—is also provided to the end user as part of the implementation process. The NDCEE's implementation goal is for site personnel to operate, maintain, and repair the installed technology on their own.

Outreach & Follow-up

The NDCEE provides follow-on outreach and technical services to close out the effort. Outreach materials are prepared and disseminated as appropriate and, in some cases, a horizontal search is conducted to identify other DoD sites with interest in considering the technology solution. Success stories regarding the transfer process and outcomes are prepared and disseminated. As needed, unforeseen operational problems are thoroughly investigated to develop technical recommendations for process or equipment modifications or procedural changes. Lessons learned from follow-up visits are incorporated into updated technology transfer data packages.

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Contacts

NDCEE Program Director:

Mr. James Dries
Office, Assistant Secretary of the Army
OASA (I&E) - ESOH
1235 South Clark Street
Crystal Gateway 1, Suite 307
Arlington, VA 22202
(703) 602-5500
(703) 602-5554 Fax

NDCEE Program Manager:

Dr. Charles Lechner
OASA (I&E) - ESOH
1235 South Clark Street
Crystal Gateway 1, Suite 307
Arlington, VA 22202
(703) 602-5538
(703) 602-5554 Fax
charles.lechner@hqda.army.mil

CTC Program Director:

Mr. Fred Mulkey
Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904
(814) 269-2877
(814) 269-6882 Fax
mulkey@ctc.com

CTC Program Manager:

Ms. Heather Moyer
Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904
(814) 269-6474
(814) 269-6882 Fax
moyer@ctc.com

Inquiries/Comments:

NDCEE@hqda.army.mil

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Technologies



TRANSFERRING TECHNOLOGY SOLUTIONS
Supporting DoD Readiness, Sustainability, and Transformation

NDCEE

National Defense Center for Environmental Excellence

NDCEE Technology Portfolio

Since its inception in 1991, the NDCEE has investigated nearly 150 technologies, which has resulted in more than 330 technology transfers and/or demonstrations. Under the NDCEE Program, technology is defined as “tangible systems or tools that are operated to extend human capabilities in performing practical functions.” Based on this definition, technology is considered to include the following three categories:

- Equipment
- Materials
- Software tools

Equipment includes machinery, processes and devices, and associated operating software. Materials are physical items that are used as inputs to the manufacture or operation of equipment. Software tools are computer programs that perform technical functions or databases that store technical data on computer devices.

The table on the next page shows the variety of technologies that the NDCEE has developed, investigated, demonstrated, and transferred including manufacturing materials and processes, environmental treatment and control devices, and site assessment and clean-up technologies. Following the table are summaries of the NDCEE’s technology demonstration and transfer activities in FY04.

NDCEE Technology Portfolio

Technology Name	Demonstrated	Technology Transferred
Acid monitoring system	X	X
Adams process for hazardous waste		
Air scrubber monitoring system	X	X
Air-sparged hydrocyclone (ASH) unit	X	X
Aluminum/aluminum alloy rich coating (aluminum-molybdenum, aluminum-zinc, AlumiPlate™)		
Aluminum oxide wet slurry blasting	X	
Aluminum pretreatment process	X	
Ammunition Dud and Low-Order Detonation Rate Database	X	
Aqueous immersion/steam cleaning	X	X
Biobased hydraulic fluids	X	
Biodegradation processes for propellant constituents	X	
Biofiltration of coating emissions	X	
Bullet trap technology	X	X
Cadmium/chromium alternatives database		X
Carbon dioxide blasting	X	
Carbon dioxide laser coatings removal systems [FLASHJET®, Laser Automated Decoating System (LADS)]	X	X
Carbon dioxide turbine wheel coatings removal system	X	
Catalytic extraction processing for wastes		
Centrifuge for coolant streams	X	
Chromium-free stripping process	X	X
Coolant recovery/recycle systems	X	X
Corn hybrid polymer blasting	X	
Corrosion Control Center (CCC)	X	X
Corrosion data collection system (PDA-based)	X	X
Corrosion Prevention and Control System for Army Tactical Vehicles	X	X
Corrosion training website		X
Denitrification system	X	X
Deployable Hazmat Control Center (DHCC)	X	

Technology Name	Demonstration	Technology Transferred
Design for disassembly (DfD) analysis tool for electronic equipment disassembly	X	
Diamond-like-carbon (DLC) coating	X	
Diffusion dialysis for acid stripping operations	X	
Diode laser coatings removal system	X	
DNA extraction device	X	
Doppler laser nondestructive evaluation technology	X	
Drive On/Through Containment System (DOCS™)	X	
Dust control agents		
Dynamic suspended-bed bioreactor (DSBR) for perchlorate bioremediation	X	
Electrocoat (E-coat) system	X	
Electroless nickel coating		
Electrolysis for plating baths	X	X
Electrolytic plasma processing (EPP)	X	
Electronic Equipment Demanufacturing Recycling and Reuse System	X	X
Electronic Source Book for Biobased Industrial Products		X
Electroplating (manual plating)	X	
ElectroSpark Deposition (ESD) micro-welding process	X	
Environmental Cost Assessment Methodology (ECAM SM)	X	X
Ethanol distillation monitoring system		X
Extend™ Model Simulation Software	X	
Facility Environmental Management and Monitoring System (FEMMS)		X
Fiber media blasting	X	X
Filtration (microfiltration, ultrafiltration, etc.) (wastewater and storm water applications)		X
Flow measuring/monitoring devices (FMDs) (wastewater, storm water, and groundwater applications)	X	X
Fuel cells	X	
Functional trivalent chromium plating		
Geographical information system (GIS)	X	X
Global positioning system (GPS)	X	X
Groundwater monitoring system	X	X

Technology Name	Demonstration	Technology Transferred
Gun cleaner materials	X	
Halogenated volatile organic compound (HVOC) field screening technology	X	
Hazardous Substance Management System		X
High-Velocity Particle Consolidation	X	
Honeycomb cleaning system		
Hydrotalcite coating		
Industrial wastewater treatment plant control panel	X	X
Infrared thermometer for powder cure oven	X	X
Integrated Training Area Management (ITAM) Administrative Tool for Land Condition Trend Analysis (LCTA)	X	X
Ion exchange units	X	
Ion implantation	X	
Iron phosphate pretreatment	X	
Joint Service Solvent Substitution (JS3) Tracking Database		X
Lactate ester cleaning process	X	X
LandTech - A Web-Based Brownfield Decision Making Tool		X
Laser-induced surface improvements (LISISM)	X	
LaserTouch® paint application targeting device	X	
Lead-free lubricant	X	
Lead-free solder		
Liquid nitrogen cleaning/coatings removal system (CryoJet®)	X	
Low-VOC conformal coating	X	X
Magnetically assisted impaction mixing (MAIM)	X	
Micro-electromechanical systems (MEMS)		
Mobile Aircraft Firefighting Training Device (MAFTD)	X	X
Municipal solid waste conversion system	X	
Municipal solid waste sortation system	X	X
Neodimium-Doped:Yttrium-Aluminum Garnet (Nd:YAG) laser coatings removal system	X	
NitRem Process (nitrogen removal)	X	X
Nonchromate acid etch processes for adhesive bonding	X	
Noncadmium plating processes	X	
Nonchromate conversion coating	X	X

Technology Name	Demonstration	Technology Transferred
Nonchromate plating/finishing processes	X	X
Noncyanide plating/finishing processes	X	X
Non-line-of-sight chrome plating (NLOS)	X	X
Oxygen line cleaning systems	X	
Paint handling and spray application equipment [plural component spray, conventional spray, high-velocity/low-pressure (HVLP) spray, other]	X	X
Paint spray gun washer	X	X
Particle separation (remediation application)	X	
Perchlorate measurement instrument	X	
Phosphate-induced metals stabilization (remediation application)	X	
Photochemical depainting system	X	
Physical vapor deposition (PVD) [cathodic arc, sputtering deposition system, plasma immersion ion plating (PIIP), ion plating, ion beam assisted deposition (IBAD)]	X	
Phytoaccumulation (remediation application)	X	
Piezoelectric ceramic fiber composites	X	X
Plasma arc waste processing [Plasma Energy Pyrolysis System (PEPS®)]	X	
Plasma-assisted chemical vapor deposition (PACVD)	X	
Plastic media blasting (PMB)	X	
Portable munitions monitoring system (PMMS)		
Powder coating	X	X
Powder metallurgy processing technology		
Power washer	X	X
Pulsed high-voltage ion vapor deposition (IVD) aluminum process	X	
Remote Acoustic Impact Doppler (RAID)	X	X
Reverse osmosis water purification system	X	X
Rotary basket cleaning system	X	X
Silane barrier coating		
Sludge drying system		X
"Smart-Pipe" wastewater and drinking water infrastructure analysis		
Smart wire	X	X
Sodium bicarbonate blasting	X	X

Technology Name	Demonstration	Technology Transferred
Solid media (grit) blasting	X	X
Sorbent treatment of hazardous wastes	X	
Spent acid screening process	X	X
Sponge blasting	X	
Spray casting	X	
Stormwater continuous deflective separation (CDS)		X
Supercritical carbon dioxide cleaning	X	
SuperCritical Carbon Dioxide (SCCO ₂) coating application system	X	
Tantalum coating		
Thermal transfer printing system	X	X
Thermophilic biological process (TBP) (pink water application)	X	X
Ultrasonic cleaning	X	X
Ultraviolet wastewater treatment		X
UXO Electronic Data Collection Tool (EDCT)	X	X
UXO neutralization technologies [Joint Laser Ordnance Neutralization System (J-LONS), Light Energy Absorbing Igniter (LEAI), Telepresent Rapid Aiming Platform (TRAP), The Mine Incinerator®, Fiber Optics Delivered Energy System]		
UXO Recovery Database System (RDS)	X	X
UXO Time and Cost Trade-Off Tool	X	X
Vacuum evaporation	X	
Vapor degreaser	X	X
Vitrification process for wastes		
Water-dispersible chemical agent resistant coating (WD-CARC)	X	X
Water management and conservation system		X
Waterjet (high pressure, ultrahigh pressure) (adhesive bonding & coatings removal applications)	X	X
Wax skimming system		X
Wet slurry blasting	X	
Wood recovery unit	X	
Zero-temper pure zinc-cut wire blasting	X	
Zinc phosphate conversion coatings	X	

Ammunition Dud and Low-Order Detonation Rate Database

With assistance from DoD unexploded ordnance (UXO) stakeholder teams, the NDCEE is providing technical expertise specific to the UXO challenges faced by the DoD. As part of that effort, a data-mining study was conducted that captured the dud and low-order detonation rates for a variety of ammunition types. A dud is a round that is fired/initiated, but completely fails to function at the target. It also may mean a round that failed to initiate in the weapon system and therefore never reached the target. A low-order detonation is a high-explosive round that is fired/initiated, but only partially functions at the target.

Technology Description

The database is a Microsoft® ACCESS-based database that calculates the average dud and low-order detonation rates for multiple ordnance types by utilizing over 1.3 million sample points (items fired and documented). It provides the DoD with a searchable database of average detonation rates for a variety of subsets of the total set of ammunition items for which data were collected.

Launched in June 2004, the Ammunition Dud and Low-Order Detonation Rate Database condenses complex reports into a clear, concise, and manageable data form that is more easily accessed for interpretive decision-making support. The more than 1.3 million records were compiled from Ammunition Stockpile Reliability Program reports, malfunction reports, Lot Acceptance Testing records, and summary reliability reports. Data have been sorted and compiled according to the following attributes:

- Department of Defense Identification Code (DODIC)
- Size (20mm, 25mm, 40mm, 165mm, 2.75-inch, 3.5-inch, 4.2-inch, and 8-inch)
- Type (high-explosive, smoke, and illumination)
- Family (fuzes, grenades, mines, pyrotechnics, artillery, mortar, guns, rockets)
- Other pertinent information as identified

Access to the database is available to DoD employees and current DoD contractors only.

Technology Benefits and Advantages

- Enables the assessment of the potential for release of munitions of concern to the environment from UXO as a result of soldier training
- Determines costs for remediation of UXO in the DoD's Military Munitions Response Program
- Provides the ability to analyze munition types that tend to exhibit higher dud and low-order detonation rates, allowing research, development, testing and evaluation efforts to focus on minimizing these rates

Technology Limitations

- The database presently does not contain empirical field data for the number of ordnance fired on training ranges by the DODIC compared to the number of duds or low orders per firing evolution.
- Field reporting will be required.
- This database is not a live, updatable database due to the sensitive nature of the data and its relationship to operational capabilities.

ESOH Need

UXO detection and recovery methods

PHASE III
DUD AND LOW ORDER
DETONATION RATE
DATABASE

Results Table: 9 Results Returned

DODIC	Size	Family	Type	Nomenclature	Used/Fu	Fired	DUDS	dud/perc	LO	LO/percent	Source	Year	Status
D624	8 Inch	Artillery	HERA	Proj, 8 IN M567	361	1	0.277008	0	0	0	ASRP-P	N/A	
D624	8 Inch	Artillery	HERA	Proj, 8 IN M562M1	210	0	0	0	0	0	ASRP-P	N/A	
D680	8 Inch	Artillery	HE	Proj, 8 IN M557	67	0	0	0	0	0	ASRP-P	N/A	
D680	8 Inch	Artillery	HE	Proj, 8 IN M582	176	9	5.113636	0	0	0	ASRP-P	N/A	
D680	8 Inch	Artillery	HE	Proj, 8 IN Various	160	0	0	0	0	0	ASRP-P	N/A	
D683	8 Inch	Artillery	HES	Proj, 8 IN M591	18	0	0	0	0	0	ASRP-P	N/A	
D683	8 Inch	Artillery	HES	Proj, 8 IN M543M1	18	0	0	0	0	0	ASRP-P	N/A	
D684	8 Inch	Artillery	HE	Proj, 8 IN M566	18	0	0	0	0	0	Acceptan	N/A	
D684	8 Inch	Artillery	HE	Proj, 8 IN M566	57	0	0	0	0	0	ASRP-P	N/A	

Screen capture of search results from the Dud and Low-Order Detonation Rate Database

NDCEE FY04 Accomplishments

- Produced a Final Report that documents the activities and contains the results from the FY03 full-scale field demonstrations
- Coordinated literature reviews, data requests, and telephone interviews with Naval Surface Warfare Center, Crane Division, and with the United States Marine Corps Systems Command, Project Manager Office for Ammunition
- Conducted a data-mining mission comprised of gathering over 1.3 million records of actual fired munitions with dud and/or low-order information from a Joint Service consortium of resources including the Army Joint Munitions Command, Air Force Munitions Directorate, Navy Ammunition program office, and Marine Corps munitions center
- Collected, documented, and correlated all data for inclusion in the database
- Demonstrated the database to the DoD and UXO community
- Initiated a technology transition of the database to USAEC and the JMC that included the transfer of all gathered dud rates
- Developed a multimedia presentation, depicting the database, that can be used by the DoD and UXO community
- Developed a users guide and training package for the software database and transitioned them along with the Final Report on packaged CD-ROM, which is available through the USAEC and JMC

Economic Analysis

The NDCEE has not presently conducted a cost-benefit analysis. However, by using this database, the DoD will be able to make a better determination on the extent of munitions and explosives of concern found at response sites. Consequently, the DoD will be able to make more informed technical and cost decisions affecting the areas of range safety; range clearance and remediation; and research, development, test, and evaluation related to munitions.

Suggested Implementation Applications

This technology can be utilized at any DoD facility or rapid deployment site that is used for ammunition live firing and/or training operations. The system was designed for use by all Services and all base environmental coordinators as well as the entire ammunition stockpile, logistics, and inventory community.

Points of Contact

- Thomas Guinivan, USAEC, (410) 436-5910, Thomas.guinivan@us.army.mil
- Bob Pickett, NDCEE/CTC, (217) 283-4963, pickettr@ctc.com

Applicable NDCEE Task

Unexploded Ordnance (Task N.318, Subtask 10)

Automated Pathogenic-DNA Extraction

The NDCEE is assisting small- and medium-sized enterprises with commercializing their federally developed or supported technologies, which have both DoD and private-sector applications. As part of this assistance, the NDCEE has successfully evaluated an alternative technology that can be used for automated plasmid and genomic deoxyribonucleic acid (DNA) purification and extraction. This technology is of interest to the DoD, Department of Homeland Security, and medical community.

Technology Description

DNA extraction technologies can rapidly and reliably isolate DNA and ribonucleic acid (RNA) from various types of samples such as soil, blood, urine, stool, or broth. As a result, they are used to prepare samples of biological pathogens and toxins for identification by genetic amplification and tagging techniques. These technologies replace the traditional method in which DNA samples were extracted by hand, which is costly, labor-intensive, prone to human error, and presents a higher risk of exposure of pathogens to technicians.

DNA extraction involves a three-step process whether it is automated or performed manually:

1. Perform cell lysis (destruction of cells by disruption of the bounding membrane) to make the cellular DNA accessible for extraction
2. Strip away carbohydrates and surface proteins that are bound on the DNA (to allow better separation and for the genetic amplification of the DNA in its analysis)
3. Separate DNA from the rest of the sample matrix.

The separated nucleic acid extracts are then analyzed by polymerase chain reaction (PCR)-based techniques to confirm and identify pathogenic biological agents found in the sample.

To meet its field operations medical missions, the Air Force has evaluated two automated DNA extraction devices for possible field use. One technology is based upon magnetic bead separation technology, while the other is based upon elution liquid chromatography. The NDCEE uncovered a third technology that makes use of an electrophoresis technique to separate both genomic and nongenomic DNA. This automated gel electrophoresis extraction technology offers to provide significant cost savings and performance improvement over the two most recently evaluated techniques by the Air Force.

Technology Benefits and Advantages

- Magnetic bead separation, elution liquid chromatography, and gel electrophoresis are very mature techniques.
- DNA extraction technologies, coupled with rapid PCR-based analysis, offer rapid and accurate diagnosis and the ability to reduce the amount of inappropriately prescribed antibiotics.
- The electrophoresis extraction technique can be optimized to specific sample types and mitochondrial DNA, which could be useful for identifying some biological agents such as ricin.
- The technologies have a relatively low footprint (e.g., some brands have a footprint of less than 3 square feet).
- The automated process decreases risk of exposure of pathogens to technicians.

ESOH Need

Molecular diagnosis techniques



Automated pathogenic-DNA extraction technology equipment

Technology Limitations

- Because the electrolysis gel dissolves at extraction temperatures greater than 100° Fahrenheit (F) [38° Celsius (C)], separations need to be conducted in an air-conditioned environment.
- Certain samples may require mechanical agitation to ensure the lysis of DNA/RNA components in such a form as to be viable for DNA/RNA amplification.

NDCEE FY04 Accomplishments

On behalf of the Air Force Institute of Occupational Health, the NDCEE successfully demonstrated and validated an automated plasmid DNA extraction device in a laboratory environment. The NDCEE determined that the device could extract genomic DNA from cell culture solutions of several pathogenic bacteria. Yields of up to 80 nanograms (ng) per microliter (μl) were obtained using 25% of the sample volume. In comparison, initial tests of AFIOH-tested alternative technologies provided yields of 3-4 ng/μl. The DNA extraction device obtained up to 96 samples per hour in an automated and simultaneous mode of operation.

Economic Analysis

Depending primarily on the volume of samples to be treated, the use of an electrophoresis extraction technology could provide a significant savings to the Government over other DNA extraction technologies. Capital costs are approximately \$10,000 compared to \$20,000 to more than \$100,000, depending on brand and desired features. In addition, the cost in consumables per sample can be up to 10 times less expensive than other technologies.

Suggested Implementation Applications

The DNA extraction technology can be utilized for any applications involving the utilization of molecular diagnosis techniques. More specifically, applications include diagnosing patients who are suffering from diseases caused by infection from pathogenic microorganisms such as viruses, bacteria, and fungi or related biological agents in the case of an act of war or terrorist event. In addition, as DNA-driven treatments are developed, this technology offers a means for cost-effectively tailoring drug products to individual genotypes for maximum effectiveness.

Potential environmental applications include monitoring landfills, buildings, and water treatment facilities for the presence of pathogens in the air, water, and soil.

Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Bill Tumblin, NDCEE/CTC, (864) 271-8218, tumblinb@ctc.com

Applicable NDCEE Tasks

Commercialization of Technologies to Lower Defense Costs (Tasks N.319 and N.0403)

Biobased Hydraulic Fluids

The NDCEE, in conjunction with the TARDEC Fuels and Lubricants Research Facility, identified, tested, and evaluated biobased hydraulic fluids for use in military equipment for the Defense Logistics Agency. The initial NDCEE evaluation, including working with industry leaders in biobased hydraulic fluid development, will facilitate establishing performance levels for biobased hydraulic fluids. The U.S. Department of Agriculture plans to use project findings to assist in establishing biobased content ranges and definitions for future procurements of new biobased products. In FY04, under a new follow-on task, the NDCEE requested reformulated samples from previous vendors for a third round of laboratory analysis based on military tactical equipment requirements. The NDCEE also evaluated performance data of currently available off-the-shelf commercial-grade biobased hydraulic fluids against existing Government requirements for nontactical, construction-grade Government equipment.

Technology Description

Biobased hydraulic fluids are derived from renewable plant resources and are generally more environmentally benign than their petroleum-based and synthetic counterparts. Hydraulic fluids, under pressure, transmit power to moving parts of many machines and equipment, including tanks, airplanes, cars, bulldozers, tractors, and most heavy equipment. Although presently formulated for commercial use, the new biobased fluids are being developed to meet more stringent military specifications.

Traditionally, petroleum-based fluids have been used because they are inexpensive and readily available. Biobased fluids are biodegradable, commercially available, and becoming less expensive.

For the NDCEE evaluation, TFLRF identified 10 target performance properties based on two demanding synthetic (MIL-PRF 46170) and petroleum-based (MIL-PRF 6083) hydraulic fluid military specifications for combat tactical vehicles. The specifications require cold temperature performance below -76°F (-50°C) and flash points above 392°F (200°C). In addition, candidate biobased lubricants were required to have a minimum biobased content of 25%, which all of the candidates met or exceeded. Of the seven candidate fluids submitted for evaluation, only one passed all 10 screening tests. The passing fluid was tested against the remaining specification requirements (24 additional tests) and passed all but three of the remaining tests. The DLA has indicated that it is premature at this time to proceed with field-testing of the biobased hydraulic fluid formulated for tactical equipment.

The NDCEE also evaluated product data sheets and Material Safety Data Sheets on 80 commercially available biobased hydraulic fluids. Submitted by 19 manufacturers, the fluids were evaluated against 10 existing Government specifications to determine their potential usage as alternatives in construction-grade, nontactical Government equipment. The results of the evaluation concluded that no commercially available biobased hydraulic fluid participating in this effort met all of the requirements of any one Government specification. However, insufficient test data were supplied on the majority of the fluids, which indicates that the product data sheets did not provide sufficient information to make a determination.

ESOH Need

Biobased lubricants
and fluids



The DoD is seeking to switch to biobased hydraulic fluids for combat tactical equipment, such as this Bradley Fighting Vehicle (foreground), M1A2 Abrams Main Battle Tank, and Landing Craft (in water), which currently use petroleum-based or synthetic hydraulic fluids.

Thirty-six products from seven manufacturers passed more than 50% of the test requirements in two of the 10 Government specifications and had no failing results. Specifically, 35 products passed more than 50% of the A-A-59354 Commercial Item Description (CID), and nine products passed more than 50% of the MIL-PRF-17672 specification. Additionally, eight products passed more than 50% of both the A-A-59354 CID and the MIL-PRF-17672 specification.

Technology Benefits and Advantages

- Is biodegradable, nontoxic, and nonflammable (depending on additives used)
- May provide greater operator safety than conventional hydraulic fluids
- Prevents cleanup liabilities and costs associated with spills and leaks of conventional hydraulic fluids
- Provides excellent lubricity and many have higher flash and fire points (which means they are safer to store and handle) than most petroleum-based lubricants
- May offer a better cost and performance profile than current products for many applications
- Helps the DoD comply with Executive Orders 13101, 13123, 13134, 13148, and 13149 as well as RCRA and other regulations
- Is made from domestically produced renewable agricultural material, lessening the United States' dependency on foreign-produced oil
- Is commercially available

Technology Limitations

- Fluids that may meet all of the military requirements for combat tactical vehicles are still in development.
- Because the manufacturers do not provide test data on all Government requirements of any one individual specification, further laboratory testing of biobased hydraulic fluids will need to be conducted to determine if commercially available biobased hydraulic fluids can meet existing Government requirements.

NDCEE FY04 Accomplishments

- Completed laboratory analysis on the most promising tactical fluid candidate
- Developed a functional database comparing 80 commercially available biobased hydraulic fluids against 10 existing Government requirements for hydraulic fluids
- Evaluated technical data sheets on 80 commercially available biobased hydraulic fluids from 19 vendors

Economic Analysis

Many types of petroleum-based hydraulic fluids contain constituents that are considered toxic or hazardous. As a result, leaking equipment can contaminate soils, groundwater and surface water, polluting sensitive ecosystems where military maneuvers are conducted. Besides the incalculable costs to wildlife and their environment, restoration of fluid-contaminated sites can be costly to the Air Force, Army, Marines, and Navy.

The NDCEE conducted a life-cycle cost analysis that took into account purchasing, waste disposal, and spill costs. The current baseline costs for the purchasing and disposal of MIL-PRF-6083 and MIL-H-46710 hydraulic fluids are \$9.28 and \$13.88 per gallon, respectively. A spill event would add approximately \$68 per gallon to those costs. These figures are derived from actual use and purchase data for Sandia National Laboratory. Biobased fluids have a purchase and disposal cost of \$12 per gallon. In the event of a spill, no additional costs should be accrued because the material is biodegradable. Other costs may be

associated depending on the size and location of the spill; however, these spill-related costs should still be less than those associated with petroleum-based fluids.

Suggested Implementation Applications

The following general purpose and tactical equipment are among those that currently use petroleum-based and synthetic fluids: Bradley Fighting Vehicle, M1A2 Abrams Main Battle Tank, Carrier Ammunition Carrier Command Post, Carrier Multiple Launch Rocket, Carrier Mortar 107mm, Carrier Personnel M113A2, Carrier Smoke Generator, Combat Vehicle ITV-M901A1, Infantry Fighting Vehicles, Landing Craft Mechanized LCM8, Landing Craft Utility, Lighter Air Cushion Vehicle 30-ton, Tank Combat Full Tracked, Armored Combat Earthmover ACE M9, Armored Recon ABN Assault Vehicle, Bridge Launcher Armored Vehicle, Carrier Ammunition, Crane Shovel 20-ton, Hammer Pile Drivers, and Howitzers.

Points of Contact

- Linwood Gilman, DSCR, (804) 279-3518, linwood.gilman@dscr.dla.mil
- George Handy, NDCEE/CTC, (803) 641-0203, handyg@ctc.com

Applicable NDCEE Task

Biobased Hydraulic Fluid Evaluation (Military Tactical and Construction Grade Equipment) (Task N.326)

Biodegradation Processes for Propellant Constituents

Through the Managing Army Technologies for Environmental Enhancements (MANATEE) Program, the NDCEE is continuing to identify, evaluate, design, and deploy high-priority pollution prevention technologies that improve process efficiency and reduce wastes at Radford Army Ammunition Plant. In FY03, the NDCEE evaluated, through bench-scale testing, biodegradation technologies for treating waste propellants. This technology has been transferred to RFAAP, which scaled-up the laboratory system to an in-house system that handles 100,000 gallons of waste propellant.

Technology Description

Biodegradation technologies are being developed as potential treatment alternatives to open burning of waste propellants. Regulatory allowances for open burning are expected to be eliminated within 5–10 years.

Bench-scale tests were conducted on microbes from RFAAP's facultative biological process alone as well as mixed with microbes from NDCEE's Thermophilic (Biological) Process technology (see page 65 for its description). Three propellants were tested and are listed below along with their constituents.

- 1) M14 grit from grains: The grit particles are the size of coarse sand. M14 constituents include nitrocellulose, diphenylamine, 2-nitrodiphenylamine, dibutylphthalate, dinitrotoluene, and graphite.
- 2) PAP grit from grains: PAP constituents include nitrocellulose, ethyl centralite, Class-C Fly Ash 2, potassium sulfate (K_2SO_4), and graphite.
- 3) M36 paste (similar in composition to AA2 paste): The solid portions of paste are similar in dimension to grains of sand. M36 paste constituents include nitroglycerine, nitrocellulose, triacetin, 2-nitrodiphenylamine, lead copper resorcyate/salicylate, candelilla wax, and di-n-propyl adipate.

The tests were conducted at three different temperatures [room temperature of 77°F (25°C), 100°F (38°C), and 140°F (60°C)] to determine the effect of temperature on the degradation rate. The higher temperatures (100°F and 140°F) were achieved by immersing the bioreactors in a temperature-controlled water bath. The test condition was maintained for seven days, which included three days with aeration and four days without aeration. At the end of the seven-day period, the supernatant liquid was decanted. The test cycle was repeated twice. The parameters that were analyzed include pH, total settleable solids, chemical oxygen demand, nitroglycerine, dinitrotoluene, phthalates, diphenylamine, nitrate, ammonia, and sulfate. Of the three propellants tested, M36 paste propellant shows promise for partial biodegradation.

Technology Benefits and Advantages

- Shows promise for degrading propellant materials
- Reduces the settleable solids for propellants
- Poses limited health and safety risks; however, several propellant components are dangerous and precautions should be taken

ESOH Need

Waste propellant treatment methods



Propellant paste at RFAAP's Open Burning Ground

Technology Limitations

- The processes are in the developmental stage.
- Operator training will be required.
- Open-vessel processes should not be used to biodegrade propellants at 100°F and above because, at those elevated temperatures, the resultant foaming and evaporation are too difficult to control.

NDCEE FY04 Accomplishments

In FY03, the NDCEE conducted bench-scale degradation tests on three propellants (M14 grits, PAP grits, and M36 paste). The bench-scale testing consisted of two biological processes conducted in duplicate plus controls. The test data were used to calculate the propellant constituent biodegradation rate and destruction and removal efficiency for these biodegradation processes. Testing was performed in accordance with the NDCEE-prepared, Government-approved Test Plan. In FY04, the NDCEE successfully transferred the biodegradation technology to RFAAP, which is using the technology to treat these propellant wastes. In FY05, the NDCEE, at RFAAP's direction, will be performing a pilot-scale demonstration of the technology for treating nitroglycerin paste.

Economic Analysis

The NDCEE conducted a cost analysis for this project that compared the costs for the baseline method of disposal of waste propellants via open burning to the costs of disposing of these wastes via biodegradation. The process has a discounted payback period of less than three months, an internal rate of return of 428%, and a five-year net present value of \$185,865.

Suggested Implementation Applications

The technologies are being developed for installations that use open burning as a means for treating waste propellants.

Points of Contact

- Brad Jennings, RFAAP, (540) 639-7417, Brad.Jennings@ATK.com
- Brad Biagini, NDCEE/CTC, (814) 269-2840, biaginib@ctc.com

Applicable NDCEE Tasks

Managing Army Technologies for Environmental Enhancements (Tasks N.310, N.315, and N.0402)

Bullet Trap Technology

In August 2004, the NDCEE, in support of the DoD, demonstrated and validated a bullet trap technology at a host installation, Fort A.P. Hill, as an alternative to the conventional soil berm/backstop. The NDCEE validated the ability of the bullet trap to reduce the amount of lead that soil berms release into the environment. Fort A.P. Hill chose to retain the bullet trap due to positive test results and is in the process of acquiring funds to implement this technology on its largest small arms firing range. In addition, efforts are under way for the NDCEE to demonstrate and validate the technology in at least one different climate area (e.g., hot, cold, or high precipitation).

Technology Description

Bullet traps are designed for use on outdoor small arms firing ranges to capture and contain bullets, thereby reducing, eliminating, or otherwise controlling lead contamination. The bullet trap technology is an alternative to traditional soil/sand berms, which are prone to soil erosion and the possibility of migration of lead and other heavy metals off of the range.

The NDCEE validated a bullet trap that utilizes the granular rubber material as the stopping media to first decelerate the bullet through friction and second to encapsulate the bullet. Because the bullet remains intact, fragmentation and lead dust are significantly decreased or eliminated. Contained bullets are recovered by sifting the granular rubber. Once the bullets are removed from the stopping media, the granular rubber is placed back into the bullet trap for continued use and the collected bullets are properly recycled or disposed of.

This bullet trap system is constructed from the bottom up and includes a layer of rubber sheeting, a water-collection system and reservoir, granular rubber, and a top protective rubber cover. The technology is fully contained. It is built over a dirt berm and uses a support frame that is comprised of flame-resistant and recycled polyethylene. The top rubber cover is used to prevent precipitation and moisture from entering the bullet trap.

Other bullet trap technologies are available in several designs, including the use of a steel decelerator, rubber blocks, or shock-absorbing concrete as the stopping media. These technologies have not been evaluated by the NDCEE.

ESOH Need

Lead contamination reduction and elimination in soil and the environment

Technology Benefits and Advantages

- Captures and contains bullets, preventing them from penetrating and contaminating the soil
- May accommodate tracer/incendiary rounds as long as proper maintenance occurs in accordance with the manufacturer's recommended repair protocols
- Prevents/eliminates ricochets, fragmentation, and the creation of lead dust, thus lowering health and safety concerns
 - Is constructed from flame-resistant and recyclable materials (i.e., automobile tires that are shredded and sized to approximately the size of a BB pellet)
 - Is self-healing and low maintenance
 - Does not require any utility support such as power or water
 - Incorporates a water-collection and containment reservoir in the event that precipitation enters the bullet trap, which ensures that potentially contaminated water does not migrate outside of the bullet trap
 - Enables collected bullets to be recycled or disposed of properly while the granular rubber is placed back into the bullet trap for further use



Troops firing upon the bullet trap technology

Technology Limitations

- Is limited to accommodating rounds that are 12mm or smaller (e.g., 5.56mm, 7.62mm, and 9mm rounds)
- Requires further research to accommodate rounds that are greater than 12mm, such as 50-caliber rounds that measure 12.7mm

NDCEE FY04 Accomplishments

The NDCEE completed a demonstration at Fort A.P. Hill that consisted of live-firing more than 30,000 rounds of 9mm, 5.56mm, 7.62mm, and 50-caliber ammunition, including tracer and armor-piercing rounds, on four lanes equipped with the test bullet trap. A draft Demonstration/Validation Report was prepared and submitted to the Government. The report contains a pictorial record of events, results of the demonstration, associated maintenance and firing data forms, as well as captured lead/bullet removal data. During this demonstration, a total of 82 pounds of bullets and approximately 17 gallons of lead-contaminated water were removed from the bullet traps. Based on positive demonstration findings, the installation has confirmed its intent to retain and take ownership of the bullet traps.

Economic Analysis

The capital and maintenance costs for the bullet trap technology will vary depending on site requirements and use. However, it is generally under \$51 per square foot. For instance, the capital cost for the technology that was demonstrated at Ft. A.P. Hill would be approximately \$60,000. Maintenance costs during the six-month demonstration were less than \$12,000, primarily associated with sifting bullets from the granular rubber and removing/disposing of the water from the water collection system. Specific cost items included labor, associated materials and tools, analysis of collected water as well as waste disposal. Waste materials included bullets and water, which were removed from the bullet trap.

Suggested Implementation Applications

An implementation candidate is any outdoor small arms firing range at which 5.56mm, 7.62mm, and 9mm rounds are fired. Further testing is planned before concluding whether tracer use is recommended. The United States military operates greater than 1,800 small arms firing ranges. Use of the bullet trap technology on outdoor ranges may serve as a means to reduce or control lead contamination by reducing the risk of contaminating soil, groundwater, and surface waters as well as associated remediation issues.

Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Gino Spinos, NDCEE/CTC, (814) 269-2894, spinosg@ctc.com

Applicable NDCEE Task

Commercialization of Technologies to Lower Defense Costs (Task N.319)

Corn Hybrid Polymer Blasting

The NDCEE and Naval Surface Warfare Center, Carderock Division have tested several alternatives, including the laser decoating and sodium bicarbonate blasting, to current coatings removal methods. As part of their efforts, corn hybrid polymer (CHP) blasting was evaluated and found to be effective at removing coatings from select delicate substrates such as Navy surface ship radar dome (radome) sections and passive countermeasure system (PCMS) tile.

Technology Description

The CHP blasting is a dry abrasive blasting process, which is an alternative to traditional chemical paint strippers, hand sanders, and manual cutting tools. CHP blasting has the potential to provide reasonable stripping rates while imparting low mechanical effects to aluminum and composites. CHP blasting uses a crystallized cornstarch that is organic, nontoxic, and biodegradable. This media is most applicable to delicate substrates where plastic media blasting is too aggressive and can damage the substrate.

A feed unit is used to deliver CHP media to the surface at pressures less than 20 pounds per square inch (psi), which reduces the risk of damage to delicate substrates. CHP media can be used in standard, light abrasive, blast equipment and can be considered a drop-in replacement for plastic media. Solvents, such as methyl ethyl ketone (MEK), that are used to clean a surface after blasting with plastic are not required for CHP blasting because CHP media residue is easily removed with a water wipe-down. CHP media also yields a characteristic ultraviolet fluorescence when radiated. This property of the media enhances post-stripping surface inspections.

CHP blasting is similar to a process that uses wheat starch media, which is currently being used for coatings removal from specific delicate substrates. However, in comparison with wheat starch blasting, CHP blasting offers significant benefits such as improved strip rates and increased moisture resistance.

If CHP blasting is conducted on large surfaces, such as a surface ship deckhouse, a Close Proximity Containment (CPC) unit is necessary to collect and recover the spent medium. The CPC unit allows the operator to remain outside of the containment area, with the use of inflatable surface seals and a functional access area.

ESOH Need

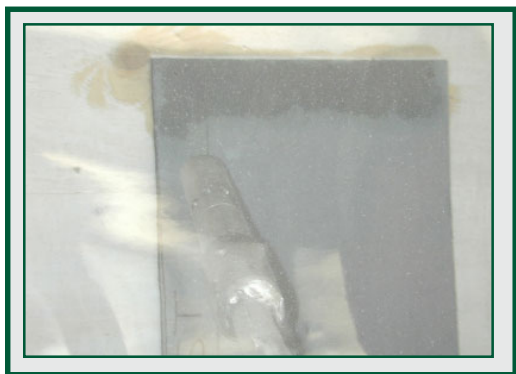
Coatings removal techniques

Technology Benefits and Advantages

- Uses a blasting medium that is organic, nontoxic, and biodegradable
- Has the potential to strip delicate substrates without damage
- May eliminate the use of chemical strippers
- Avoids ESOH concerns by eliminating hazardous waste and the need of MEK for post-stripping wipe-down
- Enhances post-stripping surface inspections

Technology Limitations

- Requires worker protection against inhalation of airborne dust from the blasting operation
- Is subject to quality insufficiencies with regard to stripping based on skill and experience level of the operator



PCMS tile being stripped with CHP

NDCEE FY04 Accomplishments

- Held evaluations of CHP blasting with results indicating that the process could effectively remove coatings from MK-92 radome sections at an approximate rate of 22 square feet per hour without visible damage to the substrate
- Held evaluations of CHP blasting with results indicating it could effectively remove 15 mils of MIL-PRF-24763A LSA latex, haze gray paint from Type 3R PCMS tile at a rate greater than 13 square feet per hour without visible damage to the substrate
- Evaluated a CPC unit that, when used in conjunction with CHP on vertical surfaces similar to those on a ship, achieved a greater than 80% media recovery rate

Economic Analysis

Expected benefits include a reduction in the use of chemical strippers, resulting in a reduction/elimination of solvent vapors and volatile organic compounds that are released into the atmosphere. It will also cause a reduction in hazardous waste generation (i.e., contaminated paint residue and rags). Although these reductions are not quantifiable at this time, the environmental and associated cost benefits are expected to be significant.

This process will reduce labor costs associated with maintenance, repair, and overhaul activities. For example, using labor reductions in commercial industry as a baseline, estimates are that the labor associated with manually stripping a single surface ship radome will be reduced by approximately 35 hours. Using an estimated hourly wage of \$50 per hour, the net savings would be \$1750 per radome that is stripped. Labor savings alone for removing coatings from Navy surface ship radomes could approach \$70,000 per year. In addition, ESOH benefits and improvements are anticipated.

Suggested Implementation Applications

CHP blasting can be utilized to strip aluminum and composites substrates such as surface ship and aircraft radomes, engine cowlings, and PCMS tile.

Points of Contact

- Dr. Scott Sirchio, NSWCCD, (301) 227-5196, sirchiosa@nswccd.navy.mil
- Georgette (Kotsagrellos) Nelson, NDCEE/CTC, (412) 992-5355, nelsong@ctc.com

Applicable NDCEE Task

Coatings Removal from Delicate Substrates and Application Process Improvements for Department of Defense Industrial Facilities (Task N.308, Subtask 2)

Corrosion Prevention and Control System for Army Tactical Vehicles

The NDCEE is identifying, investigating, and developing environmentally friendly technologies that can be used to measure, control, and prevent corrosion. For instance, at Fort Hood, the NDCEE has designed, built, and demonstrated a prototype automatic Corrosion Prevention and Control System for Army tactical vehicles. These efforts were used to optimize the final facility design and processing variables, allowing formal specifications and operating procedures to be generated. The findings from the portable automated system are being applied to construct and operate new corrosion inhibitor application facilities at U.S. Army shipping locations, maintenance facilities, and depots. Besides the portable unit, the NDCEE implemented a permanent, manual-application Corrosion Control Center (CCC) at Fort Hood. The permanent CCC processes vehicles daily.

Technology Description

The Corrosion Prevention and Control System for Army Tactical Vehicles is used to apply a TACOM-approved corrosion inhibitor on vehicles for metal surface protection. Both a portable and a nonportable version of this system are available.

The portable system relieves operators from manually applying the inhibitor to tactical ground vehicles prior to shipboard transportation. It was designed based on user requirements and offers cost and ESOH improvements over the manual application process. It utilizes commercial off-the-shelf equipment to both wash the vehicles and apply a corrosion inhibitor in less than half of the time associated with the manual application process. In addition to operator benefits, the system reduces process wastes and contains a closed-loop reclamation system that reduces wastewater discharges.

The CCC is a manual application-type operation whereby CCC operators first inspect the vehicles and then manually apply a corrosion inhibitor. Vehicles are allowed to cure for approximately 24–48 hours before being picked up by the unit drivers.

For both types of system, vehicles are required to be washed before the corrosion inhibitor is applied. With the automated system, vehicles are sent through the first time to be washed, and then they re-enter the facility to receive the corrosion inhibitor. The CCC requires the vehicles to be delivered free of major dirt and debris.

ESOH Need

Corrosion prevention
in tactical vehicles



The portable Corrosion Prevention and Control System automatically cleans vehicles, such as this Heavy Expanded Mobility Tactical Truck, and then applies a corrosion inhibitor for metal protection.

Technology Benefits and Advantages

- Both types of systems can accommodate a wide variety of vehicle sizes and meet the required throughput.
- Both types of systems utilize commercial-off-the-shelf equipment to both wash the vehicles and apply a corrosion inhibitor. The automated system can apply the corrosion inhibitor in less than half of the time associated with the manual application process, but it coats the entire vehicle and does not allow the operator to target specific corrosion-prone areas of the vehicles.
- Both systems prevent the formation of corrosion in vehicles.
- Both systems improve mission readiness through reduced risk of vehicle failure.

- Both systems reduce maintenance costs associated with corrosion protection of vehicles and ground support equipment.
- The automated system uses a closed-loop system that reduces discharges to industrial wastewater treatment plants. Overspray is captured in a sump, which is emptied on a regular basis by Fort Hood Department of Public Works. A filtration system was installed at the corner of the curing pad to filter run-off from the concrete curing pad.
- The automated system is designed to make it nonintrusive to the host site (system may be relocated as needed or incorporated into maintenance and logistics facilities).

Technology Limitations

- A National Environmental Policy Act (NEPA) report analysis should be conducted and environmental permitting should be considered at all sites where a corrosion inhibitor application will be performed. A NEPA document was prepared prior to construction of the CCC at Fort Hood, and a Finding of No Significant Impact was issued.
- Both systems will require access to utilities, such as water and electricity.
- Additional space is needed for staging and curing areas, depending on expected throughput.

NDCEE FY04 Accomplishments

- Demonstrated the successful dismantlement of the portable, automated Corrosion Service Center at Fort Hood. The system is in the process of being relocated to Fort Bragg, where lessons learned from the Fort Hood demonstration will be applied. In FY05, the NDCEE will modify, build, demonstrate, and operate the system at Fort Bragg.
- Demonstrated and validated the CCC at Fort Hood in which the center applied a TACOM-approved corrosion inhibitor on nearly 3,000 vehicles and ground support equipment. As part of that effort, the NDCEE established a Memorandum of Agreement between TACOM and Fort Hood as well as produced a Letter of Instruction, Standard Operating Procedures, Safety Plan, and Environmental Risk Mitigation Plan. The NDCEE also conducted a NEPA analysis.
- Creating, in conjunction with TACOM, a Vehicle Tracking Database for the CCC. The database will document reoccurring corrosion problems and trends on a specific model or series of vehicle/ground support equipment. Its data will help to determine the cost payback of using the corrosion inhibitor on these types of vehicles and equipment.



This Corrosion Control Center at Fort Hood will help offset the high corrosion-related operations and sustainment costs associated with fielded vehicles.

Economic Analysis

In FY03, the NDCEE conducted field demonstration tests on the prototype portable facility at Fort Hood. Findings revealed that material and labor costs are approximately 40% lower and process times are approximately 30 minutes shorter with the automated system than the traditional manual method. Using these costs, a cost-benefit analysis showed that the system has a payback period of 12 months. Based on data from Fort Shafter, a manual operation has a payback of 16 months.

An estimated total investment of approximately \$270,000 is necessary to acquire equipment comparable to that which was installed at Fort Hood. The corrosion inhibitor is approximately \$1,000 per 55-gallon drum, with an estimated 1 gallon of product used per vehicle. Other operational costs include utilities, labor, alkaline detergent, petroleum-decomposing enzymes and personal protective equipment.

Suggested Implementation Applications

This technology can be installed at any maintenance facility or rapid deployment site used for trans-oceanic transports. The systems were designed for use by all-wheeled tactical vehicles and ground support equipment such as Heavy Expanded Mobility Tactical Trucks (HEMTTs), High-Mobility Multipurpose Wheeled Vehicles (HMMWVs), tankers, M870 40-ton low-bed semitrailers, and other support equipment.

Points of Contact

- I. Carl Handsy, TACOM-ARDEC, (586) 574-7738, Handsyl@tacom.army.mil
- Wayne Powell, NDCEE/CTC, (727) 549-7216, powellw@ctc.com
- Cristina Bressler, NDCEE/CTC, (814) 269-2863, bressler@ctc.com

Applicable NDCEE Tasks

Corrosion Measurement and Control (Tasks N.304 and N.0409)

Corrosion Preventive Treatment of Fielded Tactical Vehicles and Ground Support Equipment at Fort Hood (Task N.311)

Deployable HazMat Control Center

The NDCEE demonstrated and evaluated Deployable HazMat Control Center (DHCC) technology by utilizing comprehensive technology transfer protocols developed in its ongoing Commercialization Technologies to Lower Defense Costs (CT/LDC) Program. As part of this activity, the NDCEE demonstrated and validated three DHCC units at Fort Hood for their potential to provide appropriate control of hazardous material (hazmat) thereby lessening the potential for deleterious environmental effects as well as reducing the quantity of hazmat that is released into the environment. The three DHCC units that the NDCEE evaluated are designed for petroleum, oil, and lubricant (POL) storage.

The final report on the test results for this product is available to DoD users only by contacting the Army Program Office of the NDCEE at 703-602-5500, ndcee@hqda.army.mil.

Applicable NDCEE Task

Commercialization of Hazardous Material Containment and Control Technologies
(Task N.327)

Drive-On/Through Containment System

The NDCEE demonstrated and evaluated the Drive-On/Through Containment System (DOCS™) by utilizing comprehensive technology transfer protocols that have been developed in its ongoing CT/LDC Program. As part of this activity, the NDCEE demonstrated and validated DOCS II units (improved version of the DOCS I) at Fort Hood for their potential to provide secondary containment for leakage during vehicle refueling and maintenance operations, aiding in compliance with applicable local, state, and federal environmental regulation regarding secondary containment.

The final report on the test results for this product is available to DoD users only by contacting the Army Program Office of the NDCEE at 703-602-5500, ndcee@hqda.army.mil.

Applicable NDCEE Task

Commercialization of Hazardous Material Containment and Control Technologies
(Task N.327)

Dynamic Suspended-Bed Bioreactor for Bioremediation of Perchlorate

The NDCEE has extensive technical expertise with remediation technologies. Technology applications include treatment of lead-contaminated soils, removal of unexploded ordnance from military training ranges, and degradation of explosive-laden wastewater. In FY05, the NDCEE will be demonstrating and validating a dynamic suspended-bed bioreactor (DSBR) for the treatment of perchlorate-contaminated water. Perchlorate and nitrates are primary ingredients in solid-fuel missile and rocket propellants, explosives, and pyrotechnics and have been identified by the EPA as potentially harmful to human health.

Technology Description

The DSBR technology is being developed to destroy perchlorate (and nitrates) from drinking water, groundwater, and wastewater. It uses microorganisms to reduce perchlorate to chloride through an anaerobic degradation process. As with other bioreactors, a DSBR eliminates the waste generation and disposal requirements that are associated with physical removal technologies, such as ion exchange and membrane filtration, which do not destroy contaminants.

Bioreactors are an *ex-situ* form of biological treatment in which contaminated process wastewater or extracted groundwater is pumped into an above-ground reactor vessel and placed into direct contact with microorganisms. Careful control of environmental conditions (pH, temperature, oxygen content, nutrients, etc.), hydraulic flow, and residency time of the contaminated water in the bioreactor is necessary to support the growth of the microorganisms. These bacteria are obtained from local geologic formations and can rapidly metabolize and destroy perchlorate ions. They are expected to be able to reduce high concentrations of these contaminants in water to regulatory levels.

A DSBR is a hybrid of a continuously stirred tank reactor and fixed-film technology. The system, which is fully automated via a programmable logical controller, consists of a de-aeration tank, main bioreactor tank, substrate and nutrient feed tanks, nutrient feed pumps, and piping. The reactor vessels are populated with microbes that consume oxygen, nitrate, and perchlorate in the presence of an added food source (e.g., a sugar, alcohol, or similar substrate) as part of their respiratory process. The de-aeration tank removes dissolved oxygen and nitrate, which inhibit perchlorate reduction, from the extracted groundwater prior to it entering the main bioreactor. The main pilot bioreactor tank is sized to allow for hydraulic residence times that range from 0.5–1 hour based on varying the flow rate into the reactor.

The bioreactor contains plastic media to which the microbes attach. The unique design of the main vessel permits continuous circulation of plastic biocarrier material within the reactor, without the structural integrity and pressures that are required for fluidization [as with a fluidized bed reactor (FBR)] and without any internal moving parts. Circulation of the biocarrier within the reactor vessel occurs via induced water flow. The biocarrier material has a very large surface-area-to-volume ratio, which is excellent for bacterial colonization. The continuous circulation provides a uniform “field” for the bacteria, allowing a homogeneous mix of microbes, contaminants, and nutrients. It also permits mild contact among the biocarrier, which helps it to retain relatively clean surfaces and thereby prevent clogging. The reactor design also is amenable to fabrication from fiber-reinforced plastic, which can then be easily installed on site at a

ESOH Need

Perchlorate and nitrates removal from drinking water, groundwater, and wastewater



Preparing DSBR for testing

relatively low cost. The DSBR has undergone successful proof-of-concept testing and initial pilot-scale operation. The system can likely be scaled to flow rates of 1,000 gallons per minute or higher.

Technology Benefits and Advantages

- Reduces high concentrations of perchlorate contaminants in water to <1 parts per billion
- Destroys nitrate, which co-occurs with perchlorate in groundwater at numerous locations, without any major cost impacts (as opposed to ion exchange processes that are significantly impacted by nitrate)
- Is expected to have lower capital costs than other biological technologies (e.g., FBRs require large stainless steel reactor tanks, while DSBRs require smaller plastic tanks, producing up to a 50% cost savings)
- Does not produce hazardous byproducts; thus, eliminating the need for subsequent treatment and disposal
- Is less prone to clogging than other technologies

Technology Limitations

- Is still undergoing testing and has not been made commercially available
- Will require operator training

NDCEE FY04 Accomplishments

The NDCEE assisted the vendor with completing reactor construction, testing equipment installation, and conducting a reactor start-up/short-term operation at the West Valley Water District in Rialto, California. The reactor start-up/short-term operation demonstrated that perchlorate reduction was occurring and that all reactor components functioned optimally. Based on these findings, a 5-month demonstration test is planned for FY05.

Economic Analysis

A preliminary cost analysis indicated that the DSBR could be substantially less expensive to construct and operate than FBR technology, which is presently the only bioreactor system that has been successful for the removal of perchlorate from groundwater. The technology developer estimates that the DSBR could treat water for about \$70 per acre foot for nonpotable applications, and \$150 per acre foot for potential potable applications (biotreated water is currently not accepted for potable applications). These costs compare favorably with costs for current bioreactor technology (\$80 per acre foot) and for ion exchange for potable production (\$100–\$500 per acre foot, with the \$500 amount reflecting a situation in which water contains high nitrate levels).

Suggested Implementation Applications

The DSBR technology is being developed for any site that requires the removal of perchlorate and/or nitrates from drinking water, groundwater, and wastewater. The technology is being developed in response to the Army Environmental Requirements and Technologies Assessments (AERTA) Environmental Requirement A (1.2a), *Enhanced Alternative and In-situ Treatment Technologies for Explosives and Organics in Groundwater*. It also is of interest to the Naval Facilities Engineering Command and the Air Force Center for Environmental Excellence.

Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Bill Tumblin, NDCEE/CTC, (864) 271-8218, tumblinb@ctc.com

Applicable NDCEE Tasks

Commercialization of Technologies to Lower Defense Costs (Tasks N.319 and N.0403)

Electrolytic Plasma Processing

The NDCEE has assisted small- and medium-sized enterprises with commercializing their federally developed or supported technologies, which have both DoD and private-sector applications. As part of this assistance, the NDCEE demonstrated and validated a hydrogen plasma coating process known as electrolytic plasma processing (EPP) for Benét Laboratories, a division of the Armaments Engineering & Technology Center, Weapon Systems & Technology Directorate, Armament Research, Development & Engineering Command. Benét Laboratories is currently focusing on developing protective coatings for the internal diameter of 81mm mortar barrels for the U.S. Army. The NDCEE's demonstration and validation focused on extending the lifespan of the mortar, reducing scrap rates, and reducing the environmental issues and costs that are associated with processing the scrap.

Technology Description

EPP is an environmentally friendly, closed-loop, cleaning and coating process that is similar to electrolytic cleaning or electroplating. However, the applied potential of EPP is approximately 100–150 volts, while conventional electroplating is typically less than 12 volts. This high voltage leads to the formation of plasma by ionization of hydrogen in gas bubbles in the vicinity and/or near the work piece (cathode). The resulting foam solution of tap water and sodium bicarbonate is nontoxic and removes millscale, oils, grease, soaps, corrosion inhibitors, lubricants, and organic materials from metals prior to painting. It is also used to apply protective coatings using metals that are introduced into the process.

EPP involves a cathode (work piece), an anode, and an electrolyte, which are all housed in a reactor along with heaters and other components of the process. The cleaning process via introduction of an electrolyte, usually a sodium bicarbonate solution, results in local surface melting and creation of shock waves at the metal surface. The net effect is removal of contaminants. Some surface microroughening also occurs, which enhances adhesion of subsequently applied coatings. Also, the steel surface is passivated (coated with a protective substance) against general corrosion, which shields it from rust from days to weeks, giving sufficient lead-time prior to coating applications.

Coating deposition occurs by introducing metals and metal alloys into the electrolyte. These ions are carried to the metal surface by riding the surface of the hydrogen bubble as it collapses. Examples of deposits include zinc, zinc/aluminum, copper, nickel, copper/nickel, zinc/nickel, and copper/zinc. Coating technologies are available that have the potential to provide greater benefits in terms of readiness and overall cost and life-cycle requirements. These technologies, such as EPP, which can improve the reliability and maintainability of these components, must be investigated and evaluated before they can be implemented.

Technology Benefits and Advantages

- Shows the potential to alloy molybdenum with zinc and the ability to apply thin coatings of molybdenum and tantalum
- Shows evidence of being ductile and nonbrittle with no flaking or cracks
- Has potential to provide an alternative to manganese phosphating that is used on the outside diameter of the 60mm, 81mm, and 120mm mortar barrels and other parts of the mortars such as bipods, base plates,

ESOH Need

Cleaning and coatings application process



Prototype of electrolytic plasma processing unit
Transferring Technology Solutions

eyepieces, and breech plugs. An alternative is desired because manganese does not provide adequate corrosion protection for the external diameter of the barrel in certain environments.

Technology Limitations

- The technology requires additional research and development prior to commercial release. Presently, the coating thickness on all of the samples does not currently meet Benét Laboratories' desired thickness of 3–4 mil and was too thin for all testing to be completed and report accurate results.
- Operating training will be required.

NDCEE FY04 Accomplishments

- Completed laboratory validation to develop operating parameters for cleaning 4330 vanadium steel and Inconel 718 (IN718) and depositing tantalum and molybdenum, which were chosen as the best candidates for the internal diameter
- Completed screening tests to evaluate the cleaning and coating performance on the test coupons
- Determined that an increase in coating thickness must be obtained so that accurate measurements of thickness, hardness, and adhesion characteristics can be completed and evaluated

Economic Analysis

A preliminary economic analysis focused on the investment, costs, and potential savings that could be realized by implementing EPP. The investment costs range from \$550,000–\$1,550,000, depending on the cost that is associated with the equipment (which is unknown). Annual costs to operate and maintain the equipment are estimated to be \$12,000. Based upon input from Benét Laboratories, the life of the 81mm mortar barrel could be increased four times by implementing EPP. Taking into account that the current cost to produce a barrel is \$17,000, a payback of less than one year is expected, and a significant savings based upon current projected volumes of 160 81mm mortar barrels produced annually is expected.

Suggested Implementation Applications

EPP is being developed for use by any weapon system manufacturer or maintenance facility that needs an effective, environmentally safe cleaning/coating process. Potential commercial applications for EPP may include the automotive and airplane industry. This type of cleaning/coating process may improve the life cycle of 60mm, 80mm, and 120mm mortar barrels, which experience wear and pitting from firing, forcing their removal from service. This technology could be an environmentally friendly alternative for parts cleaning (alternative to acid pickling, abrasive blasting, wet or dry tumbling, brushing, salt bath descaling, alkaline descaling and acid cleaning), although this application remains uninvestigated.

Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Bill Tumblin, NDCEE/CTC, (864) 271-8218, tumblinb@ctc.com

Applicable NDCEE Tasks

Commercialization of Technologies to Lower Defense Costs (Tasks N.319 and N.0403)

Electronic Equipment Demanufacturing Recycling and Reuse System

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The NDCEE has demonstrated and validated improved technologies for the demanufacturing of electronic equipment. As part of its contributions, the NDCEE revitalized standards, procedures, and facility and equipment design associated with fostering a total life-cycle approach to managing electronic equipment. In the fall of 2003, the NDCEE transitioned these technologies to Lone Star Army Ammunition Plant. As a result of its expanded capability, LSAAP will be able to support the Defense Reutilization and Marketing Service in its role and responsibility for handling and disposing of the DoD's excess electronic equipment.

Technology Description

The Electronic Equipment Demanufacturing Recycling and Reuse System is an integrated system of eight (8) modules that processes electronic equipment into reusable or recyclable components. Typical equipment includes computers and monitors with cathode ray tubes (CRTs), radar devices, and communication devices. The modules are:

1. Receiving/Storage/Shipping—controls and accounts for each retired electronic equipment item as it flows into the demanufacturing facility as well as the recovered components, recyclable materials, and waste materials that flow out of the facility. Material tracking and accounting has become an important aspect of DoD modernization efforts to reduce costs, avoid waste, and minimize pollution.
2. Handling—controls the movement of material within the demanufacturing facility.
3. Disassembly—dismantles electronic equipment into more basic subassemblies or components that can be either recovered for reuse or further processed for materials recovery. Although disassembly can be performed using basic hand tools, more sophisticated disassembly techniques may be incorporated into the disassembly process to reduce labor costs.
4. Component Recovery—efficiently identifies and recovers critical components for reuse. Recovered components can be used to maintain the operational readiness of aging DoD systems that are plagued by parts shortages.
5. Testing—identifies equipment, subassemblies, and components that have reuse potential or may have marketable value in the commercial marketplace.
6. Glass Recovery—separates unleaded from leaded CRT glass and then prepares the CRT glass for reuse. Processed CRT glass is in the form of recyclable cullet, which can be used by CRT glass manufacturing facilities.
7. Metals Recovery—uses a more cost-effective and environmentally friendly process to separate metals and nonmetal materials from printed wiring boards. The process yields improved precious metal recovery at a lower processing cost to increase revenue.
8. Plastics Recovery—uses a novel processing system wherein engineering plastics are separated into high-purity concentrations of compatible types, suitable as replacement for raw material. This process obtains the greatest possible value from the material, increasing revenues and minimizing a waste stream.

ESOH Need

Reuse/recycle
electronic materials



Typical electronic equipment includes computers and monitors, radar devices, and communication devices.

Technology Benefits and Advantages

- Reduces solid waste generation
- Accomplishes demilitarization while recovering valuable electronic parts that are needed to maintain DoD systems
- Removes hazardous components for proper disposal to avoid present and future liability
- Returns revenue to the military services
- Demonstrates that reuse and recycling of electronic waste is viable

Technology Limitations

- System is still undergoing testing and has not been made commercially available.
- Facilities require appropriate pollution controls or regulatory permits.
- Output will be dependent on the composition of the input stream of retired electronic equipment.

NDCEE FY04 Accomplishments

- Transitioned the Electronic Equipment Demanufacturing Recycling and Reuse System to LSAAP, and then demonstrated the installed system. As part of its technology transfer assistance, the NDCEE previously prepared a Technology Transfer Package that contains a training course, equipment and operations manual, and pictorial record of the demonstration testing. In addition, the NDCEE conducted hands-on training in the use and operation of the process to LSAAP personnel. The pictorial record consists of a compact disk with still photos and an approximately 30-minute video with voiceover that shows the process operating in real time, with close-up views on the working equipment.
- Produced a software design and programming software package for the electronic demanufacturing system.
- Produced the Demanufacturing of Electronic Equipment for Reuse and Recycling (DEER2) Lessons Learned Report that captures the lessons learned from the transfer of the electronic demanufacturing system to LSAAP. Data gathering was obtained through specific task reports and by interviewing principle participants.

Economic Analysis

The DRMS is responsible for disposing of more than 30 million pounds of DoD electronic equipment annually. After examining DRMS practices and DRMS contractors, the NDCEE estimated that improved DEER2 methodologies and technologies have the potential to return \$1 million per year to the Government in material recycling and component recovery fees. In addition, demanufacturing scrap electronic equipment can save approximately \$400,000 in demilitarization annually. Finally, the DoD can avoid approximately \$25 million annually in third-party site cleanups if electronic scrap disposal is properly managed. The reuse of components and systems that could be returned to the military or to commercial use is an additional savings that could be significant, but has not been quantified.

Suggested Implementation Applications

The Electronic Equipment Demanufacturing Recycling and Reuse System was designed for demanufacturing facilities to process electronic equipment into reusable or recyclable components.

Points of Contact

- John Barrett, DRMS-BCP, (269) 961-5946, John.G.Barrett@dla.mil
- Ron Patun, NDCEE/CTC, (814) 269-2719, patun@ctc.com

Applicable NDCEE Tasks

Demanufacturing of Electronic Equipment for Reuse and Recycling (Task N.302)

Pilot Electronic Equipment Demanufacturing and Recycling Validation System (Task N.251)

Facility Environmental Management and Monitoring System

Under previous efforts, the NDCEE successfully designed and implemented a Facility Environmental Management and Monitoring System (FEMMS) at Tobyhanna Army Depot. The system was tailored to meet TYAD's unique needs as the DoD's largest full-scale communications-electronics maintenance facility. The NDCEE leveraged these efforts to design and implement a FEMMS that addresses the specific monitoring and environmental needs of a munitions facility, Radford Army Ammunition Plant. Current efforts are focused on continuing to enhance the FEMMS as well as implementing other pollution prevention improvements at RFAAP.

Technology Description

FEMMS integrates environmental data, hardware (sensors, monitors, and alarms), and software into a single system for industrial and environmental operations. It provides analysts, managers, process personnel, and command-level staff with access to critical environmental information at near real-time speeds, thus providing quick response capabilities—all with off-the-shelf, commercially available technologies. As a result, FEMMS enhances productivity and environmental performance as well as reduces waste and cost while conserving valuable resources.

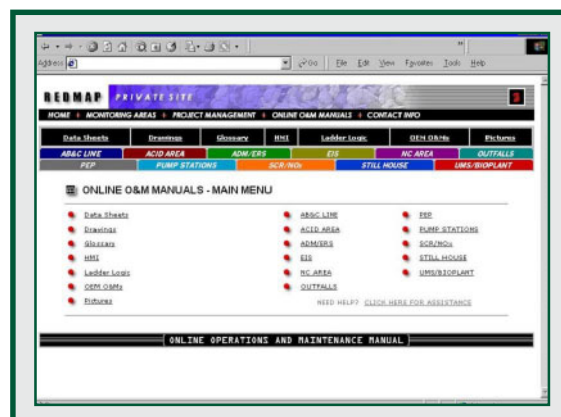
FEMMS is tailored to fit the needs of a facility. For instance, the TYAD FEMMS features monitoring/control systems for weather, drinking-water distribution and quality, steam plant emissions, road temperature, industrial wastewater treatment, sewage treatment, storm water, cold storage, hazardous materials and waste storage, and emergency power generation, as well as a centralized environmental information system with Global Information System and Global Positioning System capabilities.

The RFAAP FEMMS replaced unreliable equipment and labor-intensive manual methods and added new environmental monitoring capabilities, including early warning and alarm capabilities for corrective actions and emergency response. The system supports the activities of several independent, yet integrated, modules that connect 55 sites across the facility. The RFAAP FEMMS includes an Air Dispersion Modeling and Emergency Response System module, Selective Catalytic Reduction/Nitrogen Oxide (SCR/NO_x) Analyzer module, Virginia Pollutant Discharge Elimination System monitoring system for permitted outfalls to the New River, and monitoring system for ammonia tank farm pressures. In addition, the NDCEE is determining the system requirements, designing systems, and implementing monitoring control technologies for an acid concentration fume incinerator, audible notification systems for chemical releases, fossil-fuel energy generation opacity, and chemical recovery unit processes.

The NDCEE also is designing, developing, and installing a wireless Local Area Network (LAN) application to support RFAAP's nitrocellulose (NC) production, BioPlant line waste acid treatment, and SCR/NO_x areas. The LAN application includes the use of handheld devices for data entry, data retrieval, and reading bar codes. Paper forms are being converted into electronic formats to allow RFAAP operations personnel to manually enter data through the wireless handheld devices or through operations workstations available on site.

ESOH Need

Environmental monitoring and management of a facility's operations



This screen shot is from RFAAP's FEMMS, which provides near real-time data on wastewater discharges and air emissions.

Technology Benefits and Advantages

- Provides real-time situational awareness and early warning to environmental process deviations
- Provides a global perspective on facility operations
- Reduces labor-intensive environmental activities
- Verifies conformance to environmental mandates

Technology Limitations

- Initial capital and labor costs for computer and sensor technologies are high, but costs that are associated with the lack of timely data and potential environmental fines are even greater.

NDCEE FY04 Accomplishments

- Completed ECAMSM assessment on all FEMMS and pollution prevention modules installed at RFAAP
- Completed implementation of pilot Web-enabled security and surveillance camera system module
- Completed implementation of vertical integration module (wireless LAN application) in RFAAP NC manufacturing area
- Prepared System Decision Papers 30% Design Reports for four additional modules:
 - Vertical integration of RFAAP propellant finishing area
 - Vertical integration of visible emissions monitoring
 - Monitoring of wastewater from RFAAP 2,4,6 trinitrotoluene (TNT) production process
 - Security and surveillance camera system module (3 new sites added to system)

Economic Analysis

The NDCEE conducted an economic analysis on the FEMMS modules that are installed at RFAAP. The following table contains the cost-benefit findings.

FEMMS Modules	Module Cost	Annual Savings	NPV (15-yr)
Air Dispersion Model/Emergency Response System	\$397K	\$32K	\$(18K)
Virginia Pollutant Discharge Elimination System	\$958K	\$225K	\$1,733K
Pump Stations	\$179K	\$137K	\$1,453K
Ammonia Pressure Controls at Tank Farm	\$12K	\$24K	\$278K
Outfall # 007 Controls Upgrade	\$37K	\$209K	\$2,461K
Tie-in of Powerhouse Opacity Monitor to RFAAP System	\$17K	\$20K	\$223K
SCR Unit Controls Upgrade	\$96K	\$18K	\$122K
Security and Surveillance	\$248K	\$2,557K	\$30,272K
Vertical Integration of RFAAP Information, Air Emissions, Product Tracking/Waste Minimization	\$596K	\$251K	\$2,396K

K = \$1,000

Suggested Implementation Applications

With the ability to monitor, compile, and model data from all aspects of facility operations, the technologies that are employed by FEMMS are applicable to potentially all DoD facilities.

Points of Contact

- Brad Jennings, RFAAP, (540) 639-7417, Brad.Jennings@ATK.COM
- Brad Biagini, NDCEE/CTC, (814) 269-2840, biaginib@ctc.com

Applicable NDCEE Tasks

Managing Army Technologies for Environmental Enhancements (Tasks N.310, N.315, and N.0402)

Fiber Media Blasting

Under previous efforts, the NDCEE and NSWC-CD tested several alternatives, including fiber media blasting, to current coatings removal and etching methods at the NDCEE Demonstration Facility and Norfolk Navy Shipyard. The NDCEE utilized these efforts to help identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts. Fiber media blasting was found to be a technically and economically viable alternative for removing nonskid coatings from special hull treatment (SHT) tiles on LOS ANGELES (SSN 688) Class submarines.

Technology Description

Fiber media blasting offers a seamless method of surface preparation, cleaning, and decontamination of substrates. The media is a fiber-reinforced polymer matrix that is a composite of fiber, resin, polymer, and the desired surface treatment particles (plastic, cellulose, walnut, steel, or aluminum oxide). On average, this technology has a throughput of 400–600 pounds of media per hour and consumes 50–70 pounds of media per hour.

Three common types of fiber media are cleaning fiber medium, walnut fiber medium, and aluminum oxide fiber medium 30. The cleaning fiber medium consists of a no-profile, nonabrasive, cleaning medium. It is used for soft substrate cleaning as well as grease and oil removal. It contains no abrasive content and is safe for rubber and plastic surfaces. The walnut fiber medium is also a no-profile-cleaning medium, but uses walnut shells for low abrasive cleaning. This type of medium is typically used for coatings removal on sensitive substrates and equipment and is effective in cleaning harder surface contaminants. The aluminum oxide fiber medium 30 is the most aggressive medium available with a 3-plus mil profile. This medium is used for industrial coatings removal and decontamination.

The NDCEE has demonstrated an engineered media blaster that includes a media vibrator to ensure even flow rates for a wide range of media types, an air muffler for quieter depressurization, a pneumatic media flow valve for maximum control, a large manhole cover for easy clean-out, and a large pop-up valve and inlet for fast charging. Other systems that are available for use with the media blaster are a vapor injection system and media classifier. The vapor injection system introduces pressurized vapor into the blast air stream to accelerate surface treatment operations, combine multiple surface preparations into one process, and dramatically reduce dust generation. Using a classifier, the media can be recycled anywhere from 5–15 times. The amount of times that the media can be recycled depends on the type of surface and contaminants that are being removed. Some features of the classifier include a waste screen that separates large debris and contaminants from the media, another screen to remove dust and consumed abrasives from reusable media, a rotational system to ensure an exact flow pattern to maximize production, and a motor access panel for easy maintenance.

ESOH Need

Coatings removal techniques

Technology Benefits and Advantages

- Eliminates hazardous airborne particulates from blasting operations, decreases solid waste, and eliminates the use of chemical strippers
- Reduces labor and operating costs as a result of decreased pre-removal preparation and post-removal cleanup
- Improves safety and worker health conditions due to the elimination of airborne emissions of heavy metals and other contaminants when used with vacuum recovery
- Uses recyclable media

- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

Technology Limitations

- Not as aggressive on metallic substrates as some, more abrasive media. However, unlike fiber media, abrasive media do not have the capability to be used on delicate substrates.

NDCEE FY04 Accomplishments

The NDCEE produced a Final Report on Task N.301 accomplishments. Included in this report was a discussion on NDCEE field demonstration activities at NAB Little Creek and on behalf of Fort Eustis on four coatings removal processes. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities' production requirements and waste reduction needs. In addition, they were tested on aluminum and fiberglass HMMWV parts to determine if these delicate substrates would be damaged during a coatings removal process. They also were tested on steel Modular Causeway Systems and a 2 1/2-ton truck component. Based on test results, fiber media blasting was recommended for NAB Little Creek.

Economic Analysis

The NDCEE conducted a cost-benefit analysis in which it compared fiber media blasting to current removal methods for nonskid removal from SHT tiles. Capital costs for the fiber media blasting equipment are approximately \$44,500. Annual operating costs are estimated to be \$13,779. The operating costs for the dry abrasive blasting equipment is estimated to be \$63,247. Pearl Harbor Naval Shipyard supplied the baseline data. Based on ECAMSM results, the simple and discounted payback periods for the fiber media technology are less than one year. The NPV for each study period (5, 10, and 15 years) is positive ranging approximately \$200,000–\$600,000. The IRR values of 120–122% are acceptable to justify the investment.

The NDCEE also conducted a cost-benefit analysis using the baseline removal rate that was received from Fort Eustis on its dry sodium bicarbonate blasting process for aluminum and fiberglass components. Test results show that the fiber media technology offers a comparable strip time to the baseline of 4–5 hours, causes no damage to delicate materials, and emits little to no dust. Because of the comparable strip rates, associated labor costs should be the same as the baseline method. Reduced procurement and disposal costs are anticipated because the fiber media are recyclable. Procurement savings are dependent on the price of the raw materials. Prior to technology implementation, a complete cost analysis should be performed.

Suggested Implementation Applications

Fiber media blasting may be used on a variety of delicate substrates such as aluminum and fiberglass. Applicable weapons system components include SHT tiles on submarines, fiberglass hoods on HMMWV, and potentially Navy and Air Force radomes.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Mary Nelson Bush, NDCEE/CTC, (904) 722-2509, bushm@ctc.com
- Melissa Klingenberg, NDCEE/CTC, (814) 269-6415, klingenb@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

Field-Based Perchlorate Measurement

The NDCEE has assisted small- and medium-sized enterprises with commercializing their federally developed or supported technologies, which have both DoD and private-sector applications. As part of this assistance, the NDCEE is evaluating a field-based perchlorate measurement technology as a candidate that can be used by the DoD and the private sector to screen water and wastewater for contamination by perchlorate in support of demonstration activities for the military. Perchlorate is a widely used component of solid fuel missile and rocket propellants, explosives, and pyrotechnics.

Technology Description

Field-based perchlorate measurement technology uses a combination of ion chromatography and ion-selective electrodes to quantify perchlorate levels in water samples. Ion chromatography is a robust method for separation of charged ions and is also the basis for the current EPA Method 314 for perchlorate analysis. An ion-selective electrode is significantly more selective to perchlorate than the current EPA Method 314, because the EPA method combines ion chromatography with suppressed conductivity.

The portable perchlorate measurement technology is presently in the prototype stage. It consists of an instrument case with an associated computer to operate the instrument and acquire data using commercial software, buffer reservoirs, solenoid valves and pumps, an injection valve, a high-performance liquid chromatography pump, an ion chromatography column, the flow-through perchlorate electrode, and a reference electrode. The entire instrument assembly and computer weigh approximately 40 pounds.

In operation, an aqueous sample is injected into an aqueous flow stream. The flow stream is directed into a chromatographic column and the various charged components are separated into different fractions depending on the characteristics of the column and the sample constituents. The ion-selective electrodes then allow selective determination of the perchlorate ion in the effluent from the ion chromatography column. The commercial software controls the flow through the instrument and records the measurements from the electrode.

ESOH Need

Perchlorate
measurement in water
samples

Technology Benefits and Advantages

- Can be employed in the laboratory or in the field for the detection of either perchlorates or (after reconfiguration) heavy metal ions in water
- Has a demonstrated detection limit capability of approximately 2.5 parts per billion
- Provides portable capability that is not currently available with the existing EPA Method 314 and therefore will enable on-site field testing and site characterization
- Is less expensive (between \$13,000–\$15,000) than instruments that are currently available for Method 314 (such as ion chromatography with suppressed conductivity, and liquid chromatography with mass spectrometry), so it will serve the need for cost control in compliance testing, site characterization, base closure, and routine use in remediation facilities
- Has greater specificity (through ion-selective electrodes) than current methods and will therefore provide more accurate measurements in high-salinity (high total dissolved solids/high-conductivity) samples

Technology Limitations

- Electrode stability, conditioning/storage conditions, and making reproducible ion-selective electrodes are issues to be resolved.

- To obtain the best separation and the lowest detection limit, the pH of the mobile phase may need to be modified after the ion chromatography separation activity.
- Further work is needed to validate the calibration method.

NDCEE FY04 Accomplishments

- Completed a field demonstration of the technology at Rialto, California, and Edwards Air Force Base, in which the developer built and tested approximately 45 electrodes during the demonstration; and a detection limit of 10 parts per billion was obtained
- Identified that the ion chromatography conditions that were tested allowed the complete separation of perchlorate from competing anions in about five minutes, compared with about 20 minutes for EPA Method 314
- Wrote a “virtual instrument” computer program to control fluidic events for the instrument, controlling operation of pumps and collection of data in a spreadsheet format
- Designed and constructed a rugged field prototype instrument for field demonstration
- Achieved demonstration results indicating that the field prototype instrument performed well: data that were obtained from the analysis of groundwater samples containing high concentrations of perchlorate showed good correlation with data from a commercial laboratory that used EPA Method 314

Economic Analysis

The developer estimates that a complete ion chromatography/ion-selective electrode system for perchlorate will have a retail price between \$13,000–\$15,000. This price compares favorably with the price of \$30,000–\$240,000 for instruments that are used for EPA Method 314.

Suggested Implementation Applications

Field-based perchlorate measurement technology is being developed for field-testing and site characterization of water and wastewater that may be contaminated with perchlorate or heavy metal ions. In addition, the technology is suitable for laboratory applications for batch analyses.

Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Bill Tumblin, NDCEE/CTC, (864) 271-8218, tumblinb@ctc.com

Applicable NDCEE Tasks

Commercialization of Technologies to Lower Defense Costs (Tasks N.319 and N.0403)

Halogenated Volatile Organic Compound Field Screening Technology

The NDCEE assists small- and medium-sized enterprises with commercializing their federally developed or supported technologies, which have both DoD and private-sector applications. For instance, the NDCEE helped Western Research, Inc., developer of the X-Wand™, to enter into an agreement with an instrument manufacturer/distributor. A halogenated volatile organic compound (HVOC) field screening technology, using the X-Wand (for soils analyses), should enter into Government and commercial markets in 2006.

Technology Description

The HVOC field screening technology can detect and quantify HVOC concentrations in soil and potentially in groundwater samples. It has multiple functions including site characterization, real-time monitoring of remediation activities, and long-term monitoring after a site has been remediated. The technology is an improvement over the common screening method, which is conducted with photoionization detectors (PIDs). These detectors are only capable of detecting, but not measuring HVOCs.

The HVOC field screening technology is based on refrigerant leak detector technology that is modified to provide a numerical output and operates as an organic vapor analysis tool. Its key element is the use of the heated-diode-based X-Wand. The X-Wand's small portable design incorporates a plastic or metal case with sensors, a digital readout, and a custom power supply. The diode sensor is heated between temperatures ranging from approximately 1,110–1,835°F (600–1,000°C). A heated alkali metal vapor stream in the sensor selectively reacts with halogens that are present in HVOC molecules, creating ionized product species that cause an ionized current to flow between a cathode and an anode. The sensor operates in a manner similar to an electron capture detector (ECD), and response is linear with the log of concentration of HVOC (a characteristic of a first-order reaction between the HVOC and alkali vapor). As with an ECD, other volatile electronegative compounds, such as carboxylic acids, ethers, nitro compounds, and hydrochloric acid, can cause some response. However, the heated diode sensor does not respond to water vapor nor volatile aliphatic or aromatic hydrocarbons that are commonly found in volatile fuels.

ESOH Need

Soil and groundwater remediation

After collection of soil or water samples, the HVOC field screening technology analyzes the headspace of the sample container above the soil or water media. For water samples, a partition constant is used. For soil samples, a method that is similar to the widely used Mason jar/PID screening is used. The X-Wand's halogen-selective sensor detects HVOCs in the vapor phase at the parts-per-million (ppm) level. This level

corresponds to a parts-per-billion level in soil when analyzing headspace above soil. These detectors do not respond to non-halogenated VOCs, and humidity does not interfere with or degrade the detectors.

Technology Benefits and Advantages

- Is small and portable, enabling easy use in the field
- Has lower capital costs (\$2,000) than current technologies (\$4,000–\$5,000), which only measure VOCs
- Enables long-term monitoring
- Meets field-screening benefits sought by the EPA Office of Superfund Remediation and Technology Innovation, including:
 - Faster and cheaper analysis (minutes rather than days for laboratory analysis and \$5–\$15 versus \$70 per sample for laboratory analysis)



X-Wand portable test kit components for HVOC field screening

- Quick optimization of remediation processes in real-time
- Three-dimensional understanding of a site
- Reduction of decision error due to heterogeneous sampling

Technology Limitations

- The interpretation of the readout from the X-Wand device needs to be further defined. Currently the readout is in volts (from 1mV to 20mV), but will likely be modified to include a direct readout of log of concentration of contaminant, which is a linear function of the voltage.
- The technology is still undergoing testing and is not commercially available. Future design improvements may include incorporation of digital data processing, a computer interface using a USB connector, and possibly an on-board datalogger.

NDCEE FY04 Accomplishments

- Performed the first field evaluation of this new technology and of the associated methodology that will become an American Society for Testing and Materials (ASTM) standard for soils analysis
- Modified initial methodology and identified necessary modifications to the hardware for incorporation into the system, based on results of the demonstration
- Assisted the technology developer into entering an agreement with an instrument/distributor who intends to introduce the X-Wand (for soil analyses) into the marketplace in 2005 and incorporate any modifications for water analyses into an updated commercial product
- Incorporated the field and laboratory method development and validation into a new ASTM method for submission
- Developing an X-Wand demonstration for water analysis applications

Economic Analysis

Because an economic benefit is generated by the reduction in the number of laboratory samples that is required, a break-even analysis was performed to determine the potential economic benefit of the X-Wand. The analysis indicated that the use of the X-Wand for 33 or more samples during site assessments and 16 samples during remediation would produce an economic benefit because a typical site assessment could require approximately 100 samples and a typical site remediation could require hundreds of samples.

Suggested Implementation Applications

The HVOC field screening technology may be suitable for DoD and commercial sites with soil and groundwater contamination. In accordance with EPA regulations, HVOCs must be measured before, during, and after a site is remediated. The DoD has targeted approximately 9,000 sites for remediation, 71% of which have contaminated groundwater and 67% have contaminated soil. According to the EPA, nearly 70,000 non-DoD and non-Department of Energy (DOE) sites that are polluted with HVOCs will require remediation over the next 30 years. VOCs are the most prevalent groundwater contaminant, occurring at 74% of the DoD groundwater sites and 43% of the contaminated soil sites, with HVOCs often representing the highest percentage of VOC contamination. In the commercial market, the requirements of federal and state regulations will lead to the clean up of more than 200,000 sites (non-DoD and non-DOE) at an estimated cost of \$187 billion. (Source: U. S. Environmental Protection Agency. 1997. *Clean Up the Nation's Waste Sites: Markets and Technology Trends*. EPA 542-R-96-005.)

Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Bill Tumblin, NDCEE/CTC, (864) 271-8218, tumblinb@ctc.com

Applicable NDCEE Tasks

Commercialization of Technologies to Lower Defense Costs (Tasks N.319 and N.0403)

Laser Decoating

The NDCEE has extensive technical expertise with coatings removal using laser decoating technologies. For instance, the NDCEE has evaluated the applicability of the FLASHJET® process for the removal of coatings from submarines and surface ships as well as on flight-critical helicopter rotor blades. The NDCEE also evaluated four laser decoating systems on their ability to remove coatings from Naval Sea Systems Command (NAVSEA) radomes. As part of the evaluation, the NDCEE supported NSWC-CD in conducting field demonstrations at three sites: a vendor site, Ogden Air Logistics Center, and Wright-Patterson AFB.

Technology Description

Laser decoating is a nonintrusive, nonkinetic energy process for removing organic coatings from a variety of substrates, including composites, glass, metal, and plastics. A laser, which is an acronym that stands for Light Amplification by Stimulated Emission of Radiation, is a device that generates monochromatic, coherent light that can be focused and concentrated into a narrow, intense beam of energy. This energy beam can be applied to coatings removal operations due to its ability to ablate a coating from a substrate.

The high-level energy from a laser beam is absorbed at the surface of a coating material, resulting in the subsequent decomposition and removal of that coating. As the coating is volatilized, decomposition by-products are thrown into the laser beam and incinerated to produce carbon dioxide, water, inorganic pigment ash, and trace amounts of other compounds. The organic constituents are exhausted into the atmosphere, and particulate matter is collected in conventional filters for future disposal. Because of this action, the amount of waste to be disposed of represents a fraction of the original coating volume.

The optical output from a laser may take the form of a continuous wave or a pulsed beam. Continuous wave lasers reflect photons so that the number of stimulated emissions equals the number of photons in the optical output. Pulsed lasers use various methods to output photons in surges instead of continuously. Both pulsed and continuous beam outputs have been proven effective for coatings removal applications.

Four main categories of lasers are used for coatings removal applications: solid-state, gas, excimer, and semiconductor. These categories are based upon the medium that is used to create the laser output. Solid-state lasers have material that is distributed in a solid matrix such as ruby or neodymium:yttrium-aluminum garnet (Nd:YAG) lasers. Gas lasers commonly use CO₂, helium, helium-neon, or argon as the medium. Excimer lasers use reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton, or xenon. Semiconductor lasers are commonly called diode lasers and are contained on a small wafer of semiconductor material, such as gallium arsenide, that is less than a millimeter thick. This wafer produces a laser when an electrical charge is applied. Each of these types of lasers has unique characteristics that must be considered when selecting the laser type for a coatings removal application.

A typical laser coatings removal system consists of a laser, a beam delivery system, a manipulation system, and a waste management system. The laser beam delivery system is used to transfer the laser output to the work surface with the appropriate spot size and shape for delivering the energy density that is required for efficient coatings removal. A manipulation system controls the position of the laser as it moves over the substrate surface, and the waste management system captures the particulate residue that is created by the ablation process. Another possible addition to the laser system is a feedback control system that allows the selective removal of primers, paints, topcoats, sealants, and other surface coatings.

ESOH Need

Coatings removal techniques

Previous materials testing that was conducted by the NDCEE has shown that laser decoating technology was effective at removing even the most difficult coatings, including powder coats, electrocoats, chemical agent resistant coatings, and specialty coatings such as Rockhard stoving enamel. Removal rates varied between 5.8 and 17.5 square feet per hour (250-W system) and 46 and 140 square feet per hour (200-kW system) during this testing.

Technology Benefits and Advantages

- Is available as either handheld or robotic system
- Is capable of selective stripping
- Reduces environmental impact from elimination of the use of hazardous chemicals and reduction of solid waste generated for disposal
- Reduces health and safety risks due to the elimination of exposure to hazardous chemicals and decoating residues
- Decreases operating costs due to reduced labor, materials use, damaged parts, and waste disposal costs
- Is applicable for removing organic coatings from composites, plastics, fiberglass, and metals

Technology Limitations

- Operator training required
- Line-of-site technology (although it can strip moderately contoured parts – up to approximately a 45-degree angle)
- High capital investment (starting at ~\$500,000) associated with the robotic system

NDCEE FY04 Accomplishments

As part of Task N.308, Subtask 2, Coatings Removal from Delicate Substrates, the NDCEE conducted four laser decoating demonstrations in the summer of 2003. Demonstrations occurred at three locations: Laser Hardened Material Evaluation Laboratory (LHME) at Wright Patterson AFB, Laser Automated Decoating System (LADS) facility at OO-ALC, and a vendor site. In FY04, the NDCEE evaluated demonstration results, which were documented in a Final Technology Evaluation Report, dated October 2004, and summarized below:

- A 40 W and 120 W handheld yttrium aluminum garnet crystals doped with Nd:YAG laser system was demonstrated at the LHME facility. The removal rate on the MK92 Navy radome samples provided by NSWC-CD was approximately 1 square foot per hour using the 120 W Nd:YAG laser system and approximately 0.5 square foot per hour using the 40 W Nd:YAG laser system. The surface area of a MK92 Navy radome is approximately 872 square feet; therefore, the removal rates of the evaluated handheld laser systems would need to be improved for this technology to be feasible for use on these Navy radomes.
- A 6 kW infrared CO₂ laser system, which was developed for decoating Air Force radomes, was demonstrated to remove coatings from a small section of a MK92 Navy radome at the LADS facility. The stripped sample had surface areas where the coating was partially removed and areas where the substrate sustained significant damage to the surface. Therefore this process would require additional time and money to be optimized for use on these Navy radomes.
- A 2 kW automated diode laser system was demonstrated at a vendor site. The robotically controlled laser head made multiple passes over the sample MK92 Navy radome, during which several corrections were made to optimize coatings removal and minimize substrate damage. The diode laser system efficiently and effectively removed the coating; however, some uneven removal of the coating occurred due

to variable paint thickness on the radome. The addition of a color-recognition software package and floating head design are expected to correct the observed removal inconsistencies.

Economic Analysis

The estimated capital cost for a laser decoating system for depot-level maintenance activities varies from \$100,000–\$320,000 for a handheld system to between \$500,000–\$1.5 million for a robotic system.

Suggested Implementation Applications

Laser coatings removal systems can potentially be used by DoD maintenance and sustainment facilities that use manual, hand-sanding, abrasive blasting, and hazardous chemicals to remove coatings from metallic and composite substrates that are found on aircraft, surface ships, and submarines. For instance, OO-ALC is using a robotic CO₂ laser system to remove coatings for Air Force and Naval Air Systems Command (NAVAIR) radomes. In addition, the Air Force is in the process of qualifying 120 W and 500 W handheld Nd:YAG lasers for coatings removal from small areas on aircraft.

Points of Contact

- Dr. Scott Sirchio, NSWCCD, (301) 227-5196, sirchiosa@nswccd.navy.mil
- Georgette (Kotsagrellos) Nelson, NDCEE/CTC, (412) 992-5355, nelsong@ctc.com

Applicable NDCEE Task

Coatings Removal from Delicate Substrates and Application Process Improvements for Department of Defense (DoD) Industrial Facilities (Task N.308)

Magnetically Assisted Impaction Mixing

The NDCEE, in conjunction with researchers at the New Jersey Institute of Technology, researched environmentally friendly technologies and processes to produce new materials and recycle both new and old materials (including composites and ceramics). As part of that effort, the NDCEE team has investigated three critical technical issues: (1) research on mixing of nano-sized particles, including the ability to scale-up; (2) evaluation of mixing effectiveness of any mixing process; and (3) consideration of environmental impact of the mixing processes. The main technical objective was to investigate techniques that can effectively mix two nano-constituents, with the eventual objective of using the technique for mixing metastable intermolecular composites (MIC), mixtures of metal and metal oxides. These composites are alternatives to conventional lead-based primers for bullets/ammunition and other potential applications.

Technology Description

Magnetically Assisted Impaction Mixing (MAIM) is being developed to improve the effectiveness of mixing powders with nano-sized particles without the aid of a solvent or heat. In general, uniform mixing of nano-sized materials is more difficult than mixing of larger sized materials. Still in development, the technology will aid manufacturing applications in producing higher quality products. It is being developed in response to the DoD need for a safe and cost-effective approach to producing MIC as well as a variety of other applications involving nano- as well as sub-micron particles. Current methods of mixing MIC involve the use of solvents that contain VOCs, and the methods are not scalable for large-scale production.

With MAIM, small magnetic media (such as 1–2mm ground magnets that are coated with polymer) are added to materials to be mixed, such as dry particulate material. When a variable magnetic field is applied, the magnetic media move to produce a mixing situation that is somewhat comparable to a fluidized bed in which the other material is mixed in a timely and energy-efficient manner. At the end of the mixing process, the field is turned off and the magnetic media can be readily removed.

Apart from the mixing of particles from 1–2 microns down to nano-size in various energetic formulations, the technology has other possible applications such as facilitating coating of particles to change performance characteristics and producing products with longer shelf life. For instance, the technology has been used to coat ground magnesium powder with 1–2% wax by weight in order to more than double its shelf life. When tested for firing characteristics, this coated magnesium performed as well as uncoated powder.

Technology Benefits and Advantages

- Effective mixing for nano-scale materials without the use of a solvent
- Easy removal of mixing media, particularly where desired products are not magnetic
- Readily scaled-up for large-scale production usage
- Relatively inexpensive equipment requirements
- Wide application and cross use of equipment
- Reduced ESOH risk due to the elimination of organic solvents and associated fire hazards

ESOH Need

Munitions
manufacturing
processes

Technology Limitations

- Risk with impact-sensitive materials is still being evaluated as the technology is under development.
- As with the usage of all dry powder processes, process equipment must be grounded meticulously to avoid dust explosion.

NDCEE FY04 Accomplishments

- Compared MAIM to other nonsolvent-based mixing techniques, including mechanical mixing through hybridizer, mechanofusion, rapid expansion of supercritical fluid or high-pressure liquid-based mixing, and novel fluidization techniques based on aeration and magnetic excitations, as well as conventional solvent-based techniques.
- Characterized mixing using Atomic Force Microscope, Field Emission Scanning Electron Microscopy (FESEM) imaging along with Energy Dispersive X-ray analysis (EDX), and Transmission Electron Microscopy with Electron Energy Loss Spectroscopy (TEM-EELS). Based on the FESEM-EDX evaluation technique, which was found to be the most useful of the techniques explored and can be relatively fast and cost-effective, all employed mixing techniques were found to perform as good as or better than the baseline method of solvent-based mixing. The techniques can be ranked according to best performance in the following manner: rapid expansion of supercritical fluid or high-pressure liquid-based mixing; hybridizer, mechanofusion, and MAIM; and novel fluidization techniques based on aeration and magnetic excitations. However, in terms of ease of scale-up, lower cost, and reduced chance of setting the MIC mixture while mixing, the MAIM and magnetically assisted fluidization are the best technologies.

Economic Analysis

Because the technology is still in development, a detailed economic analysis has not been performed. However, cost estimates that are related to process scale-up using the MAIM technology, in contrast to original solvent-based scale-up (with explosion-proof electrical equipment), results in substantial savings in equipment cost. Additional operating savings are expected due to the elimination of solvent usage and associated waste management and air emission treatment issues. Also, as noted previously, it seems to be the lowest in cost as compared to other, alternative mixing techniques.

Suggested Implementation Applications

MAIM is being developed to support several DoD programs including Green Gun Barrel, Green Bullet and Ammunition, and Advanced Materials. A key application area would be mixing components of complex propellant, explosive, and pyrotechnics materials, particularly where smaller-sized ingredients can be shown to benefit performance. It can also impact existing formulations where fine particles in size range 0.5–10 microns are already used, for example, in a number of delay compositions.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Melissa Klingenberg, NDCEE/CTC, (814) 269-6415, klingenb@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R2-3)

Microfiltration Systems

The NDCEE has extensive expertise with filtration systems. Several systems are featured in the NDCEE Demonstration Facility, where they are used by DoD and industrial facilities for demonstration and validation purposes. For instance, the NDCEE helped Red River Army Depot to validate a microfiltration system as an aid to extending the solution life of its zinc-phosphate pretreatment baths and thereby increasing production efficiency. Most recently, the NDCEE installed three microfiltration systems at Tobyhanna Army Depot to be used in conjunction with its plating lines. The NDCEE also worked with Oklahoma City Air Logistics Center and Corpus Christi Army Depot in determining that the bath life of alkaline rust removers that are currently in use could be greatly extended by using a microfiltration system.

Technology Description

Microfiltration provides a 1.0–0.1-micron absolute barrier that removes emulsified oils, greases, and particulate matter from filtered liquids, primarily alkaline cleaners. The typical configuration (known as cross-flow filtration) is a low-pressure (e.g., 5–40 pounds per square inch @ gauge), energy-efficient flow of liquid across the inner surface of a microfilter tube. Systems are available in different materials of construction and membrane pore diameters to accommodate unique bath characteristics (e.g., chemistry, volume, types of contaminants, and throughput).

These particular microfiltration modules are fabricated from graphite material that is formed into a tubular configuration. Wastes that are pumped into these tubes form a dynamic membrane that produces a high-quality filtration medium and removes all particles larger than the pore size. Turbulence helps to maintain membrane cleanliness, although periodic maintenance is recommended.

Applications include removal of heavy metal particles from semiconductor and components manufacturing as well as oil and grease removal from industrial laundry effluent and plating line cleaning baths.

Technology Benefits and Advantages

- Removes suspended particulate matter, oils, and greases from effluent discharges and reduces the frequency of bath changes
- Maintains a more stable bath consistency, thereby reducing process variation
- Reduces material and operating costs because chemical usage is reduced, secondary cleaning requirements (i.e., parts rework) are decreased, and less sludge/hazardous waste is generated/disposed
- Reduces worker health and safety risks by reducing chemical usage/handling
- Reduces waste solution discharges to industrial waste treatment plants
- May result in affordable payback period with system costs ranging \$10,000–\$100,000
- Helps facilities to meet pretreatment standards for discharges of wastewater to treatment plants or effluent limits of National Pollutant Discharge Elimination System (NPDES) permits

ESOH Need

Improved treatment of effluent discharges



Microfiltration system housed at the NDCEE Demonstration Facility

Technology Limitations

- Filtration membrane can become clogged with oil/grease if an oil coalescer is not used as part of the microfiltration process.
- Periodic cleaning of the membrane is required to optimize efficiency, adding to the operational cost of implementation.
- Proper sizing of the membrane is required to minimize loss of cleaner and/or surfactant.

NDCEE FY04 Accomplishments

The NDCEE completed its microfiltration study and produced a Final Report on Task 000-01, Subtask 5. The study investigated various types of membrane materials to determine the most effective membrane for removing solids from alkaline rust removers that are currently in use at OC-ALC and CCAD. Results of these trials showed that the polymer membranes outperformed the ceramic, even at temperatures near 165°F. Equipment recommendations were received from the vendor to provide preliminary cost information to OC-ALC and CCAD for the purchase of a mobile, skid-mounted unit that is simple to operate and can be quick-connected to various rust remover tanks throughout their facilities. This unit would extend the useful bath life of the alkaline rust removers, decreasing labor, chemical, and disposal costs associated with dumping the spent alkaline rust remover and creating a new bath.

Economic Analysis

The capital cost for microfiltration systems will vary depending on the particular removal challenge presented. However, it is generally under \$100,000. For instance, the cost for the equipment investigated for OC-ALC and CCAD was \$55,000. While no cost analysis was conducted for OC-ALC and CCAD, the cost for the equipment considered for TYAD's cleaning/plating lines was approximately \$90,000, yielding a simple payback of 3.5 years.

Suggested Implementation Applications

This technology is applicable for any site with wastewater issues, particularly those that are connected with industrial operations such as electroplating lines. For instance, TYAD cleans and plates a wide variety of parts in all configurations and sizes from many DoD weapon systems. The parts are mostly from ground support equipment such as trucks and trailers. Other parts that are processed are from surveillance equipment, satellites, radios, and other communication equipment. Two specific systems supported by TYAD are Guardrail™ and FireFinder™. Guardrail™ is a Corps Level Airborne Signal Intelligence collection/location system; FireFinder™ is a mobile radar system.

Points of Contact

- Dr. Charles Lechner, OASA (I&E) - ESOH, (703) 602-5538, charles.lechner@hqda.army.mil
- Leanne Debias, NDCEE/CTC, (814) 269-2830, debias@ctc.com

Applicable NDCEE Task

Alternative Cleaning Solutions Recycle/Recovery (Task N.000-01, Subtask 5)

Plasma Energy Pyrolysis System (PEPS®)

The NDCEE is working with the Army to transition the Mobile Plasma Energy Pyrolysis System (PEPS®) to interested DoD and industrial sites. As part of this effort, the NDCEE is assessing the reliability, maintainability, and overall effectiveness of the Mobile PEPS® for the treatment of DoD-problematic waste surrogates on behalf of the Office of the Secretary of the Army for Installations and Environment. In addition, the NDCEE held a Plasma Energy Pyrolysis Information Exchange on October 19, 2004, in which attendees were presented with the preliminary performance data from three recent demonstration tests on surrogate wastes (liquid, solid, and sludge) and on mobility testing of the system. A facility tour provided attendees with the opportunity to view the 6-trailer plasma energy pyrolysis mobile system.

Technology Description

The PEPS® utilizes plasma energy to destroy waste materials resulting from military and commercial industrial operations. Plasma energy pyrolysis is not classified as incineration and has been permitted as an alternative treatment technology. It is an alternative for other types of waste-material disposal technologies, including landfilling and incineration.

Plasma pyrolysis technology uses a single plasma arc torch to produce a clean, massless heat that is formed by highly ionizing a gas, such as air or nitrogen, using electrical power. With temperatures greater than 3,000°F (1650°C), the plasma energy pyrolyzes organic materials into their gaseous basic chemical elements (carbon, hydrogen, oxygen, and nitrogen). Organic waste materials are converted into a synthesis gas (syngas) while inorganic materials are vitrified into a nonleaching slag. Metals and gases can be recovered for reuse. During treatment, the oxygen-depleted atmosphere in the pyrolysis mode prevents burning and limits production of dangerous by-products such as nitrogen oxides, sulfuric oxides, dioxins, and furans. Unlike the combustion process, typical of incineration, only a small quantity of plasma gas is used to generate and maintain the operating temperature.

During NDCEE-monitored demonstration testing in 2004, the system successfully processed a polychlorinated biphenyls (PCB)-contaminated transformer oil surrogate, granular activated carbon contaminated with energetic surrogate, and an electroplating sludge surrogate with a high metal content. For each demonstration test, the PEPS® unit was operated between 48–75 hours. The destruction removal efficiency of the PEPS® was in excess of 99.99%. Gas emissions passed Clean Air Act standards, and the wastewater quality was acceptable for sewage discharge. Because the resultant slag passed the EPA toxicity characteristic leaching procedure tests, it was classified as nonhazardous and could be disposed in a landfill. In the processing vessel, the inorganic compounds (glass, ceramics, and metals) melt into a silica-based, nonleaching slag that chemically bonds with most metals that may be present in the waste.

ESOH Need

Hazardous waste
treatment and
disposal

Technology Benefits and Advantages

- Provides an environmentally superior technology compared to competing waste disposal practices such as landfilling and incineration
- Reduces waste volume by up to nine times on some wastes, such as spent blast media, with corresponding benefits including reduced storage, handling, and shipping costs, in addition to increased life of landfills, because less waste will be disposed at those facilities
- Treats most types of waste and is particularly useful for DoD problematic wastes with high disposal costs (i.e., greater than \$1.00 per pound)

- Treats construction and demolition waste, hazardous waste, nonhazardous solid waste, various liquids, and sludge
- Has the ability to treat three different waste streams (i.e., solid, liquid, sludge) with a destruction and removal efficiency rate of 99.9999% for the organic constituents
- Can be assembled or disassembled in 5–7 days per cycle
- Passed 150-mile mobility test for transport to DoD locations for on-site destruction of waste streams

Technology Limitations

- When processing an electroplating sludge surrogate feed, the sludge feed system failed because of the abrasiveness of the sludge feed, which corroded fittings and pump internals. A better pump selection will be required for future tests when processing abrasive slurry feeds.
- When processing liquid transformer oil surrogate, the liquid feed rate was lower than anticipated due to a proprietary additive that was contained in the transformer fluid. A better understanding of feed composition is required for future tests.
- The current Mobile PEPS® unit may need to be upgraded and modified for future testing to accommodate characteristics of the waste to be treated.

NDCEE FY04 Accomplishments

- Monitored mobility testing and assembly/disassembly
- Reviewed and provided input into the Feed Material Selection Report
- Supported development of a System Modification Plan
- Supported development of permitting packages
- Monitored shakedown testing prior to the initiation of three demonstrations
- Monitored three demonstrations that included system assembly, system start-up, surrogate feed introduction, system operation, emission sampling, data collection, and slag removal
- Supported the U.S. Army by reviewing technical documents, and monitoring the modifications and testing performed by the system developer
- Developed a commercialization video for the Mobile PEPS® unit
- Developed a System Mobility Training Manual

Economic Analysis

Although the PEPS® technology can be used to treat most types of liquid, solid, and sludge waste (including soils, tires, and medical and chemical wastes), it is particularly useful for DoD-problematic wastes with high disposal costs. A cost-benefit study is in progress. However, based on an earlier cost analysis completed in October 2002, the technology should be attractive for treating those types of wastes that have baseline treatment costs of over \$1.00 per pound.

Suggested Implementation Applications

The PEPS® can be used by any site as a waste material destruction device that meets or exceeds EPA regulatory limits. The U.S. Army is actively searching for an implementation site for this technology. Several DoD facilities have expressed interest in obtaining the PEPS® technology to dispose of various wastes. The PEPS® may be applicable for use in future industrial operations and maintenance activities, which may involve problematic wastes that contain hazardous materials and have relatively high disposal costs.

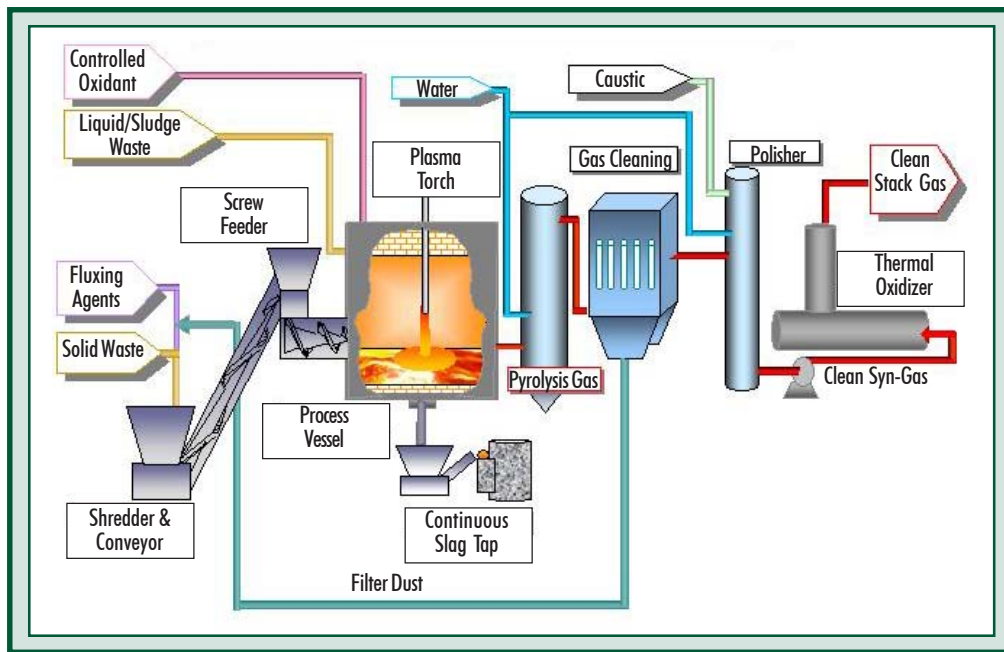
Points of Contact

- Hany Zaghloul, ODASA(ESOH), (703) 602-5526, hany.h.zaghloul@erdc.usace.army.mil
- Ron Patun, NDCEE/CTC, (814) 269-2719, patun@ctc.com

Applicable NDCEE Tasks

Mobile Plasma Energy Pyrolysis System Modification and Demonstration Program (Task N.324)

NDCEE Oversight for the EnerSol Mobile Plasma Energy Pyrolysis System Validation and Demonstration Task (Task N.0410)



Schematic of the Mobile Plasma Energy Pyrolysis System (PEPS®) depicting how the system destroys wastes through a combination of vitrification of inorganic matter and the controlled pyrolysis of organic matter

Portable Munitions Monitoring System

The NDCEE, in conjunction with the Physical Science Laboratory at New Mexico State University, is facilitating the development of an improved generation of portable munitions monitoring systems (PMMSs). In past years, several application and production issues were addressed, including conducting noise level, temperature, and random motion measurements as well as adhesive and fiber splice testing. In the current program, the PMMS system was used extensively in environmental chambers to simulate the effects of storage facilities. Through these tests, the NDCEE team identified and implemented required enhancements to improve performance and usability of the system. The new version has been tested thoroughly and contains more powerful software and hardware with improved structural integrity. The current system enables operation from remote locations and allows for data manipulation to provide input for predictive modeling. The system is ready for full-scale deployment, with significant potential for transfer of the technology to other DoD monitoring requirements.

Technology Description

The PMMS is being designed to constantly measure the temperature and dimensional changes of munitions in storage and transit. Still in development, the system would replace the current predictive technology approach, which characterizes the storage conditions of a product and then predicts the product's degradation using models. These models may be based on either knowledge of the inherent degradation processes or on empirical data. Often, once a product passes a certain threshold that is based on the measured storage conditions, it is removed from inventory. A similar approach is the use of lot testing in which representative samples of each production lot are removed from storage for functional testing. If the units pass the storage conditions threshold, the entire lot is removed from inventory.

The key element of the PMMS is the use of the fiber Bragg grating (FBG) sensor technology. This optical technology can measure mechanical strain and temperature in a variety of situations. Consequently, rather than merely monitoring the storage conditions to which products are subjected, it may be feasible and cost-effective to monitor the underlying physical properties that are a direct indicator of possible product failure. Approaches to using them to measure other physical parameters (e.g., pressure, shock, acceleration, and concentrations of certain gases) are under development.

As part of the evaluation process, a munitions test fixture was designed to test the FBG in a configuration that closely resembled a 155-millimeter projectile. The test fixture

consisted of nine pieces that were machined from low-carbon steel. One of the pieces was the test specimen, a 5.5-inch tall cylinder of aluminum, with a 6-inch outer diameter, and a wall thickness of 0.058 inches. The test specimen was instrumented with three FBG sensors. Various experiments showed that the sensors could be used to measure the amount of deformation occurring in a test specimen. In addition, extensive trials have been conducted in which the PMMS continuously monitored temperature and strain with tens of sensor elements for periods of weeks.



The Portable Munitions Monitoring System is being developed to constantly evaluate the structural integrity of munitions in storage

ESOH Need

Munitions monitoring
in storage and transit

Technology Benefits and Advantages

- Measures mechanical strain and temperature (with other physical parameters in development) in a variety of situations
- Provides immunity to radio frequency and electromagnetic interference due to the FBGs being entirely optical
- Obtains strain measurements that are better than those that are obtained with resistive strain gauges in terms of noise, repeatability, and stability
- Contains many sensors multiplexed on a single fiber, so that the “wiring” is simplified and cost per measurement is lowered
- Does not require electrical current at the measurement site (particularly beneficial to applications that involve explosives)
- Detects small dimensional changes, which are measured in terms of microstrain

Technology Limitations

- Still under development

NDCEE FY04 Accomplishments

- Identified and implemented necessary enhancements to the PMMS, including more efficient and powerful software. The hardware configuration was modified to improve airflow to the system and improve its structural integrity.
- Tested the enhanced PMMS in simulated service conditions using environmental chambers. The PMMS operated continuously for 528 hours, including 336 hours of completely independent operation. The test determined that the hardware and software performed to specification.
- Installed new communication software that enables the PMMS to be maintained and monitored from remote locations.
- Developed a database to accept data from the PMMS. The focus of the database development effort was to allow for flexible data manipulation techniques to provide information input for powerful and effective predictive modeling.

Economic Analysis

Under current munitions monitoring applications, products that should be removed from inventory may not be discovered and/or products are removed unnecessarily. This situation can result in preventable production and disposal expenses as well as increased worker safety and health risks associated with replacing and disposing of products that are removed unnecessarily. Conversely, increased expenses, worker risks, and risks to soldiers in the field can occur with undetected product failures.

Suggested Implementation Applications

The PMMS is being developed to evaluate the structural integrity of munitions in storage and transit. It is ready for testing on a full-scale deployment.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Melissa Klingenberg, NDCEE/CTC, (814) 269-6415, klingenb@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R2-14)

Powder Coating

The NDCEE has extensive technical expertise with powder coating. The technology is an integral aspect of the NDCEE Demonstration Facility where it has been used for nearly a decade by DoD and industrial facilities to explore the technology's viability for their site-specific needs. Once the technology has been validated to be technically and economically beneficial for a facility, the NDCEE provides implementation and training assistance to the facility. Most recent beneficiaries of NDCEE powder coating knowledge have been TYAD, Rock Island Arsenal, and Lake City Army Ammunition Plant. Past recipients have included CCAD, Naval Air Depot–Jacksonville, and the Joint Group on Pollution Prevention.

Technology Description

Powder coating technology is an environmentally friendly alternative to the use of conventional solvent-based, waterborne, or high-solids painting processes. It provides a durable coating and reduces operating costs while eliminating HAPs, VOCs, and solvents. The four basic powder coating application methods are electrostatic spraying, flame spray, fluidized bed, and electrostatic fluidized bed. Electrostatic spraying is the most frequently used method. For all four methods, surface preparation (i.e., cleaning and conversion coating) is required to develop a good coating adhesion substrate. Characteristics of each method are described below.

In *electrostatic spraying*, an electrical charge is applied to the dry powder particles while the component that is to be coated is electrically grounded. The charged powder and grounded workpiece create an electrostatic field that attracts and holds the paint particles to the workpiece. The coated workpiece is placed in a curing oven where the paint particles are melted onto the surface, fused into a film, and then chemically crosslinked into a cured film.

The *flame-spray* technique was developed primarily for application of thermoplastic powder coatings. After being fluidized by compressed air, the thermoplastic powder is fed into a flame gun where it is injected through a flame of propane, melting the powder. The molten coating then is deposited on the workpiece, forming a film on solidification. Because no direct heating of the workpiece is required, this technique is suitable for applying coatings to most substrates, including metal, wood, rubber, and masonry. It also is useful for coating large or permanently fixed objects such as steel frames, railcars, and large diameter pipes.

ESOH Need

Environmentally
compliant coatings
system



Automated powder application to 105-millimeter artillery projectiles

In a *fluidized bed*, an air stream keeps powder particles in suspension until they come in contact with a preheated workpiece, at which point, they melt and adhere to the workpiece surface. Coating thickness is dependent on the temperature and heat capacity of the workpiece and its residence time in the bed. Typically, post heating is not required to cure thermoplastic powder coatings, but it is required to cure thermoset powder coatings completely.

With *electrostatic fluidized beds*, the air stream is electrically charged as it enters the bed. The ionized air then charges the powder particles, which cover the grounded workpiece as it enters the chamber. Unlike with the conventional fluidized bed, this technique does not require a preheated workpiece, but curing of the coating is necessary. This technology is most suitable for coating small objects with simple geometry.

Powder coatings are individually formulated to meet specific finishing needs (e.g., desired properties) and fall into two basic categories: thermoplastic and thermosetting. Generally, thermosetting powders use epoxy, polyester, and acrylic resins and are more suitable for thicker coatings, providing increased durability. Thermoplastic powders are often used when comparatively thin coatings are desired such as decorative coatings. They primarily contain polyethylene, polyvinyl, nylon, and fluoropolymer resins.

In comparison to conventional painting techniques, powder coating provides improved safety and working conditions as well as cost savings in labor, materials, handling, and disposal of waste. It eliminates most waste streams, such as spent cleaning solvents, air emissions, and waste streams, that are generated from air emission control equipment. Cleanup time is faster because the powder is dry when sprayed, allowing overspray to be readily retrieved and reclaimed for reuse. Consequently, powder usage efficiency can approach 98% because the overspray powder is separated from the air stream by various vacuum and filtering methods and returned to a feed hopper for reuse.

Technology Benefits and Advantages

- Eliminates the use of VOCs and HAPs that are used as typical solvents in liquid paints and thereby eliminates hazardous air emissions
- Improves worker health conditions and minimizes safety risks
- Can be implemented in high-production facilities with highly automated application systems or on low-volume, manual-batch applications
- Results in nearly 98% usage efficiencies because overspray can be captured and reclaimed
- Can use specialty coating formulations that provide powder coating cure by high-intensity infrared exposure and thermal melt/ultraviolet-crosslinking film formation
- Reduces booth ventilation energy requirements by recycling spray booth air instead of venting to the atmosphere to remove solvent emissions
- Provides significant cost savings in labor, materials, and handling and disposal of waste
- Provides protection as a barrier if primers or pretreatments are not used, and prevents corrosion as long as the coating remains intact and undamaged

Technology Limitations

- As with other coatings, adequate booth ventilation must be maintained to eliminate explosion hazards (accumulation of suspended particulate). Integrated application equipment controls and fire sensors significantly limit these risks.
- System configurations are partially application specific, but not severely limited.
- Depending on the coating requirements, some applications may be restricted by complex geometry and component assembly.
- Typically, workpieces that can be oven-heated to 400°F (204°C) are suitable for powder coating application methods. The temperatures that are required to cure the coating are too high for many materials that are used in aerospace structures (primarily aluminum and magnesium); however, recently developed formulations allow baking as low as 250°F (121°C), which enables the use of powder coating on most materials. Also, infrared flash cure powder coating technology has been developed for curing more sensitive substrates (i.e., materials that must be baked at less than 180°F) or, conversely, for rapid curing of high volume parts production such as small-caliber ammunition projectiles.

NDCEE FY04 Accomplishments

The NDCEE produced a Final Report on Task N.301, Subtask R3-8 accomplishments. These accomplishments included:

- Tested and evaluated candidate powder coatings (MIL-P-53030 epoxy primer and MIL-PRF-22750 epoxy topcoat) for potential use on select components to replace the current paint system that is used at TYAD. In general, the results show that no single candidate passed all test requirements for TYAD, including the baseline coatings. The NDCEE recommended that the test requirements be prioritized to further identify top performers for a specific application.
- Developed a powder coating line specification for TYAD that is based upon the facility's needs, available space, and support of new maintenance activities and processes. This specification can be used as a basis to request vendor quotations.

Economic Analysis

The typical capital costs for a powder coating system can range from \$20,000 to greater than \$4 million. In comparison to a solvent-based system, the powder coating technology generally has lower labor costs as a result of no paint mixing requirements and reduced cleanup requirements. In addition, waste disposal costs are typically lower because less waste is generated.

Suggested Implementation Applications

Powder coatings are commonly used on a wide assortment of products from ammunition to park benches to automobiles. To ensure that powder coating is their best coating option, DoD production and maintenance coating facilities should conduct a technical and economic evaluation prior to implementation.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Patrick Tierney, TYAD, (570) 895-6724, Patrick.Tierney@tobyhanna.army.mil
- Michael Docherty, NDCEE/CTC, (814) 269-6462, docherty@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R3-8)

Sodium Bicarbonate Blasting

Under previous efforts, the NDCEE and Naval Surface Warfare Center, Carderock Division tested alternatives, including sodium bicarbonate blasting, to current coatings removal and etching methods at the NDCEE Demonstration Facility. The NDCEE utilized these efforts to help to identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts.

Technology Description

Sodium bicarbonate stripping processes can be used as alternatives to traditional chemical paint strippers, hand sanders, and manual cutting tools. Sodium bicarbonate (also known as bicarbonate of soda) is a soft blast medium with a higher specific gravity and less hardness than most abrasives. The effectiveness of sodium bicarbonate depends on optimizing a number of operating parameters, including nozzle pressure, standoff distance, angle of impingement, flow rate, and traverse speed. This process can clean and depaint such items as stainless steel, aluminum, galvanized metal, concrete, ceramic tile, glass, plastics, fiberglass, rubber, and neoprene.

The process can be used with or without water. It is most frequently used with water, which acts as a dust suppressant. In this form, compressed air delivers sodium bicarbonate media from a pressure pot to a nozzle, where the media mixes with a stream of water. The soda/water mixture impacts the coated surface and removes old coatings from the substrate. The water dissipates the heat that is generated by the abrasive process, reduces the amount of dust in the air, and assists in the paint removal by hydraulic methods. Workers do not need to prewash or mask the surface of the material that is being stripped. Settling or filtration can separate the solid residue that is present in the wastewater.

The use of sodium bicarbonate in its dry form (or when not fully mixed with water) can create a cloud of dust that will require monitoring and may require containment to meet air standards. Though the dust that is generated is not an explosive hazard, the airborne particulates that are generated from the stripping operation can contain toxic elements that are found in the paint being removed. This stripping process should be performed in areas where exhaust particulates can be contained and/or exhaust ventilation system controls are present to remove hazardous airborne metals.

ESOH Need

Coatings removal techniques

Technology Benefits and Advantages

- Eliminates the use of chemical strippers
- Reduces labor and operating costs as a result of decreased preremoval preparation and postremoval cleanup

Technology Limitations

- Wastewater and waste solids must be analyzed to determine disposal requirements.
- Media cannot be recycled.
- The use of sodium bicarbonate in its dry form (or when not fully mixed with water) can create air emissions that will require monitoring and may require containment to meet air standards.
- If the operating temperature of the part is at or above the temperature 140–160°F (60–71°C), the residual sodium bicarbonate may become corrosive.



At NAB Little Creek, the NDCEE successfully field-demonstrated wet sodium bicarbonate blasting on an aluminum HMMWV component.

- Decreases solid waste generated from non-recyclable blasting media (e.g., garnet and black beauty) and use of chemical strippers.

NDCEE FY04 Accomplishments

The NDCEE produced a Final Report on Task N.301 accomplishments. Included in this report was a discussion on NDCEE field demonstration activities at NAB Little Creek and on behalf of Fort Eustis on four coatings removal processes. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities' production requirements and waste reduction needs. In addition, they were tested on aluminum and fiberglass HMMWV parts to determine if these delicate substrates would be damaged during a coatings removal process. They also were tested on steel Modular Causeway Systems and a 2 1/2-ton truck component. Wet sodium bicarbonate blasting was not recommended for implementation at Fort Eustis because handling the slurry that is produced by the process is difficult (a residue remains on the surface of the component following blasting) and Fort Eustis is currently not capable of utilizing a wet process in its blast facility.

Economic Analysis

Equipment costs range from \$15,000 to more than \$40,000. Although the NDCEE determined that the process was not the best choice for Fort Eustis, it is a viable technology for other facilities. While site-specific cost-benefit analyses would need to be conducted prior to technology implementation, operating costs are expected to be substantially less than the chemical stripping used by many other facilities.

Suggested Implementation Applications

Potential applications include weapon system components such as PCMS tiles on submarines and radomes from ships and aircraft.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Mary Nelson Bush, NDCEE/CTC, (904) 722-2509, bushm@ctc.com
- Melissa Klingenberg, NDCEE/CTC, (814) 269-6415, klingenb@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

Sponge Blasting

Under previous efforts, the NDCEE and NSWC-CD tested alternatives at the NDCEE Demonstration Facility, including sponge blasting, to current coatings removal and etching methods. The NDCEE utilized these efforts to help identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts.

Technology Description

The sponge blasting technology cleans, etches, and removes coatings from various types of substrates. It uses an air-propelled open cell, water-based polyurethane foam cleaning media (also known as sponge media). The foam material can be impregnated with abrasive grit to enhance the performance of the media. The abrasive media may contain a variety of grit including aluminum oxide, steel, and plastic. The ability to use different media types gives the system flexibility by providing different characteristics and blasting capabilities. The foam cleaning media are absorptive and, when wetted with a cleaner or surfactant, can be used to remove a variety of surface contaminants and control dust without excess wastewater.

A feed unit is used to deliver sponge media to the surface. A media classifier is required to handle recycling chores. This classifier operates by collecting the sponge blast media and running the media through an electrically powered sifter, which separates the sponge media into four categories: oversized debris, reusable debris, reusable media, and fines (consisting of spent media and dust). Typically, 85–90% of the sponge media is reusable after each blast cycle. Using a classifier, the media can be recycled approximately 5–7 times for low dust applications. The amount of times that the media can be recycled depends on the type of surface and the contaminants that are removed from the surface. Some applications have shown up to 18 uses before the media are no longer productive.

Typically, the waste that is generated with sponge media blasting is minimal because the media are recyclable. The disposal method depends on the type of coating or substance that was removed from the surface. Generally, if the substance that is being removed is classified as nonhazardous waste, then the spent media and the material that were removed are placed into a drum and sent to a landfill. If the substance that is being removed is classified as a hazardous waste, such as a radioactive material or a lead-based paint, then it must be placed in an approved container (55-gallon drum) and sent to an approved disposal facility.

Technology Benefits and Advantages

- Decreases solid waste generated from non-recyclable blasting media (e.g., garnet and black beauty) and use of chemical strippers
- Reduces labor and operating costs as a result of decreased preremoval preparation and postremoval cleanup
- Improves safety and worker health conditions due to the elimination of airborne emissions of heavy metals and other contaminants when used with vacuum recovery
- Involves reusable media
- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

ESOH Need

Coatings removal techniques



Sponge media feed unit

Technology Limitations

- Not as aggressive on metallic substrates as some abrasive media; however, unlike the sponge medium, these more abrasive media do not have the capability to be used on delicate substrates.

NDCEE FY04 Accomplishments

The NDCEE produced a Final Report on Task N.301 accomplishments. Included in this report was a discussion on NDCEE field demonstration activities at NAB Little Creek and on behalf of Fort Eustis on four coatings removal processes. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities' production requirements and waste reduction needs. In addition, they were tested on aluminum and fiberglass HMMWV parts to determine if these delicate substrates would be damaged during a coatings removal process. They also were tested on steel Modular Causeway Systems and a 2 1/2-ton truck component.

Sponge blasting was effective for removing coatings from all the substrates presented at the demonstration; however, implementation of the technology may require minor maintenance or upgrades to the current blast facilities to ensure effective collection and particulate separation during recycling. Recycling blast media is expected to increase production and reduce procurement and disposal costs.

Economic Analysis

Equipment costs are approximately \$50,000. Using the baseline removal rate that was received from Fort Eustis on its dry sodium bicarbonate blasting process for aluminum and fiberglass components, a comparison was made with the sponge alternative technology. Test results show that the sponge technology offers a comparable strip time to the baseline of 4–5 hours, causes no damage to delicate materials, and emits little to no dust. Because of the comparable strip rates, associated labor costs should be the same as the baseline method. Reduced procurement and disposal costs are anticipated because the sponge media are recyclable. Procurement savings are dependent on the price of the raw materials. Prior to technology implementation, a complete cost analysis should be performed.

Suggested Implementation Applications

Applicable weapon system components include fiberglass hoods on HMMWVs and other delicate substrates.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Mary Nelson Bush, NDCEE/CTC, (904) 722-2509, bushm@ctc.com
- Melissa Klingenberg, NDCEE/CTC, (814) 269-6415, klingenb@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

Thermophilic (Biological) Process

The NDCEE has demonstrated and evaluated the feasibility of a pilot-scale Thermophilic (Biological) Process (TBP) plant at both the Milan Army Ammunition Plant and Iowa Army Ammunition Plant (IAAAP). Through these demonstration projects, the NDCEE determined that the process is technically sound and environmentally safe. Under optimized conditions, the process consistently degraded over 90% of the nitrobodyes from loaded granular activated carbon (GAC). The NDCEE has also investigated the ability of the TBP process to treat nitrate esters in wastewater that is generated by the Naval Surface Warfare Center, Indian Head Division facility. Positive bench-scale results indicate that some nitrate ester wastewaters can be treated directly with the microbes that are associated with the TBP process, without the need for GAC loading. Degradation rates of greater than 90% have been reproduced.

Technology Description

TBP was developed to treat pink water, which is explosive-laden wastewater originating from two munition functions: 1) load, assemble and pack; and 2) demilitarization. The technology also has demonstrated control of discharges from DoD-wide ammunition processing operations such as the water-dry propellant extraction waste in the sumps of ammunition plants. Although additional research is required, the TBP process potentially could be adapted to treat explosives-contaminated groundwater and soils. Bench-scale demonstrations have also been conducted to evaluate the process's ability to treat wastewater containing nitrate esters.

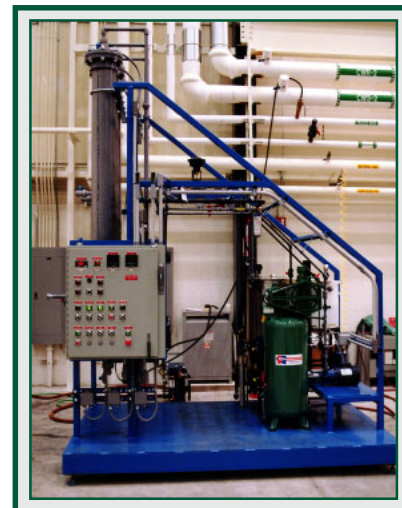
TBP is a modification of the U.S. Army's present method of GAC regeneration systems. Currently, ammunition plants meet pink water discharge requirements by removing the contaminants using GAC adsorption systems. The explosive-laden GAC is either regenerated for reuse or incinerated for disposal. Under the present method, regeneration often does not achieve Army requirements, and the GAC must be disposed of as a hazardous waste. TBP utilizes the GAC to adsorb the explosives from the wastewater, followed by base hydrolysis and thermophilic regeneration of the GAC. The treated wastewater is sent to a wastewater treatment plant.

The process begins with the contaminated water flowing into the GAC adsorption system. The contaminants are first adsorbed onto the GAC, which has demonstrated a high affinity and capacity for nitrobody compounds. After an adsorption cycle, flow through the GAC column stops and recirculation of a regeneration solution starts. The GAC column is first heated to 176°F (80°C) for base (caustic) hydrolysis, and then cooled to 131°F (55°C) for thermophilic regeneration, inoculated with nitrate-degrading organisms, and aerated. The column becomes a bioreactor. Thus, nitrated compounds, concentrated by the previous adsorption step, are depleted, and the GAC in the column is regenerated. The bioreactor fluid, containing natural organisms and enzyme systems, passes to the industrial wastewater treatment plant. In the last step, the regenerated GAC column cools and is placed on stand-by.

The microorganisms that were utilized in the TBP also were used to treat nitrate ester-containing wastewaters from IHDiv production activities. The microorganisms were exposed to the wastewater directly, in a batched process, without concentrating the nitrate esters onto the GAC. Successful treatment of some of the nitrate ester wastewater streams allows the use of activated carbon to be eliminated.

ESOH Need

Explosive-laden wastewater (pink water) and nitrate ester wastewater treatment



Prototype TBP unit

Technology Benefits and Advantages

- Biodegrades most nitroesters in explosives-laden wastewater and renders them nontoxic, according to results from toxicity testing using the Microtox® instrument
- Can be retrofitted to the existing GAC adsorption systems, with only minor modifications
- Requires less energy than other processes that are currently in use
- Is commercially available, economically viable, and environmentally safe
- Poses limited health and safety risks; however, several contaminants in the explosive-laden wastewater are dangerous and precautions should be taken
- Regenerates loaded GAC columns, *in situ*, avoiding the risks and losses that are associated with handling and incinerating and/or regenerating the spent GAC by combustion
- Biodegrades nitrate esters in wastewater, thereby eliminating the use of the explosive-laden GAC and any exposure hazards associated with handling it. Possible scale-up options include incorporating the thermophilic microorganisms into a fluidized bed reactor, which has similarities to the GAC regeneration column set-up, requiring minimal retrofit. Additional technology options include using membrane bioreactors that utilize an activated sludge batch system followed by membrane filtration and sequencing batch reactors.

Technology Limitations

- Operator training is required when using the TBP pilot-scale system or any installed hardware.
- Capital costs may be substantial, depending on the technology that will be installed.

NDCEE FY04 Accomplishments

- Performed bench-scale studies to optimize the degradation of nitrate esters in wastewater generated by IHDIV and attempt to understand the degradation pathway of these compounds.
- Produced a Final Report and presented the results of the optimization studies to IHDIV personnel. The document and presentation summarized the results of the bench-scale studies and how this project related to previous work done with degradation of nitrate esters with the TBP microbes. The results of the testing showed that the degradation rates of propylene glycol dinitrate (PGDN) and N-butyl-2-nitroethylnitramine (BuNENA) in wastewater treated directly were reproduced from the previous study and the degradation rates and treatable concentrations of 1,2,4-butanetriol trinitrate (BTTN) and 1,1,1-trimethylolethane trinitrate (TMETN) could be increased with optimized parameters. This report also presented the technology options for scale-up of the technology. These technologies included fluidized bed reactor, membrane bioreactor, and sequencing batch reactor.

Economic Analysis

The capital cost to retrofit the TBP technology to an existing 20-gallons-per-minute system is approximately \$230,000. Although the NDCEE determined that the process was not the best choice for IAAAP due to its volume of production/demilitarization, the TBP technology could be a viable technology for other facilities. While site-specific cost-benefit analyses would need to be conducted prior to technology implementation, no other cost-effective alternatives to GAC adsorption systems have been found that could treat the explosive-laden pink water.

Suggested Implementation Applications

The TBP technology was designed to treat pink water and potentially may be able to treat explosives-contaminated groundwater and soils. Pink water by definition is a RCRA K047 hazardous waste due to the presence of nitrocompounds, including TNT, cyclotrimethylene-trinitramine (RDX), and cyclotetramethylene-tetranitramine (HMX). The exact composition of pink water is highly variable and dependent on process materials and operations.

In addition to facilities that are generating pink water, facilities manufacturing nitrate esters for Navy and Army weapon systems may be candidates for implementation. Current uses of nitrate esters include the production of PGDN, TMETN, TEGDN, BTTN, and NG for various weapon systems.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Leanne Debias, NDCEE/CTC, (814) 269-2830, debias@ctc.com
- Paul Brezovec, NDCEE/CTC, (814) 269-2844, brezovec@ctc.com

Applicable NDCEE Tasks

Sustainable Green Manufacturing (Tasks N.301, Subtask R2-8)

Treatment of Spent GAC Containing Nitrate Esters Using TBP Technology (Task N.309)

Treatment-Train Approach for Small Arms Firing Range Soils

At a small arms firing range at Fort Dix, the NDCEE demonstrated and validated a treatment-train approach that involved particle separation followed by stabilization to reduce total and leachable lead concentrations from impact berm soils. This project processed 7,576 tons of lead-contaminated soil and reduced the total soil lead levels by an average of 93% and the leachable lead concentrations by more than 98%. Because the purity of the recovered metal met the technology performance standards (i.e., greater than 90%), the recovered metals were sent to a recycling facility. Prior to the demonstration, treatability studies were conducted to develop a total range excavation plan to separate those portions of the range that required particle separation and stabilization (1,824 tons or 24%) from areas that required only particle separation (5,752 tons or 76%).

Technology Description

The treatment-train approach consists of a particle separation technology combined with phosphate-induced metals stabilization. The particle separation technology uses a placer-mining technique to separate particulate metals, such as spent bullets and bullet fragments, of a certain particle size (i.e., cut point) from the range soils. If the remaining particulate and nonparticulate metal concentrations are below the cut point, the soil undergoes stabilization, which chemically binds the metal into stable, insoluble minerals.

The treatment-train process begins with excavation, removal, and stockpiling of firing range soils. The particle separation system consists of several physical components that are integrated into one continuous process. The soil processing process features a wash plant for size separation; a mineral jig for gravity separation of metal and nonmetal particles; a pug mill for mixing soils and stabilization materials; a water treatment unit for elutriation of organic materials, process water clarification and settling, and water storage and management; a belt filter press for fines dewatering; and one-ton containers for the recovered metals.

The soil from the stockpiles is fed into the plant through a grizzly feeder and conveyor to a water-based vibrating screen equipped with a No. 10-mesh (0.0787-inch) screen. Larger items (such as rock, particulate metal and vegetation) are then conveyed into the gravity separation unit. The particulate metals are separated from the other items and then piped to a bagging module. The other items are discarded.

Smaller items (primarily fine sand, silt, and clay) are conveyed to the pug mill where they are mixed with dewatered fines from the belt filter press and the stabilization material, as required, and then discharged to the treated soil stockpile. Process water from the vibrating screen deck and the gravity separation unit as well as water from the belt filter press are transferred to a clarifier where a nonhazardous, nonionic coagulant is added to settle the fine particle size material from the water. The settled fraction is then discharged to the belt filter press for final dewatering, with

ESOH Need

Particulate inorganics
removal from soils



The NDCEE demonstration at Fort Dix showed that lead-contaminated range soils could be effectively treated in the field and the recovered metals could be recycled.

subsequent discharge to the pug mill for mixing and stabilization, and final discharge to the treated soil stockpile. Recovered water from the clarifier is reused within the plant.

Variations in soil structure, gradation, chemistry, and contaminant concentrations will result in recovery rates that are site- and cost-specific and cannot be universally applied. For instance, one site may contain a high level of leachable lead caused by acidic soil conditions, while another site may contain predominately particulate lead due to more neutral soil conditions.

Technology Benefits and Advantages

- Removes particulate contaminants from the soil rather than transferring them to a landfill; thus, potential long-term ESOH risks are eliminated.
- Recovers metals that can be classified as a “recyclable material” under 40 *Code of Federal Regulations* 261.6(a)(3)(iv) of RCRA and are not subject to the requirements for generators, transporters, and storage facilities of hazardous wastes specified in paragraphs (b) and (c) of 40 CFR 261.6. Therefore, the recovered metal does not need to be regulated or manifested as a hazardous waste during range processing activities or transportation to a smelter for recycling.
- Achieves some reduction in the volume of the hazardous wastes that are associated with the range soils, although it is typically less than 1%, depending upon the composition of the waste streams (i.e., heavy metal particle size and concentration). Corresponding benefits include reduced storage, handling, and shipping costs, in addition to increased life of landfills, because less waste will be disposed of at those facilities due to the ability to reuse the processed soils at the range or for other construction projects requiring soil fill.

Technology Limitations

- Substantial initial investment in equipment and staff training is required.
- Thorough, site-specific treatability studies are required to determine: (1) whether physical separation would be technically feasible and cost-effective in reducing particulate heavy metal concentrations in the soil; and (2) the type and concentration of stabilization materials required to sequester leachable lead.
- Air, water, and other permits may be needed; however, the NDCEE demonstrations revealed air emissions met Clean Air Act standards and the process generated wastewater that could be recycled back into the system.

NDCEE FY04 Accomplishments

- Conducted a literature search and feasibility study for using small portable (i.e., handheld or ATV [all terrain vehicle]-mounted) pneumatic equipment for separation of particulate metals from impact berm soils.
- Produced a Final Report that documents the activities and contains the results from the FY03 full-scale field demonstrations of both the particle separation and the stabilization technologies. In this demonstration, the particle separation technology removed 10.6 tons of particulate lead (i.e., bullets and bullet fragments) from 7,576 tons of lead-contaminated soils. The removed lead was sent to a smelter for recycling. The stabilization material immobilized the nonparticulate lead and reduced Toxicity Characteristic Leach Procedure extract lead concentrations by more than 98%, from more than 27 milligrams per liter (mg/L) to an average of 0.22 mg/L. Overall, total soil lead concentrations were reduced from 5,683 milligrams per kilogram (mg/kg) to less than 100 mg/kg.

Economic Analysis

Based on demonstration activities and accounting for a higher production rate, the NDCEE conducted an economic analysis for annually conducting full-scale particle separation on approximately 30,000 tons of range impact berm soils at Fort Dix. The projected full-scale unit cost estimate is \$60 per ton. For a long-term project that would include the physical processing of soils from all of the small arm firing ranges at Fort Dix, the unit cost could be reduced further because the costs associated with mobilization/demobilization would become one-time events, which would be applied to the entire quantity of soil processed.

The baseline approach to manage soils from small arms firing ranges is excavation and off-site disposal at an approved facility. Because the impact berm soils routinely qualify as a characteristic hazardous waste, RCRA requirements apply to the excavation, transportation and disposal of these soils. A comparison cost estimate for excavation and off-site disposal at a secure RCRA disposal facility indicates a unit cost of approximately \$243 per ton, which results in a unit cost difference of approximately \$183 per ton, based on the projected full-scale physical separation unit cost of \$60 per ton. For a full-scale project that encompasses 30,000 tons, this differential represents a cost savings of approximately \$5,490,000.

Suggested Implementation Applications

Any location with inorganic soil contamination is a candidate. According to the Army Environmental Requirements and Technology Assessments, 477 unique sites with confirmed inorganic soil contamination are present at 74 Army installations, while 80 unique sites with suspected inorganic soil contamination are present at 17 Army installations. In addition, long-term monitoring of inorganic soil contamination was needed for 63 unique sites present at 19 Army installations.

Points of Contact

- John Cefaloni, TACOM-ARDEC, (973) 724-3295, cefaloni@pica.army.mil
- Dr. Stephane Guillard, NDCEE/CTC, (904) 722-2501, guillard@ctc.com

Applicable NDCEE Task

Demonstration of RangeSafe Particle Separation and Stabilization Technology at Range 25, Fort Dix (Task N.257)

Impact Berm Soil Estimated Disposal Costs

Description	Unit Cost	Total Cost
Disposal Charges:		
7,576 tons	\$125.00	\$947,000
New York State Hazardous Waste Fee	\$26.50	\$200,764
Freight Charges (roll-off containers, liners, surcharges)	\$79.94	\$605,625
Labor/Mobilization	Lump	\$37,273
Equipment	Lump	\$52,730
Total	\$243.32	\$1,843,392

Ultrahigh-Pressure Waterjet Technology for Coatings Removal Applications

The NDCEE has extensive technical expertise with coatings removal using water-blasting technologies. A water-blasting system that can be operated either manually or with a robot has been a featured component of the NDCEE Demonstration Facility for nearly a decade. Several DoD facilities, as well as commercial industry, have used the Demonstration Facility to explore the technology's viability for their site-specific needs. Once the technology has been validated to be technically and economically beneficial for a facility, the NDCEE provides implementation and training assistance to the facility. Most recent beneficiaries of the NDCEE's coatings removal knowledge include Ogden Air Logistics Center, U.S. Army Kwajalein/Regan Test Site, Schofield Barracks, Fort Eustis, and Combat Equipment Group-Afloat. Past beneficiaries include Crane Army Ammunition Activity; Naval Air Depot - Jacksonville; NSWC-CD; Norfolk Naval Shipyard; and CCAD.

Technology Description

Waterjet stripping uses the impact force of pressurized water to effectively remove a variety of coatings ranging from paints, rubbers, and sealants to more tenacious coatings such as aerospace adhesives and metal flame spray coatings. These coatings may be removed from many different types of substrates including metals, plastics, composites, and concrete. Due to its high versatility, waterjet stripping has applications in several industries including automotive, aerospace, shipbuilding, and construction.

Ultrahigh pressure waterjet (UHPWJ) stripping involves the use of water at pressures above 10,000 psi to mechanically remove coatings. High-pressure pumps force water through specially designed nozzles that direct the high-velocity stream to impinge upon the coated substrate. The kinetic energy of the waterjet physically erodes the coating to expose the underlying substrate surface.

The waterjet can be operated under an open or closed-loop system. If the waterjet unit is a closed-loop system, it will also eliminate water discharge, reduce water consumption, and concentrate waste for less costly disposal. In a closed system, a sump pump directs the resulting water/coating mixture to a centrifugal separator that removes most of the particulate matter. The water then passes through a series of filters and tanks for further purification before reuse. The system requires only a small amount of make-up water to compensate for evaporative losses, but both recycled and make-up water must be of sufficient purity so as not to introduce sediments or other impurities that may interfere with the proper functioning of equipment.

In an investigation that was conducted on behalf of TACOM, the NDCEE determined that a manual UHPWJ system is effective at removing paint and preparing surfaces of Army tracked and wheeled vehicles. As part of its investigation, the NDCEE designed and constructed a user-friendly, portable closed-loop UHPWJ system that uses water pressures up to 36,000 psi. The system consists of a heavy nylon-shelled shelter that is 28 feet long x 24 feet wide x 17 feet high. The shelter rests within an inflatable subfloor that consists of a heavy vinyl floor and individually inflatable berms to contain process water. The system meets all National Emission Standards for Hazardous Air Pollutants, and Control Techniques Guidelines. In FY01, the shelter, with minor modifications, was transitioned to Schofield Barracks.

ESOH Need

Cleaning and coatings removal techniques



Removal of organic coating using automated UHPWJ

Technology Benefits and Advantages

- Eliminates hazardous airborne particulate from blasting operations, decreases solid waste by 90%, and eliminates the use of chemical strippers
- Minimizes, and in some cases eliminates, part preparation steps such as masking
- Reduces labor and operating costs as a result of increased removal rates and decreased preremoval preparation and post removal cleanup
- Improves safety and worker health conditions due to the elimination of exposure to hazardous chemicals and decoating residues
- Is available in automated systems, both stationary and portable, that are fairly simple to operate and maintain
- Provides vacuum recovery and recycling via commercially available systems; therefore, construction or containment of the blast area is not needed when using these types of systems
- Results in “near zero” discharge
- Allows for selective stripping with system adjustment
- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

Technology Limitations

- Capital costs are high. Manual systems are available for \$100,000–\$120,000, while robotic systems may cost over \$1 million.
- Technology has operational and maintenance training requirements.
- A separate system is needed to collect, filter, and recycle stripping water containing coating debris.
- The proper selection of blasting pressure, nozzle type, and standoff distance is critical.

NDCEE FY04 Accomplishments

- Produced a Final Report on Task N.301 accomplishments. Included in this report was a discussion on NDCEE field demonstration activities at NAB Little Creek and on behalf of Fort Eustis on four coatings removal processes. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities’ production requirements and waste reduction needs. In addition, they were tested on aluminum and fiberglass HMMWV parts to determine if these delicate substrates would be damaged during a coatings removal process. They also were tested on steel Modular Causeway Systems and a 2 1/2-ton truck component. UHPWJ was determined to be suitable for use on metal substrates, but too aggressive for stripping fiberglass substrates.
- As part of its Air Force FY04 effort, the NDCEE conducted equipment trials and cost-benefit analyses on three automated UHPWJ coatings removal systems that feature both automated precleaners and material handling equipment. These systems can meet Air Force production and maintenance requirements such as being able to process a wheel half within 4 minutes. More details are contained in the economic analysis section below.
- Conducted three field demonstrations in support of future UHPWJ operations at U.S. Army Kwajalein Atoll/Reagan Test Site: 1) vacuum recovery system for the transitioned waterjet; 2) handheld waterjet tool (with a self-contained vacuum recovery unit); and 3) a vacuum lance for coatings removal. The results of the demonstration proved that UHPWJ technology was capable of removing coatings and corrosion from a large buoy. It also showed that the vacuum recovery of spent UHPWJ process water would not be effective for all geometries present at the

USAKA/RTS Marine Center. As a result, the NDCEE recommended an approach that involved further study of wastewater processing options, the installation of drydock containment troughs, and the use of a handheld lance (without vacuum capabilities). This approach will allow USAKA/RTS to use gravity recovery of process water in a sump, which can be pumped into water recycling equipment or to the wastewater treatment plant. The NDCEE also recommended an investigation of utilizing available reclaimed water (sewage treatment plant effluent) as a feed to the UHPWJ system, thereby reducing the burden on a limited freshwater supply.

Economic Analysis

As part of its Air Force FY04 effort, the NDCEE conducted a cost-benefit analysis on three automated UHPWJ systems that feature both automated precleaners and handling equipment. Findings showed that the technologies offer good potential labor, materials, maintenance, and hazardous waste disposal cost savings. For instance, the systems are expected to yield a hazardous waste reduction of 7,000 pounds of solid waste and 500,000 gallons of wastewater contaminated with methylene chloride. Capital costs ranged from \$1.6–2.7 million dollars, and the payback period ranged from 3.6–5.7 years.

A limited-scope cost-benefit analysis was performed in conjunction with the NDCEE efforts at USAKA/RTS. The analysis revealed potential cost savings associated with implementation of UHPWJ technology. Based on engineering estimates for purchase and installation of containment trough materials, and vendor quotations for purchase and installation of vacuum recovery equipment (for some applications) and process water recycling equipment, the NDCEE calculated an annual savings of more than \$70,000 and a payback period of approximately 3 years. This savings is primarily the result of reducing annual material cost by nearly \$30,000 and reducing annual disposal costs by more than \$50,000.

Suggested Implementation Applications

Because of its high versatility, UHPWJ blasting has applications in several industries, including automotive, aerospace, shipbuilding, and construction. As a cleaning process, water blasting is efficient at removing oil and grease from parts with simple geometries and removing particulates from parts with complex geometries to precise cleanliness levels. Applicable weapon system components include aircraft landing gear, ship and aircraft radomes, SHT tiles on submarines, and fiberglass hoods on HMMWVs.

Points of Contact

- Richard (Guy) Whalen, OO-ALC, (801) 775-6866, richard.whelen@hill.af.mil
- Alan Taylor, USASMDC, (256) 955-4118, alan.taylor@smdc.army.mil
- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- Georgette (Kotsagrellos) Nelson, NDCEE/CTC, (412) 992-5355, nelsong@ctc.com

Applicable NDCEE Tasks

Automated Plastic Media Blast for Depainting Landing Gear Wheels for Commodities
Directorate Ogden Air Logistics Center (Task N.258)

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

U.S. Army Kwajalein/Regan Test Site Corrosion Control & Removal (Task N.305)

Unexploded Ordnance Electronic Data Collection Tool

Through an earlier effort, the NDCEE led a stakeholder team to develop and populate a Web-enabled, searchable database for UXO recovery and removal actions. In FY04, the NDCEE built upon those efforts and developed a field-deployable application that allows recording of data in the field using an electronic data collection tool (EDCT). The EDCT can be synchronized with the UXO Recovery Database to improve the accuracy of data collection and reduce data collection and entry costs. The NDCEE developed and field-tested a handheld EDCT by following a consistent, methodological approach to software development and documentation. Key elements of the development process included working with the stakeholder team to identify the features and capabilities that are required to field-deploy the UXO Recovery Database.

Technology Description

The EDCT provides the capability to enter data while in the field and to synchronize with the UXO Recovery Database System through any personal computer (PC) with an Internet connection using ActiveSync® software. This capability should eliminate handwriting hardcopy reports in the field, manual transcription to electronic format, and manual entry of UXO recovery data into the UXO Recovery Database System. Because these labor-intensive activities have been eliminated, the potential for human error is unlikely. In addition, reformatting data to produce tables for reports is unnecessary, based on EDCT's capability for exporting to Microsoft® programs.

The EDCT was developed using Visual C#® (C sharp) as the programming language with Microsoft Visual Studio® .NET™ (MS .NET Compact Framework) interface. Although development was optimized first for the MS Pocket PC platform, EDCT is compatible with any handheld unit running Pocket PC 2000 or higher or any Windows® CE 4.1 or higher platforms.

The moderate level of security that is prescribed for the UXO Recovery Database System is maintained through password protection. The user will be required to enter a username and password with administrator privileges prior to synchronizing the EDCT and UXO Recovery Database System. Use of the EDCT, though not requiring a username and

password itself, will require physical security measures to prevent data loss. For example, in the event that the EDCT is lost or stolen, one of the following scenarios might apply:

- The EDCT is recovered intact.
- The EDCT is recovered, but data is lost or compromised.
- The EDCT is never recovered.

Note that in any of these possible scenarios, never is the integrity of the UXO Recovery Database System or the data therein violated, due to authentication that is required for synchronization.

ESOH Need

UXO detection and recovery methods

Screen shots of EDCT Interface: opening screen (left), general data entry (center), and location entry (right)

ActiveSync®, which provides 100% complete connectivity, is required for data transfer between the EDCT and any PC with an Internet connection. A user with an administrator account may log on to the UXO Recovery Database System to synchronize data. Data transmission will be smooth, and the user will be notified when synchronization is complete. Synchronization is bidirectional as follows:

- Site information, document control numbers, and optimization sets are transferred from the Recovery Database System to the EDCT.
- UXO recovery data that is associated with a site and document control number are transferred from the EDCT to the Recovery Database System.

If transmission issues occur (e.g., loss of Internet connection), data will remain saved in its original location and the user will be notified to try again later.

Technology Benefits and Advantages

- Provides a simpler, automated method for collecting and incorporating field data into the UXO Recovery Database System while reducing operator error, increasing efficiency, and lowering overall project costs
- Offers flawless synchronization between the UXO Recovery Database System and EDCT from any PC with an Internet connection with no data loss
- Is generally accepted by the ordnance and explosives community

Technology Limitations

- Initial cost is higher with purchase of the equipment.
- Cost savings of labor effort is not realized until conclusion of project.
- EDCT program is not compatible with PalmSource, Inc.'s Palm OS®.

NDCEE FY04 Accomplishments

- Defined system requirements based on input from key stakeholders
- Identified candidate operating systems and interfaces
- Selected candidates for development based on thorough research
- Developed and demonstrated a test prototype system
- Developed and demonstrated a beta system in accordance with a technology transfer plan
- Executed a test plan to validate requirements completion
- Transitioned the field-deployable EDCT to the Government with documentation including source code and user manual

Economic Analysis

The NDCEE conducted a cost-benefit analysis in which three scenarios were considered: 1) baseline cost without use of the EDCT, 2) use of the EDCT under normal environmental conditions, and 3) use of the EDCT under extreme environmental conditions, where the unit will be regularly exposed to potentially damaging events (e.g., cold, rain, and salt). The cost-benefit analysis, which was conducted using an average per-project basis, demonstrated the economic feasibility of incorporating this technology into daily UXO recovery operations instead of using handwritten field notes by saving up to \$18,000 per six-month project.

Suggested Implementation Applications

The EDCT may be used in any ordnance and explosives-response scenario. Field-testing, along with user demonstration and training, has been conducted in several United States

locations. A technology transfer plan was developed to introduce the EDCT to potential users. Field-test and demonstration locations were selected to provide a range of climate and topography to ensure proper functioning of the EDCT in all conditions.

Points of Contact

- Thomas Guinivan, USAEC, (410) 436-5910, Thomas.guinivan@us.army.mil
- Chuck Tomljanovic, NDCEE/CTC, (814) 269-6834, tomljano@ctc.com

Applicable NDCEE Tasks

Unexploded Ordnance (Tasks N.307, Subtask 4; N.318, Subtask 5; and N.0407, Subtask 6)

Unexploded Ordnance Recovery Database System

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With assistance from UXO stakeholder teams, the NDCEE is helping the DoD to improve the timeliness and cost-effectiveness of ordnance and explosives restoration projects. For instance, the NDCEE is currently testing the effect of freeze- and salt-heave on buried UXO. In addition, the NDCEE has developed a UXO data collection device, a database containing dud and low-order detonation rates, and a time and cost trade-off tool for comparing UXO technologies. The NDCEE also has developed a UXO Recovery Database, which is a modification and update of a database that was initially created by the U.S. Army Corps of Engineers, Huntsville, several years ago.

Technology Description

The UXO Recovery Database offers a centralized, electronic repository for UXO recovery depth data and the capability to perform searches and statistical analysis. Knowledge of historical and current UXO recovery depths provides a sound basis for UXO recovery site decision-making. In addition, the database provides site managers and UXO removal project managers with insight based on various site conditions that can impact UXO depth data, including soil/terrain type, detector type, frost depth, etc. Government decisions affecting the timeliness and cost effectiveness of ordnance and explosives restoration projects can be improved with the database. This improvement is based on the capability of users to understand the nature of UXO penetration through the analysis of legacy data.

The MS SQL Server 2000-operated database condenses complex, cumbersome reports into a clear, concise, and manageable data form that is more easily manipulated for interpretive decision-making support. The database presently contains 33,000 records that represent 35 UXO sites in the United States, Germany, and Panama. The records contain data pertaining to UXO recovery depth, environmental factors, and UXO removal methodology.

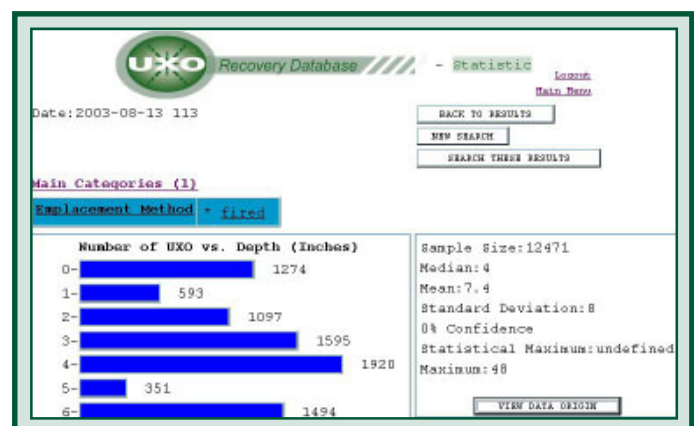
The database includes components for data entry, quality assurance, administration, and search and statistical analysis capabilities. The search capability allows searches on any database field. Search results are presented in a tabular format, and the user may choose to view a statistical format featuring a histogram of depth versus any user-selected category and site origin. The user can also exclude any data source from the search results and recalculate statistics. All saved searches include a date and time stamp along with the search parameters.

ESOH Need

UXO detection and recovery methods

Technology Benefits and Advantages

- Enables users to conduct a search on any or all database fields and view search results as statistics in a histogram format, which offers a better understanding of UXO penetration characteristics and/or detection tools' capability of locating UXO
- Allows users the capability to evaluate and summarize important environmental and UXO information
- Improves the prediction of UXO recovery depths and ultimately UXO response
- Aids in developing enhanced UXO detection technologies and establishing recovery procedures for restoration projects



Screen shot of the UXO Recovery Database's Statistical Analysis Page, which can be generated for any search criteria versus number of UXO located at a particular depth

- Provides an option to view the origin of data within the search results
- Includes components for data entry, quality assurance, and site and user administration, which provide mechanisms for continual updates, expansion, and maintenance

Technology Limitations

- Limits current data set to 33,000 recovery entries, representing only 30 munition response sites—statistically only a small portion of current sites
- Does not permit verification of legacy data outside of removal action reports
- Presents a bias within the database due to bias in depth measurement from removal action reports

NDCEE FY04 Accomplishments

- Established data quality objectives based on input from key UXO stakeholders
- Redesigned the USACE database and doubled the number of database records from 16,000 to 33,000
- Reduced data from a high volume of USACE Removal Action Reports into UXO-only data, eliminating non-useful information such as scrap metal or other materials
- Assessed human bias in current methods of reporting UXO depth and location and the need for stricter methods for accuracy
- Activated a live limited-access Web site

Economic Analysis

The DoD has estimated a wide-ranging cost from \$24–\$200 billion to fully address risks from UXO at both operational and former ranges. The scope of the necessary cleanup effort is such that completion, even within the next 20 years, can only be seriously envisioned if significant advances are made in terms of time and cost effectiveness, as well as reduction of risk to personnel, for the technologies employed to neutralize UXO.

Suggested Implementation Applications

The UXO Recovery Database System can be used by the DoD to continuously assure the uniform management of UXO recovery data. These data are used to characterize and remediate sites, allocate resources, and develop environmental management systems in accordance with Environmental Restoration at Base Realignment and Closure Sites, Formerly Used Defense Sites, and other DoD bases and ranges involved in the detection, neutralization, and evacuation of munitions and explosives of concern, including UXO.

Points of Contact

- Thomas Guinivan, USAEC, (410) 436-5910, Thomas.guinivan@us.army.mil
- Chuck Tomljanovic, NDCEE/CTC, (814) 269-6834, tomljano@ctc.com

Applicable NDCEE Tasks

Unexploded Ordnance (Tasks N.307, Subtask 4; N.318, Subtask 5; and N.0407, Subtask 6)

Unexploded Ordnance Time and Cost Trade-Off Tool

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The NDCEE led a stakeholder team to develop a UXO Time and Cost Trade-Off Tool for technology evaluation and removal action time and cost assessment. The primary purpose of the tool is to provide users with a straightforward, spreadsheet-level, time and cost estimation instrument that allows trade-off calculations at the project level and various stages of mitigation. The NDCEE is providing developmental support to advance the ability of project managers to reduce the time and cost associated with UXO site remediation and technology assessment. Development of the tool has great potential to support the primary mission of clearing ordnance and explosive hazards from contaminated properties.

Technology Description

The UXO Time and Cost Trade-Off Tool is used primarily for UXO technology evaluation. Range managers and scientists can use the tool to evaluate the time and cost impacts of technology intervention on the remediation process. For example, a timesaving but more expensive technology may become available. Project managers will need to evaluate whether the projected reduced cleanup time is worth more than the capital and operating costs that will be incurred with the new technology. This tool is an improvement to using handwritten reports and a calculator to determine costs because it is quicker, more accurate, and takes into account more than cost factors.

The UXO Time and Cost Trade-Off Tool application estimates the cost to perform UXO cleanup based on “as currently performed” technology use. In other words, the tool compares baseline data against newer methods of cleanup such as bulk remediation and digital geophysical mapping with post-processing and anomaly discrimination. The tool will allow installations to easily estimate their specific cleanup costs as well as evaluate alternatives to traditional cleanup methods.

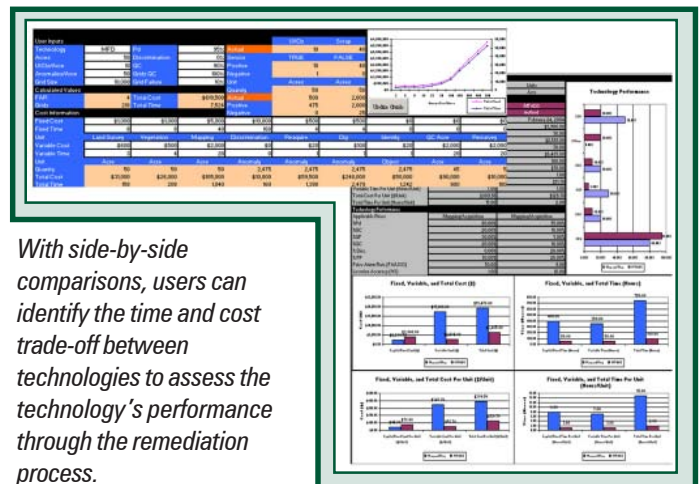
Users can enter technology information directly into a user-friendly Microsoft® Excel™ spreadsheet. The tool can perform a stand-alone evaluation of a technology or can assess the combined effect of multiple technologies. The technology information can then be shared between users to promote information dissemination.

Technology Benefits and Advantages

- Allows users the opportunity to evaluate and summarize important environmental and UXO remediation technology information, which can improve efficiency of UXO response
- Enables UXO site managers to develop a better understanding with regard to project resource allocation that can assist in decision-making and assessment of need based on remediation deficiencies
- Allows users an opportunity to identify UXO detection technology and recovery procedure development efforts that will result in substantial payback
- Enables users to evaluate the time and cost savings when using an alternate technology over a baseline technology as well as back-calculate what necessary parameters a technology must possess to achieve a desired remediation time or cost

ESOH Need

UXO detection and recovery methods



Technology Limitations

- The tool lacks the capability to analyze all factors within a remediation project.
- As a prototype system, the tool contains limited technology information.
- Concise and consistent technology information must be entered for reliable performance.
- Time and cost deviations could not be generated from the UXO Time and Cost Trade-Off Tool due to the use of generalized models for time and cost prediction.
- Distortions in the data can result over time due to advances in technique and procedure.

NDCEE FY04 Accomplishments

- Defined needs and requirements based on stakeholder input and UXO data pertaining to remediation and technology time, cost, and performance
- Developed the UXO Time and Cost Trade-Off Tool computer code, user interfaces, and software requirements
- Developed the test plan and conducted beta testing
- Produced a user manual source code document
- Validated the tool against the 2003 Defense Science Board's UXO Report to Congress Cost Estimation Methodology, actual cleanup costs at UXO sites, and Remedial Action Cost Engineering Requirements 2004

Economic Analysis

The tool does not have a specific economic return; however, the tool can be used to evaluate the direct time and cost trade-offs associated with varying technology use during UXO response. It can be used to evaluate the economic benefit of using a specific technology over the baseline technology. The tool is also useful in considering the implications of time versus cost trade-offs.

Suggested Implementation Applications

This technology can be used at any facility that generates UXO as a result of training or facilities that are required to remediate UXO from past operations. The tool can be used by range managers and scientists as a project management tool to estimate remediation costs, evaluate remediation options, or identify possible technology improvements. Technology evaluators can use the tool to consider emerging technologies or identify process improvements.

Millions of acres of property in the United States and abroad contain UXO. Some of these UXO sites are a result of United States military training activities and weapon system testing, while other sites contain UXO as a result of combat operations. This product is available free to DoD users through a request to the NDCEE Program Management Office.

Points of Contact

- Thomas Guinivan, USAEC, (410) 436-5910, Thomas.guinivan@us.army.mil
- Chuck Tomljanovic, NDCEE/CTC, (814) 269-6834, tomljano@ctc.com

Applicable NDCEE Task

Unexploded Ordnance (Task N.318, Subtask 12)

Water-Dispersible Chemical Agent Resistant Coatings Technology

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The NDCEE demonstrated water-dispersible chemical agent resistant coating (WD-CARC) technology at the Combat Equipment Group Afloat (CEG-A) Goose Creek. The WD-CARC topcoat demonstration was conducted in a manner that follows the current work practices within the installation's paint operations, and in cooperation with the Army Research Laboratory and material supplier. The demonstration was designed to help to facilitate an efficient and successful transition from CARC, which contain high VOCs and HAPs, to a low-VOC, zero-HAP, WD-CARC topcoat, without affecting the current production schedule. Based on the successful demonstration findings, CEG-A Goose Creek has implemented the technology.

Technology Description

WD-CARC technology, MIL-DTL-64159 Type II, uses a two-component aliphatic polyurethane and is formulated with a water-dispersible resin system, polymeric bead flattening agents, and non-HAP-containing solvents. In addition, WD-CARC can be reduced with water as needed. It provides reduced VOCs from the current standard of a maximum of 3.5 pounds per gallon to a maximum of 1.8–1.5 pounds per gallon as packaged. These formulation parameters allow the WD-CARC technology to provide superior weathering durability and corrosion resistance, a nonmarring surface, and reduced overall environmental effects while continuing to ensure signature reduction (camouflage) in combat zones.

The WD-CARC topcoat was developed by ARL in support of the Army's efforts to reduce or eliminate HAP and VOC emissions that are associated with the application of conventional organic coatings. In light of the upcoming Defense Land Systems for Miscellaneous Equipment (DLSME) rule from the U.S. EPA, installations will be required to reduce the amount of HAPs that are generated from coating processes. This new formulation offers installations a HAP-free alternative while providing superior durability performance as compared to earlier generations of the CARC topcoat.

By conducting demonstrations and other efforts that are focused on technology transition, the NDCEE has been assisting ARL in supporting Army emission-reduction goals. WD-CARC implementation is a key component of the Army's overall National Emissions Standards for Hazardous Air Pollutants (NESHAP) strategy.

Technology Benefits and Advantages

- Reduces emissions of VOCs and HAPs that are related to coatings application activities
- Reduces mixing and clean-up times in comparison to other plural-component coatings due to the use of water in place of solvent-based thinners
- Can be applied during the same conditions as with conventional coatings
- Produces little to no overspray when properly applied, which improves visibility, increases amount of areas being coating due to better coverage, and reduces the overall amount of coating material that is being used (noted to be 35-45% by painters at Army, Marine Corps, and Air Force facilities during demonstrations and actual implementation)
- Will aid the DoD in efforts to comply with upcoming military-specific NESHAP regulations
- Is commercially available

ESOH Need

Coatings application systems



WD-CARC application at CEG-A Goose Creek

- Exceeds the performance of prior CARC topcoat formulations

Technology Limitations

- Cure time and re-coat application time may be higher with WD-CARC than with CARC.
- Adequate surface preparation must be adhered to and employed on every maintenance item being processed. Preparation involves cleaning, pretreatments, priming, etc. because WD-CARC is more sensitive to hydrocarbon or oil contaminants than the solvent-borne coating.
- No coating should be applied if any airborne dust is present.
- The pot life of coating system following mixing of components may be reduced.
- Additional mixing is required when compared to single-component coating systems.
- Some minor equipment changes, such as the addition of Teflon®-lined fluid hoses for moisture protection and the use of a drill and “squirrel cage” mixer or other appropriate mixing equipment, may be necessary prior to implementation.

NDCEE FY04 Accomplishments

- Identified CEG-A Goose Creek as an end user/stakeholder that was applying high-VOC CARC coatings
- Worked with CEG-A Goose Creek to identify production requirements
- Drafted a Demonstration Plan for the application of WD-CARC on site at CEG-A Goose Creek, which ensured that the standard production schedule would not be affected
- Trained CEG-A Goose Creek painting personnel on the proper preparation, mixing, application, and clean-up procedures that are to be followed when working with WD-CARC
- Produced a Demonstration Report that detailed demonstration findings in which WD-CARC was successfully applied to CEG-A production items
- Provided CEG-A Goose Creek with a basic cost-benefit analysis
- Fostered the implementation of WD-CARC technology at CEG-A Goose Creek

Economic Analysis

The use of WD-CARC at CEG-A Goose Creek was found to lower overall production costs due to a reduction in the preparation, application, and clean-up times that are associated with the application of CARCs. In addition, a cost-benefit analysis indicated that the facility should have a cost savings of approximately \$2,000 per month in materials (assuming current production schedules remain consistent). This cost reduction can be credited to: 1) the elimination of the high-VOC solvent, MIL-T-81772, that is used for cleanup and thinning operations; and 2) a reduction of 40% in the coatings that are required to coat the equipment. In addition, WD-CARC usage should reduce waste streams by 20% and reduce VOC and HAP emissions associated with CARC operations by 75%.

Implementation

The WD-CARC topcoat can be used by any site that is required to reduce or eliminate HAP and VOC emissions associated with the application of conventional organic coatings. WD-CARC is currently in use at Marine Corps maintenance facilities and several Army and National Guard facilities. The National Guard has approved the WD-CARC technology for all equipment, while the U.S. Army has approved the WD-CARC topcoat for use on aircraft, nontactical vehicles, and ground support equipment such as generators. However, specific weapon systems will require approvals.

Points of Contact

- Charles Painter, NSWC-IHDiv, (301) 744-6772, charles.r.painter@navy.mil
- John Escarsega, ARL, (410) 306-0693, jescarse@arl.army.mil
- Mike Docherty, NDCEE/CTC, (814) 269-6462, docherty@ctc.com

Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R3-9)

Wet Slurry Blasting

The NDCEE has been working with the maintenance department at OO-ALC to identify, demonstrate, and validate environmentally sound, alternative technologies for coatings removal from aircraft landing gear wheels. As part of this effort, the NDCEE is testing the slurry blasting process. The installation's current process employs methylene chloride chemical stripping, which has been identified as both a carcinogenic material and volatile organic hazardous air pollutant solvent. After chemical stripping, plastic media blasting (PMB) is used to clean coating residues and remove thicker coated sections. Eliminating or reducing the PMB secondary coatings removal processing through a more efficient initial coatings removal process is also desired because PMB waste is currently disposed of as hazardous waste due to chromated primer contamination.

Technology Description

Slurry blasting is an old technology that had been used for mining and machining applications. In simple terms, it can be compared to using pumice hand soap for hand washing. The pumice will not work as well by itself as it will when mixed with liquid soap. Wet slurry blasting describes the process in instances when the slurry consists of greater than 50% water. Because of recent improvements, the slurry blasting technology has been revived for coatings removal purposes. More specifically, improved media quality and hardened processing pumps and nozzles, coupled with microprocessor controls, have allowed more-controlled and better processing with the aluminum oxide media. The wet slurry technology is an alternative to blasting methods using bicarbonate of soda, fiber, engineered sponge, waterjet, plastic media, and starch as well as chemical stripping processes.

Slurry is created by rapidly agitating media in water and then pumping to point of use. The most-used slurry blasting process involves low-pressure water/aluminum oxide. This process consists of a water stream of aluminum oxide particles with a hardness of 9.0 based on the Mohs Scale of Mineral Hardness. The coatings removal is accomplished by the aggressiveness of the aluminum oxide particles. The water is used as a transport for the aluminum oxide to the part and to remove the blast media and residue from the part. The blast pressure and aluminum oxide feed rate can be varied to increase or decrease the aggressiveness of the blast stream.

The aluminum oxide wet slurry blasting process produces a waste stream that consists of water, aluminum oxide, and removed coatings. The aluminum oxide and coatings can be removed from the waste stream, allowing both the water and the aluminum oxide to be reused. Due to its hardness, the aluminum oxide can be reused many times. This process does not require prewashing of the part to remove grease and dirt before blasting (although excessive quantities of grease and dirt will result in a higher consumption of the aluminum oxide media). Mechanical or robotic control of the blast nozzle is not required for this process. Preliminary demonstrations with this equipment have shown that this is an aggressive coatings removal process.

Technology Benefits and Advantages

- Can remove most organic and inorganic coatings
- Achieves a coatings removal rate that is faster than bicarbonate of soda, fiber, engineered sponge, or starch blasting methods

ESOH Need

Cleaning and coatings removal techniques



Aluminum oxide wet slurry blasting using 3/0 quartz

- Achieves a coatings removal rate that is equivalent to the waterjet and PMB removal process with multiple nozzles used in concert
- Has lower material and operating costs than chemical stripping operations and some of the other blasting methods
- Has low material costs due to its ability to reuse the media combined with the media's inexpensive procurement cost (approximately \$0.10 per pound)
- Has the capability to quickly separate slurry into abrasive media and water components, thereby allowing water to be utilized as a rinse agent after blasting
- Enables spent media to be extracted from process by filtration without shutting-down the process
- Controls blasting dust generation, limiting ventilation system costs and containment
- Uses minimal tank volume for processing and hazardous waste disposal as compared to dry media blasting techniques (i.e., produces 1/100 of the waste media volume)

Technology Limitations

- Is abrasive and can damage substrate material under uncontrolled process conditions
- Does not perform well on removal of underlying aluminum anodize film

NDCEE FY04 Accomplishments

The NDCEE demonstrated the process using two types of abrasive media (aluminum oxide and quartz) in a 20% concentration by volume in water. Initially, aluminum oxide was chosen for trial due to its application use history and removal rate. All demonstrations succeeded in removing high-performance 4–6 mil thick polyurethane coatings and primers from aluminum substrate at a rate of 50 in.²/min. per 0.375 in. diameter nozzle. Several nozzles could be combined in practice to meet production rate requirements of 200 in.²/min.

Trials indicated that while the process removed that coating successfully, it damaged the anodized pretreatment on the aluminum substrate. Quartz is another slurry material, softer than aluminum oxide, which was trialed to reduce abrasion to the substrate. Again, this process was found to be too abrasive for aircraft wheels as it also removed the anodized pretreatment.

Economic Analysis

The cost of slurry media is very low. Aluminum oxide media is in the range of \$0.12–\$0.14 per pound and quartz media is approximately \$4.00 per 40-pound bag or \$0.10 per pound. This price compares favorably with the current plastic media of \$1.20 per pound. Engineered media, such as sponge or foam, typically range from \$3–\$4 per pound. Equipment costs for the slurry blasting system range from \$100,000–\$200,000 depending on production rates and part size. Operationally, the slurry blasting process does not use a significant amount of compressed air or electricity and is equal to waterjet and plastic media blasting in labor allocation. Because of cheaper material costs and less energy demands, wet slurry blasting is less expensive to operate than waterjet, chemical strippers, or PMB in most instances.

Suggested Implementation Applications

Wet slurry blasting using aluminum oxide may be used on soft, nondelicate composites and thin aluminum surfaces. Applicable weapons system components include a variety of vehicle and aerospace components. Parts, such as vehicle wheels, fenders, doors, engine components, mounts, and racks, can be removed and transported into a stripping booth.

This technology can eliminate the use of surface profiling (roughening) pretreatment.

Points of Contact

- Richard (Guy) Whalen, OO-ALC, (801) 775-6866, richard.whelen@hill.af.mil
- Doug Atterbury, NDCEE/CTC, (814) 269-2849, atterbud@ctc.com

Applicable NDCEE Task

Automated Plastic Media Blast for Depainting Landing Gear Wheels for Commodities
Directorate Ogden Air Logistic Center (Task N.258)

Zero-Temper Pure Zinc Cut-Wire Blasting

The NDCEE has been working with the maintenance department at OO-ALC to identify, demonstrate, and validate environmentally sound, alternative technologies for coatings removal from aircraft landing gear wheels. As part of this effort, the NDCEE demonstrated two types of zero-temper pure zinc cut-wire (ZCW) blasting as potential alternatives to chemical stripping and ultrahigh-pressure waterjet removal system. OO-ALC is currently using methylene chloride chemical stripping, which involves both carcinogenic materials and a volatile organic hazardous air pollutant. However, OO-ALC has installed a UHPWJ based upon familiarity with the technology and its suitability for use on landing gear strut assemblies. Because of positive demonstration and economic findings, OO-ALC is considering using a ZCW process.

Technology Description

Zero-temper pure ZCW blasting is a dry blasting process by which the ZCW media, comprised of zero-temper (very soft) pure zinc alloy, can be applied to a work surface by either of two delivery methods—by conventional air pressure and nozzle (air-blown) or thrown by constant rpm motorized wheel (airless). ZCW blasting is used to remove casting flash and heavy coating residues from coating line jigs and hooks.

Both the airless and air-blown blasting methods use a zinc shot material that is made from high-grade zinc wire that has been cut into segments approximately 1–2 times in length as its diameter. The cut edge of the zinc produces the abrasion that is necessary to remove the coating. The ZCW shot has a density of 240 pounds per cubic foot and a hardness of 20–30 Rockwell B. It is much softer than other metallic media, such as steel shot, which have a hardness of 200–300 Rockwell B. In addition, the ZCW shot has a very low breakdown rate and fairly constant mass size.

With the airless ZCW blasting method, a spinning wheel is used to mechanically project the blast media while the part is moved within the blast stream. The blast pressure is dependent on the speed of the rotating wheel. The blast pressure and media feed rate can be varied to increase or decrease the aggressiveness of the blast stream. The air-blown ZCW blasting method uses compressed air instead of a spinning wheel to project the blast media at the part.

The media can be recycled by separation of the media from the blast residue and spent media particles. Media life depends on the blast pressure and the part substrate type.

As the cut edge of the zinc shot dulls, the effectiveness is reduced. The disposal method of the blast waste is dependent upon the removed coating. Generally, if the coating that is being removed is classified as nonhazardous waste, then the spent media and the coating particles can be separated and the media recycled. If the coating is classified as a hazardous waste, then the facility must determine the proper disposal method. With ZCW, the spent media can be sold to metal recyclers.

Technology Benefits and Advantages

- Can be specified for specific diameters and lengths, allowing for control of applied kinetic energy of the media to the work surface
- Offers chisel points that provide good cut edges for removing high-performance polyurethane aerospace coatings

ESOH Need

Cleaning and coatings removal techniques



Landing gear wheel mounted in a motorized ZCW airless test machine

- Allows continuous use without having to anneal metallic media in order to return it to a desired hardness range because of the zero work-hardening characteristics of the used media
- Reduces dust generation that is associated with most dry media blasting because of the malleability of the pure zinc
- Allows for 50% higher coatings removal rates than PMB or 30% higher than UHPWJ removal rates with motorized airless method: these two methods were determined to meet the production needs of the Air Force wheel maintenance program (14,000 wheels per year) and were analyzed further to develop a full cost analysis review
- Permits recycling of zinc directly to metal recyclers at a positive cost per pound (e.g., typical recycling for zinc nets \$0.60 per pound versus a hazardous waste disposal charge for other solid blast media of \$0.40 per pound)

Technology Limitations

- May not be suitable for soft substrate materials such as composites
- Requires precleaning of parts to remove grease and dirt before blasting because any grease or dirt on the part will attach to the media, resulting in clumping and reduced effectiveness
- Requires postcleaning because of a zinc residue that is left on some substrates
- Requires a dedicated air compressor or compressed air source for the air-blown method, which can result in a greater equipment cost and process footprint size than the airless system

NDCEE FY04 Accomplishments

- Demonstrated both methods, conventional air-blown and motorized airless, of media application for the Air Force at two vendor locations
- Validated that coatings removal rates for conventional air pressure blasting process were approximately 150 in²/min per nozzle and 350 in²/min. per motorized throw wheel respectively
- Validated that both methods preserved the underlying anodized pretreatment layer while removing 99+% of the coating

Economic Analysis

The NDCEE performed an economic analysis on the mechanical airless process because it met the stated Air Force coatings removal production rate of 4 minutes per wheel half. Each wheel separates into two unique halves and is thus treated as an individual piece for production calculation purposes. Using baseline data from OO-ALC, the NDCEE calculated an annual savings of more than \$850,000 and a payback period of less than 2 years. This savings is primarily the result of reducing annual material cost by nearly \$175,000 and reducing annual disposal costs by more than \$108,000. The technology is expected to reduce Hill's solid waste by approximately 90%.

Because the conventional air-blown method did not meet the Air Force-required production rate, no economic analysis was performed on this process.

Suggested Implementation Applications

ZCW blasting technology may be used by the Air Force for coatings removal from aircraft landing gear wheels and for other coatings removal needs such as ground equipment and vehicles. Parts, such as vehicle wheels, fenders, doors, engine components, mounts, and racks, can be removed and transported into the stripping booth. Surface profiling (roughening) pretreatment may be eliminated by use of this technology.

Points of Contact

- Richard (Guy) Whalen, OO-ALC, (801) 775-6866, richard.whelen@hill.af.mil
- Doug Atterbury, NDCEE/CTC, (814) 269-2849, atterbud@ctc.com

Applicable NDCEE Task

Automated Plastic Media Blast for Depainting Landing Gear Wheels for Commodities
Directorate Ogden Air Logistics Center (Task N.258)

Technology Demonstration Facility Equipment



TRANSFERRING TECHNOLOGY SOLUTIONS
Supporting DoD Readiness, Sustainability, and Transformation

NDCEE

National Defense Center for Environmental Excellence

NDCEE Technology Demonstration Facility

Located in Johnstown, Pennsylvania, the NDCEE Demonstration Facility is a venue for independent, third-party verification of environmentally beneficial technologies. In this real-life production environment, clients can try-out, validate, and receive hands-on, in-depth training on new environmentally acceptable processes and materials before implementing them in their own facilities.

By using the Demonstration Facility, clients can reduce many of the technical and financial risks that are associated with implementing a new technology. For instance, DoD installations can select the best alternative for their application by evaluating several state-of-the-art technologies in proof-of-principle demonstrations at the facility instead of shutting down their own production lines. Hardware and software can be tested before investments are made throughout the DoD. Client personnel can evaluate alternatives according to projected performance and cost factors, including equipment costs, start-up costs, throughput rates, operating costs, and product quality. Alternatives may be commercially available technologies or custom-designed prototypes.

Once an alternative is selected, DoD personnel can use the facility to conduct a full-scale process validation under realistic operating conditions. In this way, the technology is evaluated against client standards to ensure that technical; production; environment, health, and safety; and cost requirements are satisfied. All testing is performed in accordance with approved test plans.

The Demonstration Facility is built based on an understanding of end-user needs. It is designed to provide flexibility, modularity, and consideration of human factors. It integrates pollution prevention concepts to provide a fully self-contained operation. The facility includes quality control and device calibration laboratories, warehousing and maintenance areas, worker facilities, and a complete utility infrastructure.

The Demonstration Facility currently houses approximately 20 commercial-scale production technologies in the areas of cleaning; stripping; vacuum coating; organic and inorganic finishing; recycle, recovery and reuse; and electroplating. To ensure that these technologies remain state-of-the-art, the NDCEE keeps abreast of improvements in the technologies and provides recommendations to the Government for upgrades. These recommendations are based on existing knowledge and experience working with the DoD and industry and take into account the DoD's highest-priority environmental needs.

The following section contains a summary of each technology that is located in the Demonstration Facility. In addition to providing recommended upgrades based on current industry standards and DoD needs, each summary provides an overview of the technology, its specifications, its benefits and advantages, its limitations and disadvantages, representative NDCEE tasks, and potential technology transfer applications. The current value of each technology also has been calculated based on a straightline depreciation method as referenced by Internal Revenue Service regulation 1.167. This information is provided to aid in determining whether or not upgrades to the technology are justified.

Closed-Loop Manual Plating Line

(Electroplating)

Overview

Environmental compliance costs are driving the metal plating industry to search for ways to reduce the volume and toxicity of its waste through “greener” plating processes and materials. The closed-loop electroplating line that is located in the NDCEE Demonstration Facility reduces the volume of wastes that is associated with electroplating operations through source reduction, recycling, and resource recovery. Counter-current rinsing and recovery technologies reduce wastewater from rinsing operations and their resulting RCRA-classified F006 sludges.

The line, which is capable of operating under any condition that is necessary for general electroplating and electroless plating, is used to evaluate new electroplating processes, particularly those that use noncyanide process chemicals and replacement metals for hexavalent chromium and cadmium. Typical processes that are available for demonstration include noncyanide copper, acid and alkaline zinc nickel, electroless nickel, electroless nickel-boron, nickel-tungsten-silicon-carbide, nickel-tungsten-boron, and noncyanide silver. Each of these processes is evaluated for its engineering properties, environmental advantages, life-cycle cost, and production readiness. The line can also be used to evaluate other new alternatives as they become available.

The NDCEE Closed-Loop Manual Plating Line is easily configurable to any special requirement of the user. Designed for rack and barrel processing, the line processes parts up to 2 feet x 2 feet x 1 foot in size and weighing up to 250 lbs. Electrocleaning and acid activation prepare the parts for plating. Four in-line plating stations can handle any type of plating solution. Each plating tank is separately bussed, filtered, and heated. Temperature is automatically controlled at $\pm 5^{\circ}\text{F}$. Each tank is equipped with both air and mechanical agitation. Fumes are exhausted from each tank through a packed bed scrubber with a mist eliminator prior to discharge. All scrubber water is also recycled.

The line is designed for near-zero water discharge. Multiple rinsing sequences (spray rinsing, double or triple counter flow, or a combination of these sequences) minimize wastewater that requires treatment or disposal. All rinses are segregated and undergo a recycling process, such as microfiltration, reverse osmosis, or evaporation, depending on the specific electroplating process.

Specifications

The following table contains the specifications and parameters of the NDCEE Closed-Loop Manual Plating Line.

Closed-Loop Manual Plating Line Specifications and Operating Parameters

Specification	Parameter
Maximum Part Size	2' x 2' x 1'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Closed-Loop Manual Plating Line.

Original Purchase Cost and Current Value of the Closed-Loop Manual Plating Line

Purchase Cost	Current Value	Years of Service
\$190,400	\$47,600	9

Technology Benefits and Advantages

- High-quality parts can be obtained without generating wastes.
- Hardness, lubricity, fatigue, and corrosion resistance of the coating can be optimized by varying bath operating parameters such as time, temperature, current density, and solution concentration.
- The equipment is reconfigurable to demonstrate a variety of processes.
- The equipment reduces the volume of wastes that are associated with electroplating through source reduction, recycling, and resource recovery.
- Counter-current rinsing and recovery systems in a closed-loop plating line reduce wastewater from rinsing operations.
- The process is beneficial to the environment by reducing hazardous waste.

Technology Limitations and Disadvantages

- Part sizes that can be processed are limited by the size of the plating tanks.

Recommended Upgrades for Continued DoD Support

The plating line currently meets or exceeds modern industry standards and is maintained in operational condition. Currently, no upgrades to the system are recommended.

Representative NDCEE Tasks

Environmental Metal Plating Alternatives - Electroless Nickel Plating Rejuvenation (Task N.089)

- Evaluated technologies that are capable of reducing the amount of waste that is generated by electroless nickel plating processes

Evaluation of Noncyanide Silver Plating (Task N.104)

- Evaluated commercially available noncyanide alternatives to silver plating processes

Materials and Process Partnership for Pollution Prevention/Pollution Prevention Initiative (Task N.227)

- Evaluated commercially available noncyanide alternatives to copper and silver plating processes

Alloy Plating to Replace Cadmium on High-Strength Steels (Task N.000-02, Subtask 7)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Sustainable Green Manufacturing (Task N.301, Subtask R4-1)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Potential Technology Transfer Applications

This technology can be used in conjunction with electroplating and electroless painting technologies to reduce the volume of wastes that is associated with electroplating operations.

ESOH Need

Surface protection and corrosion control



Closed-Loop Manual Plating Line

Cross-Flow Microfiltration Units

(Kinetic Microfiltration Mobile Unit and Kinetic Bench-Scale Unit)

Overview

Microfiltration is a recycle/recovery technology that is generally used to remove solid particulate or emulsified contaminants from process solutions such as alkaline cleaning baths and electroplating/stripping bath rinses. Microfiltration can also be used to remove microorganism contamination from process solutions.

Microfiltration technology operates by use of a membrane system in which the membrane material and pore size can be varied depending on the application. Pore sizes for microfiltration membranes range from 0.1–5 microns. Smaller pore-sized membranes, utilized in ultrafiltration techniques, range from 0.005–0.1 micron.

Cross-flow microfiltration is a filtration process in which the process fluid is passed through a filter membrane under pressure. The pressure of the passing fluid forces process fluid through the membrane pores, with the solid and emulsified materials remaining on the process side of the membrane. The fluid that is forced through the membrane is known as the permeate solution and is circulated to a holding tank. The remaining process solution with the solid contamination is circulated back to the process tank for additional passes through the filter membrane until the solids in the process fluid cause the pressure of the microfiltration system to climb and the process flow to drop considerably. At this point, the remaining solution is known as the concentrate.

The NDCEE Demonstration Facility contains both a full-scale and a bench-scale cross-flow microfiltration unit.

Specifications

The following table contains the specifications and parameters for the NDCEE Cross-Flow Microfiltration Units.

Cross-Flow Microfiltration Specifications and Operating Parameters

Specification	Parameter
Flow Rate	Full-scale unit - 5 gpm Bench-scale unit - 0.5 gpm
Filter Porosity	0.005–0.8 microns
Pressure	65 psi
Membrane Material	Teflon™, ceramics, polypropylene, and other plastics
Material of Construction	PVC

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Cross-Flow Microfiltration Units.

Original Purchase Cost and Current Value of the Cross-Flow Microfiltration Units

Purchase Cost	Current Value	Years of Service
\$250,000	\$83,333	8 (for each unit)

Technology Benefits and Advantages

- Demonstrates wide array of process solutions
- Helps to meet compliance with pretreatment standards for discharge regulations
- Helps to meet effluent limits of NPDES permit
- Reduces waste volume by purifying and recycling contaminated water
- Reduces hazardous waste

Technology Limitations and Disadvantages

- Membranes can be costly and time consuming to clean, depending on the solution to be recovered.

Recommended Upgrades for Continued DoD Support

Currently, no upgrades for the NDCEE units are recommended.

Representative NDCEE Tasks

Red River Army Depot Microfiltration Evaluation of Zinc Phosphate Solution (Task N.108)

- Evaluated microfiltration as an alternative technology to prolong the life of pretreatment baths
- Completed a cost analysis and an environmental impact comparison in relation to current processes

NDCEE Demonstration Projects - Alternative Cleaning Solution Recycle/Recovery (Task N.000-01, Subtask 5)

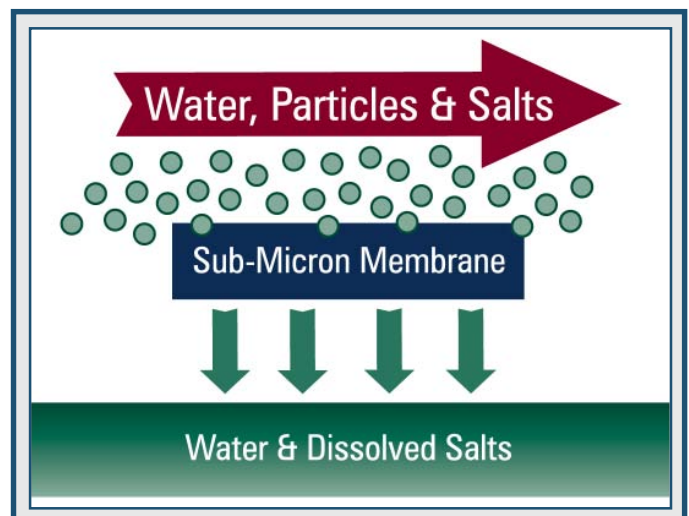
- Conducted bench-scale trials to recycle rust remover solutions

Potential Technology Transfer Applications

This technology could be applied in those applications in which a requirement exists to remove solid particulate or emulsified contaminants from various types of process solutions.

ESOH Need

Effluent discharge treatment



Microfiltration Process

Diffusion Dialysis Unit

(Kinetic Diffusion Dialysis Mobile Unit)

Overview

Diffusion dialysis techniques are generally used to remove metals contamination from concentrated acid solutions. Common uses include recycling plating or stripping baths that are composed of sulfuric, nitric, phosphoric, or hydrochloric acids, or combinations of these acids and weak acids. A variety of metals can be removed or recovered, depending on the value of the metal. Some types of metals include zinc, iron, copper, chromium, nickel, and silver.

Diffusion dialysis functions by passing process fluid through a stack of semipermeable membranes. The unit that is housed in the NDCEE Demonstration Facility utilizes an anion permeable membrane, where the acid anions pass through the membrane to the low concentration, deionized water side of the membrane. The metals remain trapped on the high concentration side of the membrane, which contains the original process solution. The result of this process is an 80–95% recovery of the initial acid solution (somewhat diluted with deionized water) and 60–95% recovery of the metals.

Specifications

The following table contains the specifications and parameters of the NDCEE Diffusion Dialysis Unit.

Diffusion Dialysis Unit Specifications and Operating Parameters

Specification	Parameter
Stack Size	2 liters/hour or 5 liters/hour
Membrane	Anion permeable

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Diffusion Dialysis Unit.

Original Purchase Cost and Current Value of the Diffusion Dialysis Unit

Purchase Cost	Current Value	Years of Service
Est. at \$200,000	\$66,667	8

Technology Benefits and Advantages

- Reduced hazardous waste volume and the associated disposal costs
- Metals reclamation and reduction of liability if sludge is recovered by an outside company
- Lower annual cost for chemical makeup and replacement
- Improved production quality and consistent reproducibility of manufactured parts due to control of the metal ion concentration in the anodizing bath solution
- Beneficial to the environment by reducing hazardous waste
- More cost-effective than conventional treatment and discharge
- Application-specific size feature

Technology Limitations and Disadvantages

- Moderately high capital costs (in the \$200,000 range)
- Increase in the number of possible exposures with regard to the handling of hazardous waste

Recommended Upgrades for Continued DoD Support

The NDCEE Diffusion Dialysis Unit currently meets or exceeds industry standards. The equipment is maintained in operational condition or in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the system are required at this time.

Representative NDCEE Task

Evaluation of Adsorption Technology to Recover Contaminated Mineral Acid Solutions (Task N.064)

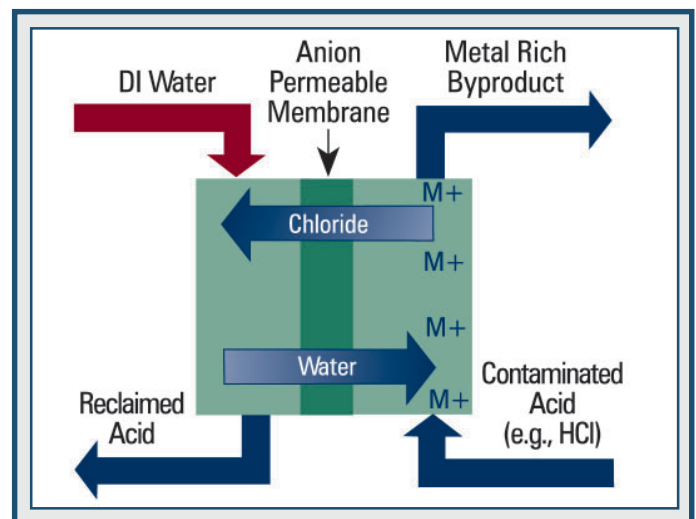
- Recovered mineral acid from iron contaminated hydrochloric acid solution

Potential Technology Transfer Applications

This technology can be used in conjunction with plating and acid stripping operations to recover mineral acids.

ESOH Need

Effluent discharge treatment



Diffusion Dialysis Process

Dual-Use Ultrasonic System

Overview

The Dual-Use Ultrasonic System uses aqueous/semiaqueous solutions to clean and degrease a wide variety of parts. The system is comprised of five stainless steel tanks and a dryer. The stages include a wash station, emulsion rinse tank, three cascading water stages, and a "hot-air" dryer. The emulsion rinse, which may also be used for aqueous washing, and first water rinse tanks use ultrasonic and mechanical spray-under-immersion agitation to clean parts. Wash and rinse solutions can be recycled after filtration and oil clarification. Parts are rinsed in fresh or deionized water. Compressed air removes moisture from the parts before they are dried in the drying chamber.

Specifications

The following table contains the specifications and parameters of the NDCEE Dual-Use Ultrasonic System.

Dual-Use Ultrasonic System Specifications and Operating Parameters

Specification	Parameter
Washing Temperature	80–180°F
Rinse Temperature	80–180°F
Dryoff Temperature	300°F
Maximum Part Size	3' x 4' x 4'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Dual-Use Ultrasonic System.

Original Purchase Cost and Current Value of the Dual-Use Ultrasonic System

Purchase Cost	Current Value	Years of Service
\$506,000	\$126,500	9

Technology Benefits and Advantages

- May be set at various temperatures, pressures, cycle times, and ultrasonic frequency settings for optimum performance
- Attains very high levels of cleanliness
- Removes particles from small through-holes
- Removes debris from parts with complex geometries
- Decreases cleaning times over traditional immersion cleaning without ultrasonics

Technology Limitations and Disadvantages

- Not as effective as directed sprays for cleaning blind holes

Recommended Upgrades for Continued DoD Support

The NDCEE system presently meets or exceeds industry standards. The equipment is maintained in operational condition. Currently, no upgrades to the system are recommended.

Representative NDCEE Task

Nonhalogenated Systems for Cleaning Metal Parts (Task N.007)

- Identified, tested, and evaluated environmentally compliant, technically and economically feasible nonhalogenated metal parts cleaning system

Potential Technology Transfer Applications

This technology is designed for applications in which a requirement exists to clean large-scale contaminated areas with aqueous/semiaqueous solutions.

ESOH Need

Cleaning methods



Dual-Use Ultrasonic System

Fuel Cell

Overview

The generation of electricity is typically performed through the burning of fossil fuels in internal combustion engines (i.e., gasoline, diesel, or gas turbine) or in boilers to generate high-pressure steam that is supplied to a steam turbine. A fuel cell generates electricity through an electrochemical process that is similar to a battery. However, with a fuel cell, as long as fuel is supplied, electricity is continually produced.

The principles behind fuel cells have been known since 1839, but were not practically applied until the NASA Gemini program in the 1960s. With improvements in the technology and increasingly strict pollutant emissions regulations, fuel cells are currently an economical solution in some applications. The market for applications requiring electricity is extremely large and diverse, resulting in a heightened interest and development of fuel cells for applications ranging from mobile phones to vehicular power to utility power plants. Fuel cells are expected to become commonplace during the next decade.

Fuel cells are generally more efficient in generating electricity than traditional methods. Unlike most traditional generating methods, they are scalable, meaning that the efficiency does not significantly change with size and power that is produced.

Several types of fuel cells are being developed for applications as small as a mobile phone (<1 Watt) to as large as a small power plant for an industrial facility or a small town (>10 Megawatts). The fuel cell that was tested by the NDCEE for the U.S. Army Engineer Research and Development Center (ERDC)/Construction Engineering Research Laboratory (CERL) is a PC25C, 200 kW phosphoric acid fuel cell manufactured by UTC Fuel Cells.

The PC25C is one of the first commercially available fuel cells in this size range. ERDC/CERL supported the installation of 30 PC25Cs at military installations around the country to gain working experience with this new technology. Under the direction of ERDC/CERL, the NDCEE established a national capability, the Fuel Cell Test & Evaluation Center (FC_{Tec}), for performing comprehensive, independent testing of fuel cell power plants. The PC25C that is shown on the next page is located in the FC_{Tec} site at the NDCEE Demonstration Facility.

Specifications

The following table contains the specifications and parameters for the NDCEE PC25C Fuel Cell.

PC25C Fuel Cell Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	-20–110°F
Electrical Power Output	0–200 kW
Thermal Power Output	>800,000 BTUs/hr
Fuel Cell Size	212" x 114" x 121"
Fuel Cell Weight	40,000 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE PC25C Fuel Cell.

Original Purchase Cost and Current Value of the PC25C Fuel Cell

Purchase Cost	Current Value	Years of Service
\$800,000	\$466,667	5

Technology Benefits and Advantages

- Use of alternative or renewable energy sources helps facilities to comply with the U.S. Energy Policy Act of 1992 and other federal, state, and military directives
- Improves energy conservation and reduces environmental impacts in comparison to traditional energy sources
- High-energy conversion efficiency, fuel flexibility, and cogeneration capability
- Modular design with no moving parts
- Very low chemical and acoustical pollution
- Rapid load response
- Simple installation, no specialized fuel cell experience needed

Technology Limitations and Disadvantages

- Initial equipment costs may be high, but are improving as the technology becomes more widely disseminated.
- As with any new and advanced power technology, fuel cells involve design and construction planning as well as additional maintenance training.
- Distributed power sources require dedicated onsite space requirements.
- Caution must be exercised since high voltages are a potential danger.

Recommended Upgrades for Continued DoD Support

The NDCEE residential fuel cell system within the FC7ec has limited functionality and remaining life. It could be replaced with a new system to provide grid independent and or multi-fuel capabilities.

Representative NDCEE Tasks

ESTCP Validation Tasks (Task N.098)

- Investigated the uses of fuel cells in DoD applications
- Identified fuel cell applications that are not currently pursued by the DoD, including premium power, direct current (DC) power, and hydrogen source applications
- Reviewed the economics of fuel cell technology including cost comparisons to more conventional energy sources

U.S. Army ERDC/CERL Fuel Cell Technology Program (Task N.211)

- Provided testing and evaluations, in cooperation with various fuel cell manufacturer's power plants, with the focus to support life-cycle cost reduction and performance improvement goals
- Provided the capability for independent design assessments of alternative technology fuel cell system configurations and components

Potential Technology Transfer Applications

Fuel cells are candidate technologies for any DoD facility that needs highly reliable, nearly emissions-free electrical power. They could substitute for older technologies, such as batteries, as an uninterruptible power supply. Collocation of electrical power needs and thermal needs (e.g., hot water or low-pressure steam) will make any installation more economical. Additional applications include remote power production in which the fuel cell is the primary energy provider, not connected to the power grid.

ESOH Need

Renewable energy



UTC Fuel Cells PC25C, 200 kW Phosphoric Acid Fuel Cell

Honeycomb Cleaning System

Overview

The Honeycomb Cleaning System was originally developed to clean aircraft honeycomb, but is suitable for difficult-to-clean parts that have strict cleaning requirements. Parts are positioned on a cart that is rolled along a track into the washer. A 385-nozzle spray bar moves back and forth beneath the parts, spraying a heated wash solution that is followed by a deionized water rinse. Overhead nozzles wash and rinse the top portion of the honeycomb. Wash and rinse solutions are then filtered and recycled. Compressed air removes excess water from the parts before they are dried by a high-capacity blower in a humidity-controlled oven.

Specifications

The following table contains the specifications and parameters of the NDCEE Honeycomb Cleaning System.

Honeycomb Cleaning Specifications and Operating Parameters

Specification	Parameter
Part Size	6' x 6' x 4'
Part Weight	250 lbs.
Wash Temperature	80–180°F
Rinse Temperature	80–180°F
Dry off Temperature	300°F

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Honeycomb Cleaning System.

Original Purchase Cost and Current Value of the Honeycomb Cleaning System

Purchase Cost	Current Value	Years of Service
Donated to the NDCEE by the Air Force	Not Applicable	9

Technology Benefits and Advantages

- Aqueous/semiaqueous closed-loop system that is good for replacing solvent cleaning
- Environmentally friendly

Technology Limitations and Disadvantages

- Designed for honeycomb cleaning (nozzles within the cabinet are set up for this application)
- Is not as versatile as some other types of aqueous cleaning systems

Recommended Upgrades for Continued DoD Support

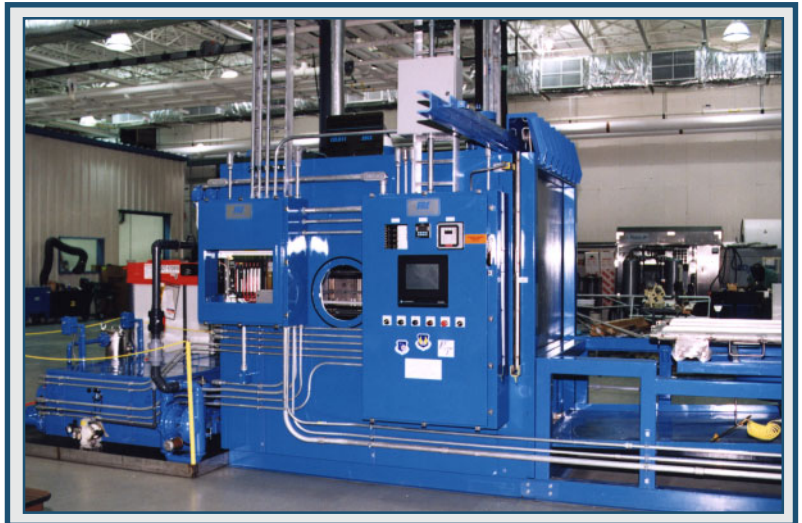
The Honeycomb Cleaning System is not currently in operational condition. However, no upgrades to the system are recommended until such time as a need for the equipment is identified.

Potential Technology Transfer Applications

This technology could be used for applications in which difficult-to-clean parts with strict cleaning requirements are involved such as aircraft honeycomb.

ESOH Need

Cleaning methods



Honeycomb Cleaning System

Ion Beam Assisted Deposition System

Overview

Most DoD repair facilities use “wet” processes to apply cadmium, chromium, and other surface coatings to a variety of aerospace, tank, automotive, and armament components. Cadmium and chromium are important metals because they impart essential physical and mechanical properties to the surface of the component that is being coated to extend its useful life. The use of traditional wet processes results in the generation of heavy metal wastes that require expensive treatment. The DoD and private industry have been searching for alternative processes that generate little or no waste, are environmentally acceptable, and pose reduced exposure risks to operators. These alternative application technologies must meet stringent performance requirements while remaining technically and economically feasible.

Ion beam assisted deposition (IBAD) is a coating process that incorporates both a means of physical vapor deposition and simultaneous ion bombardment. During processing, the substrate surface is bombarded with positively charged ions while neutral species of the coating material are delivered concurrently to the substrate via a physical vapor deposition (PVD) technique such as thermal or electron beam evaporation, cathodic arc, or sputtering. IBAD typically operates at a pressure of approximately 10^{-4} – 10^{-5} Torr and typically utilizes low-energy ion bombardment with high beam current, high-energy ion bombardment with low beam current, or a moderate beam energy and current. The impinging ions provide nucleation sites for the neutral species, and at high energies, ion beam mixing can generate a physically mixed zone between the substrate surface and the coating, resulting in increased adhesion. Other benefits that are gained with this process include reductions in porosity and pinholes and increased control of internal stress, morphology, density, and composition.

The thickness of the coating is limited at present to deposits ranging up to several micrometers. The coating species can be any element, compound, or alloy that is capable of being vapor deposited. The gaseous ions may be either inert or reactive (e.g., argon or nitrogen, respectively). Hard coatings of interest for wear applications generally include titanium nitride, chromium nitride, alumina, and other ceramic coatings. These coatings generally are used for high-cost or value-added components. Substrates include metals, plastics, ceramics, and glasses.

The NDCEE identified ion beam processing as an alternative to traditional electroplating technologies. The IBAD process generates minimal waste, poses very few health risks, and can provide superior surface properties.

Specifications

The following table contains the chamber dimensional specifications for the NDCEE IBAD System.

IBAD System Chamber Dimensional Specifications

Chamber Dimensions	Main Chamber	Extension	Load Lock
Length	72"	42.25"	48"
Diameter	72"	36"	36"

The chamber dimensions allow the IBAD unit to accommodate components up to 6 feet in length, 1 foot in diameter, and 2,000 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE IBAD System.

Original Purchase Cost and Current Value of the IBAD System

Purchase Cost	Current Value	Years of Service
\$1,980,000	\$825,000	7

Technology Benefits and Advantages

- Generates minimal waste
- Reduces health risks
- Provides superior surface finishes with respect to the current processes in use
- Is more environmentally friendly than traditional coating processes

Technology Limitations and Disadvantages

- Specific technologies can impose constraints; for example, line-of-sight transfer makes coating components with a deep internal diameter practically impossible.
- System requires large initial capital investments (i.e., greater than \$1 million).
- Coating thickness is limited to several micrometers, as opposed to several mils (where $25.4 \mu\text{m} = 1 \text{ mil}$) for electrodeposited films.

Recommended Upgrades for Continued DoD Support

The following upgrades are recommended for DoD support:

- Although the current IBAD equipment that is located at the NDCEE Demonstration Facility is considered to be state-of-the-art technology, it would be beneficial for this equipment to have a planetary gear fixture installed. This upgrade would provide the following benefits to the equipment:
 - Ability to coat multiple, complex-shaped components
 - Ability to treat more parts in a single trial, making the process more cost-effective
 - Improvements in base materials for parts that cannot be coated due to dimensional constraints.
- A commercial-off-the-shelf moderate energy ion source may increase the reliability of the process by decreasing lead times regarding maintenance. Currently, the moderate energy ion source that was provided with the IBAD system is a custom design. As such, minor maintenance issues require increased attention and longer solution times.
- The addition of other means of physical vapor deposition (e.g., cathodic arc or sputtering sources) would improve deposition rates and enable a wider range of materials to be evaporated.
- The addition of a metal ion source to enable metal ion implantation into substrate materials for improved hardness and wear resistance would

ESOH Need

Surface protection and corrosion control



Ion Beam Assisted Deposition Chamber

be beneficial. As such, materials that do not form nitrides, such as nickel, could be treated.

- New cryopumps with quicker adsorption rates for gases would benefit this equipment.

Representative NDCEE Tasks

Ion Beam Processing for Environmentally Acceptable Coatings (Task N.001)

- Gathered baseline data regarding current components, such as landing gear, pistons, and cylinder assemblies, that are refurbished with electroplated cadmium and chromium
- Identified ion beam processing methods as potential alternatives to electroplated cadmium and chromium
- Designed the ion beam system based upon the baseline information

Sustainable Green Manufacturing (Tasks N.213 and N.301)

- Conducted research in coatings development, corrosion prevention, and environmental engineering
- Treated parts for testing and performed cost-benefit analyses of same treatments

Materials and Processes Partnership for Pollution Prevention (Task N.227)

- Evaluated ion beam and plasma-based alternatives to chrome plating of gas turbine engines

Corrosion Measurement and Control (Tasks N.255 and N.304)

- Identified and investigated environmentally friendly corrosion preventive technologies
- Developed corrosion and wear preventive coatings

Potential Technology Transfer Applications

The IBAD process was investigated for use on a variety of weapons systems. In some instances, the coating or surface modification was found to be technically acceptable; however, it was not economically feasible. As shown below, other potential applications include:

- M1 intermediate and anti-friction, bearing housings
- Helicopter drive shafts and gear scuff samples
- M2A2 (Bradley) output carriers and transmission bearing assemblies (races and bearings)
- DDC series 60 engine valve stems and seats
- Diesel water pump seals
- Boeing outer diameters of rings
- Bearing hubs
- Duo cone seals for Marine Amphibious Assault Vehicle
- Test coupons for the preliminary corrosion testing for GTE components
- M1A1 bearing cups
- AGT 1500 main engine bearings
- B-2 bomber bomb door hinge

Ion Exchange Units

(Kinetico Ion Exchange Mobile Unit and Kinetico Bench-Scale Ion Exchange Unit)

Overview

Ion exchange technology can be utilized for many purposes. It is often used for polishing drinking water or wastewater for discharge, removing contaminant metal ions from rinsewaters and dilute etching solutions, recovering mineral acids from spent electroplating solutions (efficiencies of >95%), and removing organic contamination from a variety of water sources.

Ion exchange functions by performing an exchange of ionic species between the resin and the process solution. The resin is uniformly charged, either positive or negative, with an oppositely charged ion that is attached to the resin (generally hydrogen ion or hydroxyl ion). When the process solution is passed over the resin, the resin exchanges the hydrogen or hydroxyl for the more strongly charged contaminant ion. Resin materials can be composed of strong base anionic (SBA) materials, weak base anionic (WBA) materials, strong acid cationic (SAC) materials, weak acid cationic (WAC) materials, various chelating agents, mixed bed resins (both cationic and anionic), or granular activated carbon (GAC) for organic contaminant removal.

The NDCEE Demonstration Facility has both full-scale and bench-scale units. These units can be configured with any of the above resin materials or combinations of resins, such as an anionic resin bed, followed by a cationic resin bed, with a GAC bed for polishing at the end.

Specifications

The following table contains the specifications and parameters of the NDCEE Ion Exchange Units.

Ion Exchange Units Specifications and Operating Parameters

Specification	Parameter
Flow Rate	Full-scale unit - 1 gpm Bench-scale unit - 0.1 gpm
Resin	SBA, WBA, SAC, WAC, GAC, various chelating
Resin Beds	4, sequential
Material of Construction	CPVC

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Ion Exchange Units.

Original Purchase Cost and Current Equipment Value of the Ion Exchange Units

Purchase Cost	Current Value	Years of Service
\$250,000	\$83,333	8 (for each unit)

Technology Benefits and Advantages

- Helps to meet compliance with strict discharge regulations
- Reduces chemical costs and waste volume by purifying and recycling contaminated water
- Improves water quality
- Lowers operating costs for waste treatment and capital costs for chemicals
- Reduces hazardous waste
- Has compact design for efficient use of space

Technology Limitations and Disadvantages

- Some applications require specialty resins, which could cost more than \$10 per pound
- Presence of contaminants (e.g., oil and grease, oxidants, or acidity) may impact resin selection or require filtration prior to ion exchange.

Recommended Upgrades for Continued DoD Support

The NDCEE maintains the full-scale and bench-scale ion exchange units in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the units are recommended.

Representative NDCEE Tasks

U.S. Navy - Evaluation of Adsorption Technology to Recover Contaminated Mineral Acid Solutions (Task N.064)

- Tested acid recovery from a wide range of simulated waste acid streams

Office of Industrial Technology Program Coordination (Task N.133)

- Demonstrated the ability to regenerate a spent anion exchange resin bed
- Determined the breakthrough point and optimum processing conditions by running a plating solution through the bench-scale unit

NDCEE Demonstration Projects - Alternative Cleaning Solution Recycle/Recovery (Task N.000-01, Subtask 5)

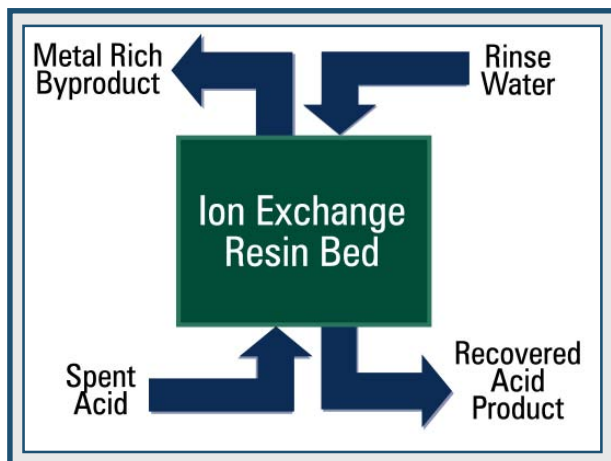
- Evaluated environmentally friendly alternatives to alkaline rust removers

ESOH Need

Effluent discharge treatment

Potential Technology Transfer Applications

This technology could be used for the following applications: polishing drinking water or wastewater for discharge, removing metals from rinsewaters and dilute etching solutions, recovering mineral acids from spent electroplating solutions, and removing organic contamination from water sources.



Ion Exchange Process

Ion Plating System

Overview

Ion plating is a physical vapor deposition coating process in which the basic mechanism is an atom-by-atom transfer of material from the solid phase to the vapor phase and back to the solid phase, gradually building a film on the surface to be coated. The three fundamental steps of ion plating include:

1. Vapor phase generation from coating material stock by:
 - Evaporation (resistive or electron beam)
 - Sputtering
 - Cathodic arc.
2. The transfer of the vapor phase from source to substrate (evaporant transition) by:
 - Line-of-sight
 - Molecular flow
 - Vapor ionization by applying a bias to the substrate to attract the ionized material.
3. Deposition and film growth on the substrate.

These steps can be independent or superimposed on each other depending on the desired coating characteristics. The final result of the coating/substrate composite is a function of each material's individual properties, the interaction of the materials, and any process constraints that may exist.

The selection criteria for determining the best method of ion plating is dependent on several factors:

- Material to be deposited
- Rate of deposition required
- Limitations imposed by the substrate such as the maximum deposition temperature, size, and shape
- Coating adhesion to the substrate
- Throwing power [rate and thickness distribution of the deposition process (i.e., the higher the throwing power, the better the process ability to coat irregularly shaped objects with uniform thickness)]
- Purity of coating materials
- Equipment requirements and their availability
- Cost
- Ecological considerations
- Abundance of deposition material

Ion plating is a desirable alternative to electroplating. It can be applied using a wide variety of materials to coat an equally diverse number of substrates. The application of ion plating surface coating technologies at large-scale, high-volume operations will result in the reduction of hazardous waste being generated when compared to electroplating and other metal finishing processes that use large quantities of toxic and hazardous materials.

Ion vapor deposition (IVD), a subset of ion plating, of aluminum is a vacuum coating process that is commonly used in DoD repair

ESOH Need

Environmentally compliant surface protection and corrosion control



Ion Plater

facilities as a replacement for cadmium plating. The IVD aluminum coating is used as a substitute for electroplated cadmium because it offers satisfactory corrosion resistance for many applications. A variety of other metals may be deposited by ion plating for applications requiring resistance to corrosion, wear or erosion.

Specifications

The following table contains the specifications and parameters of the NDCEE Ion Plating System.

Ion Plating System Specifications and Operating Parameters

Specification	Parameter
Chamber size	6' diameter x 12' length
Sample size	4' width x 7' length x 16" height maximum

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Ion Plating System.

Original Purchase Cost and Current Value of the Ion Plating System

Purchase Cost	Current Value	Years of Service
\$1,150,000	\$287,500	9

Technology Benefits and Advantages

- Does not require hazardous materials nor does the process generate hazardous wastes. Reduction of hazardous waste helps facilities to meet the requirements of waste reduction under RCRA, 40 CFR 262 and also may help facilities to reduce their generator status and lessen the amount of regulations (i.e., record keeping, reporting, inspections, transportation, accumulation time, emergency prevention and preparedness, emergency response) that they are required to comply with under RCRA.
- Can produce coatings that provide abrasion and corrosion-resistant surfaces (if appropriate materials and appropriate methods of ion plating are chosen).
- Can utilize virtually any type of inorganic and some organic coating materials on an equally diverse group of substrates and surfaces using a wide variety of finishes. In addition, it permits the usage of more than one technique for depositing a given film.
- Uses considerably less water than the traditional electroplating operations, as required under Executive Order 12902, *Energy Efficiency and Water Conservation at Federal Facilities*.
- Has numerous applications to aerospace, tool, automotive, home appliance, hardware, jewelry, and other parts that require coatings for protection, aesthetic appeal, or both.

Technology Limitations and Disadvantages

- Temperature constraints may limit the degree to which dense coatings can be deposited on some plastics and high-strength steels.
- Specific technologies can impose constraints; for example, line-of-sight transfer makes coating annular shapes difficult, if not impossible, with conventional techniques. However, newly available variations enable deposition on internal diameters.

- If high biases are being used, areas of the chamber can get hot to the touch and aspects of the chamber require cooling. Operator monitoring is required to ensure that water cooling continues throughout the deposition.
- Selection of the best technology requires experience and/or experimentation.
- This technology requires a cooling water system to dissipate large heat loads.
- This technology has high capital costs (i.e., greater than \$1 million).

Recommended Upgrades for Continued DoD Support

This system has been upgraded to improve controls and impart a pulsed high voltage bias during deposition. However, the sputtering sources and the program for the sputtering sources and the cathodic arc also could be upgraded.

Representative NDCEE Tasks

Sustainable Green Manufacturing (Task N.213)

- Developed life-cycle-based, environmental improvements in coatings and corrosion prevention
- Tested alternative finishes on DoD components for improved wear and corrosion protection

Materials and Processes Partnership for Pollution Prevention/Pollution Prevention Initiative (Task N.227, Mod 1)

- Demonstrated the efficacy of the proposed environmentally friendly materials/processes
- Validated alternative technologies prior to implementation

Corrosion Measurement and Control (Task N.255)

- Identified, investigated, and developed environmentally friendly technologies to measure, control, and prevent corrosion

Potential Technology Transfer Applications

This technology could be applied to those applications in which a need exists to identify an environmentally preferred alternative to traditional wet surface finishing processes such as electroplating. Other applications include parts that require improved engineering properties.

Liquid Coatings Application Equipment

(Conventional Spray)

Overview

The liquid coatings application equipment in the NDCEE Demonstration Facility consists of two open-face, cross-draft, paint spray booths (approximately 8 feet x 3 feet x 10 feet). The spray booths are designed with a triple combination of over-spray filters that minimize the size and amount of the particulate reaching the exhaust plenum. This design keeps the exhaust duct and plenum very clean and virtually eliminates particulate emissions. Liquid spray equipment presently consists of several conventional air atomizing and high-volume, low-pressure (HVLP) applicators, air assisted-airless application equipment, and a HVLP turbine-heated air spray system.

Specifications

The following tables contain the specifications and parameters of the NDCEE Liquid Coatings Application Equipment.

Conventional Air Atomizing Applicators Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	60–90°F
Operation Pressure	20–60 psi
Flow Rate	75–250 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

HVLP Applicators Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	60–90°F
Operation Pressure	7–20 psi
Flow Rate	125–400 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

Air Assisted-Airless Applicator Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	40–90°F
Operation Pressure	800–3000 psi
Flow Rate	400–1000 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

Turbine-Heated Air HVLP Applicator Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	90–135°F
Operation Pressure	6–20 psi
Flow Rate	125–400 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Liquid Coatings Application Equipment.

Original Purchase Cost and Current Value of the Liquid Coating-Related Equipment

Equipment	Purchase Cost	Current Value	Years of Service
2 booths (including filters, fans, etc.)	\$15,300/booth	\$0	12 years
Applicators			
Conventional air atomized	\$500/gun	\$83/gun	10
HVLP	\$450/gun	\$75/gun	10
Air assisted-airless	\$4,000	\$1,667	7
Turbine-heated air HVLP	\$42,000	\$21,000	6

ESOH Need

Coatings application systems

Technology Benefits and Advantages

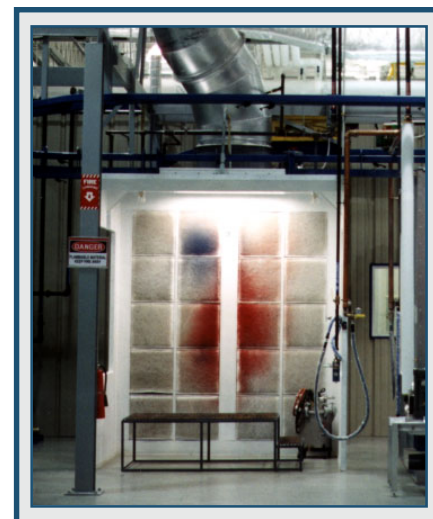
- Inexpensive application equipment
- Minimal training is needed to use applicators
- Easy to clean-up and maintain application systems
- Handles a wide variety of coating formulations
- Requires only compressed air (clean) utility
- Requires minimal storage space

Technology Limitations and Disadvantages

- Booth size limits material choice (i.e., isocyanates) due to limited air drawing power.

Recommended Upgrades for Continued DoD Support

State-of-the-art manually controlled, enclosed generator electrostatic applicators would provide enhanced transfer efficiency and surface finish quality required for most Air Force finishes. Using higher transfer efficiency applicators might allow for coating formulations with less HAP-containing solvents.



Conventional Spray Booth

Lower-cost, portable turbine-heated air HVLP cup gun systems would provide demonstration of higher-transfer efficiency HVLP application with portability. Portability is required by most large depot maintenance activities and at DoD original equipment manufacturer facilities.

To allow for the coating of larger structures that are typical of most depot facilities, a larger coating area (20 feet x 10 feet x 10 feet) should be constructed. The larger area should also contain a state-of-the-art triple filter bank and variable-frequency-driven fan exhaust for maximum ventilation.

Representative NDCEE Tasks

Paint Handling and Spraying Equipment Testing, Evaluation, and Training (Task N.023)

- Utilized as baseline for comparison with alternative coatings application technologies

Environmental Technology Verification Coatings and Coating Equipment Program (Tasks N.100, N.208, and N.306)

- Utilized conventional coating systems, per EPA standards, as a baseline when evaluating alternative coatings technology and equipment.

Potential Technology Transfer Applications

This technology would benefit all DoD facilities that are currently utilizing conventional coatings technologies to maintain small- to medium-sized components and are in need of additional production capabilities.

Membrane Electrolysis Units

Overview

Membrane electrolysis is an electrochemical process that is used to attract oppositely charged particles in solution across a semipermeable membrane. This process can be used to remove metal ion contamination from rinse waters and finishing baths that are utilized in etching, anodizing, and stripping processes. The technology can also be used to reoxidize metal finishing baths and separate acids or bases, causing salt precipitation.

Membrane electrolysis can function by two-compartment or three-compartment methods. For the two-compartment method, the positively charged anode is placed in one chamber and the negatively charged cathode in the other. Either a cation-permeable or anion-permeable membrane is placed between the two chambers. The process solution is then added to the appropriate chamber to achieve the desired type of separation. A voltage is applied to the electrodes and separation proceeds. The three-compartment system has a chamber for the process fluid in the center, with a semipermeable membrane on either side of the chamber. The cation chamber and anion chamber are then on opposite sides of the process chamber, with separation occurring by ions traveling from the process solution, through the membranes, to either outside (cation or anion) chamber.

The NDCEE Demonstration Facility contains a full-scale two-compartment unit, a full-scale three-compartment unit, and a bench-scale unit that can be configured into either two or three compartments.

Specifications

The following table contains the specifications and parameters for the NDCEE Membrane Electrolysis Units.

Membrane Electrolysis Units Specifications and Operating Parameters

Specification	Parameter
Rectifier Rating	20v, 150 amp maximum
Membrane Size	1 ft ² each
Membrane	Cation, anion permeable
Compartments	2 or 3
Anode Material	Dimensionally Stable Anode [®] , platinum/titanium, or other
Material of Construction	polyvinyliden difluoride

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Membrane Electrolysis Units.

Original Purchase Cost and Current Value of the Membrane Electrolysis Units

Purchase Cost	Current Value	Years of Service
\$250,000	\$62,500	9

Technology Benefits and Advantages

- Helps facilities to comply with strict discharge regulations
- Reduces chemical costs and waste volume by purifying and recycling contaminated water
- Improves water quality
- Lowers operating costs for waste treatment and capital costs for chemicals
- Reduces hazardous waste

Technology Limitations and Disadvantages

- A relatively slow process/batch process
- An electrical process, which may generate noxious fumes
- Nodes and membranes need to be periodically replaced or stripped

Recommended Upgrades for Continued DoD Support

The NDCEE maintains its full-scale and bench-scale membrane electrolysis units in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the units are recommended.

Representative NDCEE Task

Office of Industrial Technology Program Coordination (Task N.133)

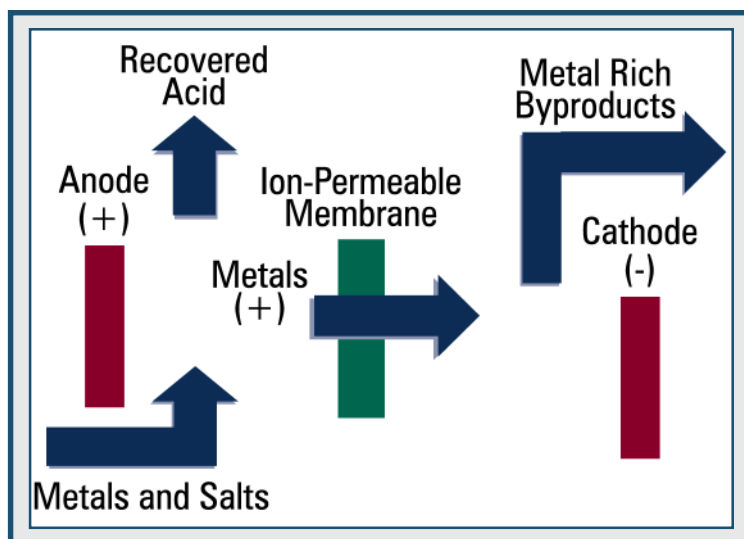
- Recovered rinse waters from oxalic acid solution for reuse

Potential Technology Transfer Applications

This technology was designed for applications in which a need exists to recover metal ions and impurities from rinse waters and finishing baths. These industries include various plating operations, precious metals recovery, and general cleaning/derusting operations.

ESOH Need

Effluent discharge
treatment



Membrane Electrolysis Process

Nonchromate Conversion Coating System

Overview

The full-scale nonchromate conversion coating system is a general-purpose aqueous solution-based pretreatment line. This prototype system can apply most currently available nonchromate conversion coating chemistries and many newly developed ones as well.

The system utilizes a linear design whereby a manual overhead conveyor moves parts from one processing tank to the next. The tanks are organized in stages, with each stage consisting of a process tank, a recirculation tank, and two rinse tanks. Because the system was designed for optimum flexibility, any of the processing steps (alkaline clean, alkaline etch, acid etch, desmut, nonchromate pretreatment or sealant) may be omitted, modified, skipped, or repeated as often as desired by the customer's and the processes' specific needs.

The system was designed to apply pretreatment processes using either an immersion or spray application technique. Therefore, the customer can determine the best application technique and its optimal parameters for spray time, concentration, temperature, etc. The system was also designed to handle both spray and immersion rinsing and comes equipped with fogging capability. This capability is generated by the use of special fog nozzles that are mounted within the processing and rinse tanks. The fog nozzles disperse water into a fine mist that gently condenses on the parts as they are being removed from a tank.

The system is extremely flexible and can evaluate any customer requirements in regards to processing parts and proving technical feasibility. Unlike other alternatives, this system incorporates the concept of bath rejuvenation and maintenance. It has quick-connect piping that can be used to individually attach any process tank with treatment technologies such as microfiltration, reverse osmosis, diffusion dialysis, membrane electrolysis, ion exchange, or any other appropriate technique for maintaining and rejuvenating process solutions. This type of process maintenance can save a tremendous amount of raw material usage, waste generation, downtime, and nonconforming product by ensuring that the solution is always as pure as possible.

ESOH Need

Coatings application systems

Specifications

The following table contains the specifications and parameters of the NDCEE Nonchromate Conversion Coating System.

Nonchromate Conversion Coating System Specifications and Operating Parameters

Specification	Parameter
Number of Stages	6 (4 polypropylene, 2 stainless steel)
Maximum Part Size/Envelope	2' x 2' x 2'
Maximum Part Weight	250 lbs.
Operating Temperature Range	Polypropylene process tanks - ambient to 170°F Stainless steel process tanks - ambient to 200°F
Tank Capacity	Polypropylene process tanks - 175 gal. Stainless steel process tanks - 200 gal.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE system.

Original Purchase Cost and Current Value of the Nonchromate Conversion Coating System

Purchase Cost	Current Value	Years of Service
\$1,384,000	\$692,000	6

Technology Benefits and Advantages

- Able to apply most currently available nonchromate conversion coatings
- Capable of both immersion and spray applications
- Capable of rejuvenating process baths using treatment technologies
- Can test and evaluate alternative pretreatments at full scale prior to implementation

Technology Limitations and Disadvantages

- Maximum part size of 2 feet x 2 feet x 2 feet
- Maximum part weight of 250 pounds

Recommended Upgrades for Continued DoD Support

The NDCEE system is currently able to process most available nonchromate conversion coating chemistries. The equipment is maintained in operational condition, or in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the system are recommended at this time.

Representative NDCEE Tasks

Evaluation of Nonchromate Conversion Coating (Task N.008)

- Designed and built a system to evaluate, at full scale, potential nonchromate alternatives

Organosilane Pretreatment of Aluminum Alloys (Task N.095)

- Evaluated the performance of a nonchromate organosilane aluminum alloy pretreatment



Nonchromate Conversion Coating System

Testing Services to Support the Development of Polyelectrolyte-Modified Zinc Phosphate Conversion Coatings for U.S. Army Tank-Automotive and Armaments Command (Task N.119)

- Conducted a full-scale demonstration of a modified zinc phosphate conversion coating process

Organosilane Pretreatment Process for Aluminum Alloys for U.S. Army Tank-Automotive and Armaments Command (Task N.295)

- Investigated spray application methods for an organosilane pretreatment
- Provided field-level coordination for the implementation of a nonchromate conversion coating at Red River Army Depot

Potential Technology Transfer Applications

The Nonchromate Conversion Coating System may be suitable for any DoD facility that is currently using chromate conversion coatings and for which a nonchromate pretreatment has been identified that meets the requirements of the application.

Organic Finishing Powder Coating Line

Overview

Powder coating is an environmentally friendly coating process that can be used on a wide assortment of products from bullets to park benches. It provides a durable coating and reduces operating costs while eliminating VOCs, HAPs, and solvent usage. The four basic powder coating methods are electrostatic spraying, conventional fluidized bed, electrostatic fluidized bed, and flame spray. Electrostatic spraying is the most commonly used powder coating application method. For all application methods, high-quality surface preparation (i.e., cleaning and conversion coating) is required to develop good coating adhesion to the substrate. Characteristics of the four different powder application techniques are described below.

In *electrostatic spraying*, an electrical charge is applied to the powdered coating particles while the part that is to be painted is electrically grounded. The applicator and grounded work piece create an electrostatic field that attracts the coating particles to the work piece. The coating particles that are deposited on the work piece retain some of their electrostatic charge, which holds the powder to the work piece. The coated work piece is placed in a curing oven, where the paint particles melt onto the surface and form a continuous film. Due to its versatility, this application method is currently employed in the NDCEE Organic Finishing Powder Coating Line. In addition, the finishing line can apply three types of chemical conversion pretreatments to steel and aluminum parts for adequate adhesion of the powder coatings. Automated conveying and a batch-load, curing oven allow for maximum process control in the handling and thermal curing of the powder-coated parts.

In a *conventional fluidized bed* applicator, powder particles are kept in suspension by an air stream in an engineered dip tank or “bed.” A preheated work piece is placed in the fluidized bed where the powder particles contact with the work piece, melt, and adhere to the surface. Coating thickness is dependent on the temperature and heat capacity of the work piece and residence time in the fluidized powder cloud. Further heating is generally not required when applying thermoplastic powder coatings. However, oven curing is required to cure thermoset powder coatings completely.

Electrostatic fluidized beds are similar in design to conventional fluidized beds, but the air stream is electrically charged as it enters the bed. The ionized air charges the powder particles as they move upward in the bed, forming a cloud of charged particles. The grounded work piece is covered by the charged particles as it enters the chamber. No preheating of the work piece is required; however, curing of the coating is necessary. This technology is most suitable for coating small objects with simple geometry.

The *flame spray technique* was recently developed for application of thermoplastic powder coatings. The thermoplastic powder is fluidized by compressed air and fed into a flame spray gun where it is injected through a flame of propane, melting the powder. The molten coating particles are deposited on the work piece, forming a film upon solidification. Rapid solidification does not allow a smooth film to develop so this technique is not suitable for high-aesthetic surfaces. Because no direct heating of the work piece is required, this technique is suitable for applying coatings to most substrates. Metal, wood, rubber, and masonry can be coated successfully using this technique. This technology is also suitable for coating large or permanently fixed objects.

Powder coatings fall into two basic categories—thermoplastic and thermosetting. The choice of powders is dependent on the end-use application and desired properties. Generally, thermoplastic powders are more suitable for thicker coatings, providing increased chemical resistance and durability, while thermosetting powders are often used when comparatively thin coatings are desired such as decorative coatings. The principal resins that are used in thermoplastic powders are polyethylene, polyvinyl, nylon and fluoropolymer. Thermosetting powders use primarily epoxy, polyester, and acrylic resins.

ESOH Need

Coatings application systems

Powder coating virtually eliminates waste streams that are associated with conventional painting techniques. These waste streams include air emissions, waste streams that are generated from air emission control equipment, and spent cleaning solvents. Powder coating also greatly reduces employee exposure and liabilities that are associated with liquid coating (wet solvent) use. In addition, cleanup times are shorter because overspray can be readily filtered, classified, and reclaimed onsite, regardless of the complexity of the system.

Care must be taken to not mix powders. Colored powders, unlike liquid coatings, will not blend together. Mixing produces discrete colored dots in the final film. Different powder coating resins melt at different rates during curing and will produce “fisheyes” and/or voids in the coating film. In all cases, the dry powder is separated from the air stream by various vacuum and filtering methods and returned to a feed hopper for reuse. Powder coating total material efficiency (powder particles reaching the intended surface) of these systems can reach 95% with reclamation. Other advantages over conventional spray painting include greater durability, improved corrosion resistance, and elimination of drips, runs, and bubbles.

Powder coatings are somewhat limited in their application to aerospace equipment. They typically are not used with primer systems that inhibit corrosion, but they can be successfully applied over many primed and pretreated metal substrates. If primers or pretreatments are not used, the powder coating provides protection as a barrier and prevents corrosion as long as it is intact and undamaged. The temperatures that are required to cure the coating are too high for many materials that are used in aerospace structures (primarily aluminum). However, recently developed formulations allow curing at as low as 250°F, which enables the use of powder coating on most materials. Powder coating can be implemented in high-production facilities with highly automated application systems or on low-volume, manually applied, batch-cured applications.

Specifications

The following table contains the specifications and parameters of the NDCEE Organic Finishing Powder Coating Line.

Organic Finishing Powder Coating Line Specifications and Operating Parameters

Specification	Parameter
Part Size	Up to 2' x 6' x 4'
Batch Size	Small (6 lbs. of powder) to Medium (50 lbs.) to Large (500 lbs.)
Conveyor Speed	Variable, 2–12'/min
Cure Temperature	Variable, up to 450°F
Cure Time	Variable, no limit

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Organic Finishing Powder Coating Line.

Original Purchase Cost and Current Equipment Value of the Organic Finishing Powder Coating Line

Purchase Cost	Current Value	Years of Service
\$2,180,000	\$363,333	10

Technology Benefits and Advantages

- No solvent usage; consequent elimination of hazardous air emissions associated with paint applications that use solvents containing HAPs and VOCs.
- Significantly reduced coating cure time in comparison to other paint methods (up to 85%)
- Improved safety and health working conditions
- Material user efficiencies approach 95% because overspray can be captured, filtered, and recycled
- Reduced energy requirements by recirculation of powder coating spray booth air
- Superior finish, greater durability, improved corrosion resistance, and elimination of drips, runs, and bubbles
- Significant cost savings in labor, materials, handling, and disposal of waste
- Effectively employed in the commercial industry for 30 years and is a mature application technology
- New powder coating formulation developments include:
 - Combined IR/ultraviolet (UV) curing powders that can reduce overall curing time by 50% or better
 - Close-coupled IR curing powders that can keep substrate temperatures below 180°F due to the short cure cycle of the process (5–20 seconds)

Technology Limitations and Disadvantages

- Powder booth ventilation must be maintained to eliminate explosion hazards (accumulation of suspended particulate). Powder and air mixtures can be a fire hazard when an ignition source is introduced.
- System configurations are partially application specific, but not severely limited.
- Depending on the system, some application limitations may apply such as intricate shapes and assembled components.
- Elimination of coating carrier solvents requires high-quality cleaning and pretreatment processing of parts.

Recommended Upgrades for Continued DoD Support

Since the organic finishing powder coating line was engineered and built for the NDCEE Demonstration Facility, several improvements have taken place in powder coating technology. These improvements both enhance the application control of the different coating materials and open the processing window for coating a wide variety of materials.

Recommendations for purchases to upgrade the coating line operations include the following items: higher-performance electrostatic applicators with voltage feedback control for more complex part coating; digital air logic and electrostatic control systems for improvement in automated powder application process engineering; UV curing lamp system for high-speed coating and select sensitive substrate coating applications such as magnesium castings and composite structures; and NIR curing tunnel system for sensitive substrate coating applications such as aluminum/plastic/fiberglass composite structures, lightweight magnesium castings, and maintenance/spot repair process development.

Representative NDCEE Tasks

Unitized Coating Application Facility, Electrocoat and Powder Coat (Tasks N.002, N.006, and N.046)

- Evaluated potential substitutes to coating systems containing VOCs and HAPs
- Demonstrated technologies to meet performance and production requirements

Evaluation of Powder Coating Technology for Small Arms Bullet Tip Identification (Tasks N.110 and N.212)

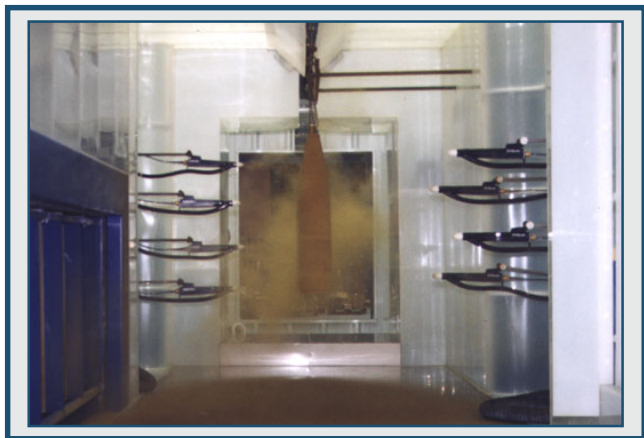
- Evaluated powder coating technologies for reduction in toxic emissions and VOCs, production cost reductions/benefits and increased transfer efficiency

Demonstration/Validation of Powder Coating for Hazardous Waste Minimization from Painting Processes at Rock Island Arsenal (Task N.130)

- Demonstrated powder coatings for elimination of VOCs, ODSs, and HAPs from coating process; increased production rates; decreased waste streams; and improved coatings performance

Sustainable Green Manufacturing (Tasks N.213 and N.301, Subtask R3-8)

- Qualified and validated powder coating as an alternative to solvent-based primer/topcoat used on internal components that were processed at Rock Island Arsenal
- Developed a powder coating specification for Tobyhanna Army Depot based upon facility's needs, available space, and support of new maintenance activities and processes.



Organic Finishing Powder Coating Line

Potential Technology Transfer Applications

Powder coating has many potential avenues for use within the DoD. The potential for coating materials cost reduction, volatile solvent emissions elimination, no HAPs formulations, and reduced overall processing time and labor should provide sufficient incentive for use of these coatings. Use could include all small maintenance part-coating activities and smaller coating facilities.

Outsourcing of initial powder coating activities could provide immediate benefits, which include minimizing facilities capital expenditure and site VOCs, qualifying mil-spec powder coatings, and utilizing higher durability coatings while coating materials are integrated into military acquisition and maintenance systems.

Power Washer

Overview

The power washer is a closed-loop, high-pressure spray system that is used to clean and degrease parts that have a relatively simple geometry. A basket can be loaded with parts and lifted onto a rotating turntable by using a jib crane. An aqueous solution is pumped from a reservoir and spray-blasted via a rotating manifold of nozzles onto the parts. A fresh water or deionized rinse removes the solution from the parts before they are hot-air dried. The system also has a bath maintenance feature that uses a process in which suspended contaminants from the solution are removed via centrifugal action. An oil skimmer removes surface oils from the solution before it is recycled to the main reservoir. The solution then passes through another oil skimmer and filter located on the main reservoir. These bath maintenance features help to extend the life of the cleaning solution in the reservoir.

Specifications

The following table contains the specifications and parameters for the NDCEE Power Washer.

Power Washer Specifications and Operating Parameters

Specification	Parameter
Maximum Part Size	3' x 4' x 4'
Maximum Part Weight	5,000 lbs.
Temperature	80–190°F
Variable Flowrate	Up to 350 gpm
Variable Pressure	20–200 psi

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Power Washer.

Original Purchase Cost and Current Value for the Power Washer

Purchase Cost	Current Value	Years of Service
\$150,000	\$25,000	10

Technology Benefits and Advantages

- Contains a programmable logistics controller that can be programmed for a variety of times and temperatures for each stage of cleaning
- Performs heavy-duty degreasing of many types of components
- Reduces EHS issues associated with solvent cleaning
- Replaces hazardous solvents with an environmentally friendly aqueous cleaner
- Saves costs in labor, materials, handling, and disposal of hazardous waste
- Recycles wash and rinse solutions after filtration, which reduces the wastestream quantity generated

Technology Limitations and Disadvantages

- The part geometries should be simple or medium in complexity for this system to provide the optimum cleaning (no small pin holes).
- The aqueous-based chemistry is not ideal for parts that are prone to rusting.

Recommended Upgrades for Continued DoD Support

The NDCEE maintains its power washer in operational condition. Therefore, no upgrades to the system are recommended.

Representative NDCEE Task

Nonhalogenated Systems for Cleaning Metal Parts (N.007)

- Identified, tested, and evaluated the most environmentally compliant, technically and economically feasible nonhalogenated metal parts cleaning system for the widest range of DoD applications

Potential Technology Transfer Applications

This technology could be used in a wide variety of cleaning and degreasing applications. This system is also transferable to those applications in which testing recycle and recovery equipment on aqueous cleaning solutions is involved.

ESOH Need

Cleaning techniques



Power Washer - Rear View



Power Washer - Front View

Reverse Osmosis Units

Overview

Reverse osmosis has numerous functions in industry. It can be used for desalination of waters, boiler feed purification, dye purification, and coolant recovery. Reverse osmosis is also used to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in waste streams before discharge. Other uses include recovery of some types of plating chemicals, heavy metals, and organics from aqueous solutions and rinse waters.

Reverse osmosis is a high-pressure technology that separates ionic species. The process fluid is forced across a semipermeable membrane (sized from 1–20 Angstroms), where the composition and permeability of the membrane is dependent on the application. Membrane-permeable materials pass through to be collected in a water stream. Metals or chemicals can be recovered from the water stream, or the water stream can be concentrated and discarded as waste, as in process fluid purification applications.

The NDCEE Demonstration Facility has both a full-scale and a bench-scale reverse osmosis unit.

Specifications

The following table contains the specifications and parameters for the NDCEE Reverse Osmosis Units.

Reverse Osmosis Units Specifications and Operating Parameters

Specification	Parameter
Flow Rate	Full-scale unit - 5 gpm Bench-scale unit - 0.5 gpm
Operating Pressure	250–1000 psi
Membrane Material	Polyamide and other thin film composites
Material of Construction	316 stainless steel

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Reverse Osmosis Units.

Original Purchase Cost and Current Value for the Reverse Osmosis Units

Purchase Cost	Current Value	Years of Service
\$250,000	\$62,500	9

Technology Benefits and Advantages

- Helps to meet compliance with strict discharge regulations
- Reduces chemical costs and waste volume by purifying and recycling contaminated water
- Improves water quality
- Lowers operating costs for waste treatment and capital costs for chemicals
- Reduces hazardous waste

Technology Limitations and Disadvantages

- High-pressure system that is relatively labor-intensive

Recommended Upgrades for Continued DoD Support

The full-scale and bench-scale reverse osmosis units are maintained in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the units are recommended.

Representative NDCEE Task

Office of Industrial Technology Program Coordination (Task N.133)

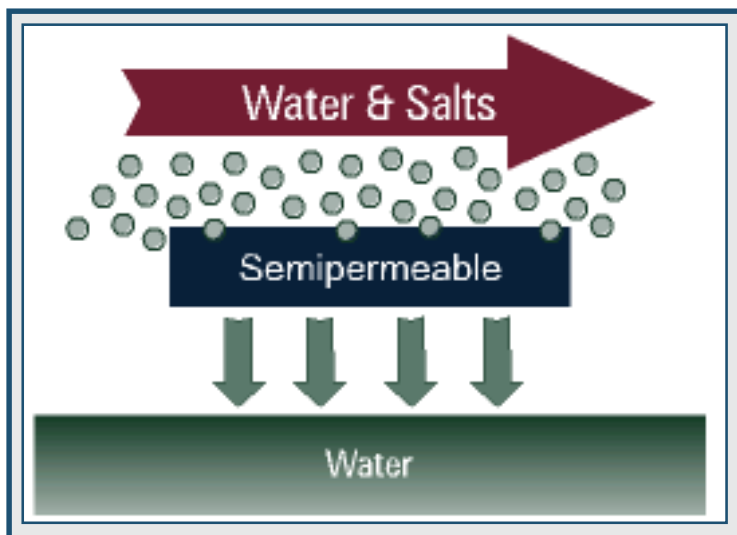
- Removed sodium chloride from rinse waters for reuse of rinse waters

Potential Technology Transfer Applications

This technology could be used to recover plating chemicals, metals, and organics from aqueous, spent bath solutions, and rinse waters. This technology can also be used in those applications that involve boiler feed purification and blowdown reclamation, dye purification, coolant recovery, and reduction of BOD and COD in waste streams.

ESOH Need

Effluent discharge
treatment



Reverse Osmosis Process

Solid Media Blast Station

Overview

The NDCEE Solid Media Blast Station consists of two standard industrial blast cabinets. The station is used for coatings removal and surface preparation applications. In both instances, solid media, such as steel, alumina, and other grit and shot, are propelled by air against either a coating to be removed or the substrate.

Both blast cabinets are manufactured by Empire Abrasive Equipment Company. Each cabinet is equipped with interior nozzles of various sizes. A Torritt Model air filter serves both blast cabinets.

The larger unit is a Model 7272, which can accommodate parts as large as 58 inches x 64 inches x 62 inches and weighing 1,000 lbs. The reclaimer is rated at 1200 CFM @ 10" standoff position (S.P.) Normally this cabinet is used to process parts requiring more aggressive processing. Alumina and steel grit are the most commonly used media types.

The smaller unit that is used for less aggressive blasting is a Model 2636. Parts as large as 22 inches x 20 inches x 30 inches can be mounted in this cabinet. The reclaimer is rated at 400 CFM @ 6" S.P. Small, soft metal parts requiring glass bead media are usually processed in this unit.

Specifications

The following table contains the specifications and parameters for the NDCEE Solid Media Blast Station.

Solid Media Blast Station Specifications and Operating Parameters

Specification	Parameter
Maximum Part Size (Model 7272)	58" x 64" x 62"
Maximum Part Size (Model 2636)	22" x 20" x 30"
Reclaimer Rate (Model 7272)	1200 CFM @ 10" S.P.
Reclaimer Rate (Model 2636)	400 CFM @ 6" S.P.
Blast Pressure	20–90 psi
Media Mesh Sizes (according to ASTM E11)	8–440

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Solid Media Blast Station.

Original Purchase Cost and Current Value of the Solid Media Blast Station

Purchase Cost	Current Value	Years of Service
\$30,041	\$5,007	10 (for each piece)

Technology Benefits and Advantages

- Improves depainting efficiency; removal can be accomplished in a fraction of the time that is associated with manual depainting
- Eliminates use of toxic chemicals
- Meets stringent air pollution requirements
- Is more cost-effective than sandpaper because of recyclable blast media
- Simplifies work process resulting in decreased labor costs due to work being able to be completed by lower-level personnel
- Removes dust to the outside via ventilation system filters

Technology Limitations and Disadvantages

- Regulatory permits may be needed.
- Appropriate solid media is needed for the process.
- Waste disposal includes both the coatings removed and spent media.

Recommended Upgrades for Continued DoD Support

The NDCEE maintains its blast station in operational condition, or in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the equipment are recommended at this time.

Representative NDCEE Tasks

Sustainable Green Manufacturing (Tasks N.213 and N.301)

- Prepared surfaces prior to ion vapor deposition of coatings

Materials and Processes Partnership for Pollution Prevention (Task N.227)

- Prepared surfaces prior to ion vapor deposition of coatings

Corrosion Measurement and Control (Tasks N.255 and N.304)

- Prepared surfaces prior to ion vapor deposition of coatings

Potential Technology Transfer Applications

This technology could be applied in coatings removal applications.

ESOH Need

Coatings removal techniques



Solid Media Blast Station

Ultrahigh-Pressure Waterjet

Overview

Waterjets are used for precision industrial applications such as cutting, cleaning, degreasing, debonding, decoating, and depainting. The NDCEE Demonstration Facility contains an ultrahigh-pressure waterjet (UHPWJ) that uses a low-volume stream of pure water at operating pressures between 25,000–55,000 psi. A 6-axis, Fanuc high-precision, industrial pedestal robot manipulates the stream against the parts, which are secured on a turntable. Various rotating blast nozzles, specifically designed to provide the correct energy pattern, are used for coatings removal or other applications. Water is supplied to the nozzle assembly by an ultrahigh-pressure, dual-intensifier pump.

An operator controls the robot, pump, and turntable with a user-friendly, menu-driven computer workstation. A teach pendant is used to program the robot's motion. To minimize downtime, the parts turntable is equipped with quick-change toggle clamps to rapidly position and secure work pieces.

The NDCEE waterjet operates as a closed-loop system that eliminates water discharge, reduces water consumption, and concentrates waste for less costly disposal. A pump directs the resulting water/coating mixture to a centrifugal separator that removes most of the particulate matter. The water then passes through a series of filters and tanks for further purification before reuse. The system requires only a small amount of make-up water to compensate for evaporative losses, but both recycled and make-up water must be of sufficient purity so as not to introduce sediments or other impurities that may interfere with the proper functioning of equipment.

Specifications

The following table contains the specifications and parameters of the NDCEE UHPWJ.

UHPWJ Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	75°F, (12°C)
Operation Pressure	25,000–55,000 psi
Flow Rate	<2 gpm
Maximum Part Size	6' x 6' x 6'
Maximum Part Weight	1,000 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE UHPWJ.

Original Purchase Cost and Current Value of the UHPWJ

Purchase Cost	Current Value	Years of Service
\$1,200,000	\$200,000	10

Technology Benefits and Advantages

- Hazardous waste is reduced by 90%.
- Individual coating layers may be selectively removed with adjustments.
- Prewashing and masking are not needed in most applications.
- A process water reclamation unit captures removed coatings and returns water to the appropriate cleanliness levels for further blasting.
- Process material costs are reduced significantly.
- Labor hours are reduced by 50% for coatings removal process.
- No dust or airborne contaminants are generated.
- Specific additives will control flash rusting and give long-term protection.

Technology Limitations and Disadvantages

- Capital costs are high (i.e., greater than \$1 million).
- Operator training is required.
- Water can penetrate and/or damage joints, seals, and bonded areas.
- Stripping rate varies with the type of paint, coating condition, and coating thickness.
- This technique is not appropriate for composite or honeycomb thin-skinned materials.
- The medium-pressure water stripping process works well as a supplement to chemical paint stripping, but is not recommended as a stand-alone paint removal process for complete aircraft stripping. It has many successful applications as a part/component stripping process. Medium-pressure water without abrasive additives, such as sodium bicarbonate, will not always remove paint completely.
- The characteristics of the coatings to be removed may impact personal protection and waste collection/disposal considerations.

Recommended Upgrades for Continued DoD Support

The NDCEE UHPWJ cell currently meets or exceeds industry standards. The equipment is maintained in operational condition, or in a state from which operation can be restored in less than eight hours. Currently, no upgrades to the UHPWJ cell are recommended.

DoD Need

Cleaning and
coatings removal
techniques

Representative NDCEE Tasks

Automated Ultrahigh-Pressure Waterjet System Workcell (Task N.020)

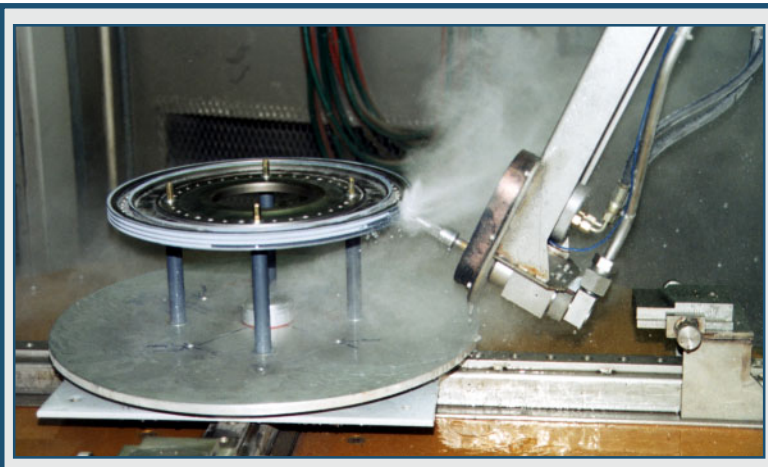
- Removed flame spray coatings from jet engine components
- Removed paint from aircraft fuselage
- Removed metallic flame spray coatings from helicopter engine components
- Conducted software and hardware training for operators and maintenance personnel

New Attack Submarine Support (Task N.087)

- Evaluated, tested, and demonstrated alternative acid etching process of soft tiles

Stripping Methods for Soft Material Tiles on Submarines and Surface Ships (Task N.122)

- Removed soft materials from submarines and surface ships
- Developed vacuum recovery capability



UHPWJ robot removing flame spray coating.

Potential Technology Transfer Applications

The UHPWJ process equipment would be a candidate technology to be transitioned/implemented at any DoD facility that is currently removing coatings from small- to medium-sized components. Additional applications include rubber tire removal from roadwheels, sonar dome cutting, and flame spray removal.



UHPWJ with robotic arm and turntable

Vacuum Evaporator

Overview

Vacuum evaporation is a separation process that is typically used to recover plating chemicals from rinse water or to concentrate wastes from wastewaters. The concentrated wastes may then be either discarded or recovered.

Vacuum evaporation is based on the simple principle that water vaporizes at 212°F (100°C), leaving dissolved salts and metals. Unfortunately, some chemicals degrade at this temperature. In a vacuum, however, water boils at lower temperatures, so water and chemicals can be separated without degradation of the chemicals. Both the water and the chemicals can then be reused.

Specifications

The following table contains the specifications and parameters for the Vacuum Evaporator located in the NDCEE Demonstration Facility.

Vacuum Evaporator Specifications and Operating Parameters

Specification	Parameter
Flow Rate	2 gph water
Material of Construction	316SS

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Vacuum Evaporator.

Original Purchase Cost and Current Value for the Vacuum Evaporator

Purchase Cost	Current Value	Years of Service
\$13,700	\$3,425	9

Technology Benefits and Advantages

- Reduces aqueous waste
- Reduces hazardous waste
- Reduces the cost of hazardous waste disposal
- Reduces the cost of drums for hazardous waste disposal
- Can operate unattended

Technology Limitations and Disadvantages

- Technology requires a utility hookup for electricity and may require utility hookups for gas and cooling water.
- Technology may require an air permit for a gas burner (new source) and for evaporation to atmosphere.
- Units require operator training.
- Units must be installed in areas with fire suppression systems.

Recommended Upgrades for Continued DoD Support

The NDCEE evaporator currently meets or exceeds industry standards, and is maintained in operational condition. Currently, no upgrades to the system are recommended.

Representative NDCEE Tasks

The vacuum evaporator has been used to process wastewater from the closed-loop plating line, which was operating under the following tasks:

Alloy Plating to Replace Cadmium on High-Strength Steels (Task N.000-02, Subtask 7)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Environmental Metal Plating Alternatives - Electroless Nickel Plating Rejuvenation (Task N.089)

- Evaluated technologies that are capable of reducing the amount of waste generated by electroless nickel plating processes

Evaluation of Noncyanide Silver Plating (Task N.104)

- Evaluated commercially available noncyanide alternatives to silver plating processes

Materials and Process Partnership for Pollution Prevention/Pollution Prevention Initiative (Task N.227)

- Evaluated commercially available noncyanide alternatives to copper and silver plating processes

Sustainable Green Manufacturing (Task N.301, Subtask R4-1)

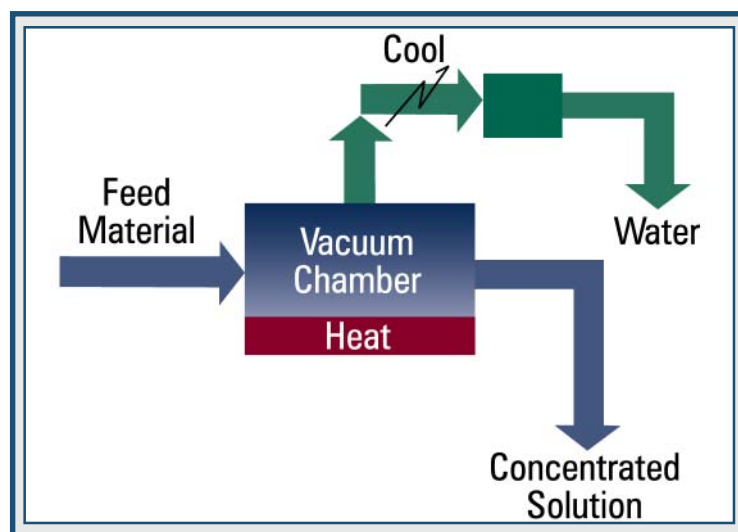
- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Potential Technology Transfer Applications

This technology can be used in applications in which a need exists to recover plating chemicals from rinse waters or concentrate wastes from wastewaters.

ESOH Need

Effluent discharge treatment



Vacuum Evaporator Diagram

Xenon Flashlamp/CO₂ Blasting (FLASHJET®)

Overview

The FLASHJET® system is a pulsed-optical energy decoating process. It uses a combination of high-intensity infrared energy that is generated by a high-intensity pulsed xenon flashlamp and abrasion from a blast medium of carbon dioxide pellets. The paint is in effect charred, and the residual particles are vacuumed and placed in a storage container.

Traditionally, coatings removal activities are performed using chemical or dry abrasive techniques. Due to the use of toxic solvents, the generation of large amounts of solid waste, and the environmental, health and safety concerns that are associated with these conventional processes, alternative coatings removal processes are being investigated. One such alternative is the FLASHJET® system.

The FLASHJET® process is an automated process that uses a manipulator robotic assembly to strip coatings from large and small components. The stripper head contains a xenon flashlamp that produces pulsed light energy to break the molecular bonds of the coating. A thin layer of the coating is essentially burned or pyrolyzed. Simultaneously, as the coating is being broken up and the pyrolyzing process is occurring, a dry ice pellet stream is sweeping away the residue while also cooling and cleaning the surface. The removed paint is vacuumed away by an effluent capture system, which consists of high efficiency particulate air (HEPA) filters and activated charcoal. The effluent capture system separates the ash from the organic vapors by removing the ash through the filters, and the organic vapor through the activated charcoal. The only wastes that are produced by this process are spent HEPA filters, which are tested for hazardous waste (dependent on the coating removed) and disposed of accordingly.

The system has a stripping rate of approximately 75 square feet per hour, depending on the reflectivity of the paint. Glossy and light-colored paints cause the pulsed light to bounce off of the surface, significantly lowering the stripping rate to inefficient levels. Conversely, dark-colored paints achieve a higher stripping rate per square foot.

Specifications

The following table contains the specifications and parameters for the NDCEE FLASHJET®.

FLASHJET® Specifications and Operating Parameters

Specification	Parameter
Part Size	Approximately 5' x 6' x 6'
Stripping Head	6" Xenon Flashlamp
Power Supply	2000 volts
CO ₂ Pelletizer Flow Rate	300–600 lbs./hr
Effluent Capture System Series	HEPA filter —> large fan —> carbon filter —> disposal

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE FLASHJET®.

Original Purchase Cost and Current Value of the FLASHJET®

Purchase Cost	Current Value	Years of Service
Donated to the NDCEE by the Air Force	Not Applicable	7

Technology Benefits and Advantages

- Does not release hazardous or toxic emissions
- Removes paint from surfaces faster than conventional chemical or mechanical means
- Generates minimal annual waste

Technology Limitations and Disadvantages

- Large capital cost investment
- Large work head

Recommended Upgrades for Continued DoD Support

The FLASHJET® unit that is currently housed at the NDCEE Demonstration Facility does not meet industry standards. Upgrades to meet current industry standards include:

- Upgraded control system including computer and interface hardware
- Upgraded flash tube capability
- Upgraded environmental system.

Based on a similar upgrade proposal, the estimated costs for the upgrades are approximately \$200,000.

Representative NDCEE Tasks

Stripping Methods for Hull Treatments (SHT) Tiles (N.122)

- Conducted demonstration and validation activities on special hull treatment tiles

Tri-Service Demonstration and Validation of the Pulsed-Optical Energy Decoating FLASHJET® Process for Military Applications (Tasks N.126 and N.226)

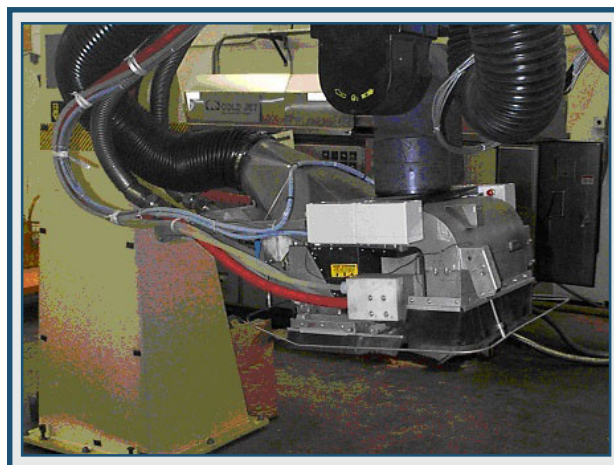
- Conducted demonstration and validation activities on CH-53 off-aircraft components
- Completed a cost analysis using the ECAMSM tool in which FLASHJET® was compared to hand sanding (baseline) for use on Apache and the Blackhawk helicopter rotor blades at Corpus Christi Army Depot

Potential Technology Transfer Applications

Transfer sites include facilities in all branches of the DoD that are currently utilizing abrasive and chemical methods to remove coatings from large surfaces with minimal curvature.

ESOH Need

Coatings removal techniques



FLASHJET® System