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WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Survey of Air and Water Quality Pollution Prevention and Control Technology Used in Shipyards and Similar Industries

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
National Steel and Shipbuilding Company
San Diego, California

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Survey of Air and Water Quality Pollution Prevention and Control Technology Used in Shipyards and Similar Industries

August 1997

Prepared and submitted by:

Applied Research Laboratory
The Pennsylvania State University
State College, Pennsylvania

Task No. 1-96-4, Subtask 14

Forward

The Survey of Air and Water Quality Pollution Prevention and Control Technology used in Shipyards and Similar Industries was produced for the National Shipbuilding and Research Program (NSRP) by the Applied Research Laboratory at The Pennsylvania State University. This project was managed by Janice Schneider with Meryl Mallery acting as principal investigator and author.

Abstract

The objective of this project was to perform a survey of U.S. shipyards and similar industries to determine what technologies are currently being implemented or planned to prevent or reduce air emissions and wastewater discharges from facility operations. The next objective was to develop a guide that shipyard environmental managers could use to perform a preliminary evaluation of technologies that may have application in their facilities.

This document covers pollution prevention and control technologies for surface preparation, surface coating, cleaning operations, welding, and wastewater treatment. The information included in this report is summarized below:

- summaries of pollution prevention and control technologies which include advantages, disadvantages, pollution prevention benefits, contact points, vendor information, and locations to obtain more technical information including case studies for industrial application and economic evaluations comparing the technology to less environmentally friendly alternatives,
- locations to order or download (from the Internet) technical papers and summaries on pollution prevention technologies, on-going technology projects, and regulations,
- results of the shipyard surveys which include an overview of the technologies that are currently being implemented in shipyard operations and recommendations for technologies currently being implemented.

The information provided for each technology is based on the author's interpretation of available literature and vendor information. This document does not intend to recommend one technology over another for a given application, but instead to provide a basis for comparable evaluations of technologies. It is left to the shipyard environmental manager to evaluate the available pollution prevention and/or pollution control technologies and determine which technologies best meets their needs.

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1. Introduction

This report focuses on the areas of the shipyard that provide the biggest pollution prevention opportunities, namely surface preparation, surface coating, and cleaning operations. Some information is also provided on welding processes and treatment of wastewater from hydroblasting operations, bilge cleaning, and storm water. These areas are quite broad and cover numerous technologies. The goal in the information presented is to provide a basis to obtain more information and to provide a summary of what technologies are currently being implemented in shipyards. This report is analogous to a tree with branches leading in the directions where more information can be found. There are numerous reports available, summarizing and comparing various "clean technologies", which have potential application in the shipyard environment. Department of Defense (DoD), Environmental Protection Agency (EPA), and National Aeronautics and Space Administration (NASA) databases were searched to obtain information for this report. A great deal of work for this project was performed via the Internet which is rapidly becoming an effective tool for finding information.

This document is not meant to be an exhaustive list of all the technologies available. Instead a summary is provided for the technologies identified and places to search for technical reports and on-going research projects. One technology is also not recommended over another but the report provides comparable summaries and information on vendors and research points of contact. References are provided so that economic evaluations and costs for each technology can be obtained. It is hoped that this document provides a useful tool for discovering technologies that may be beneficial in the shipyard building and repair environment. Good luck and happy hunting.

2. Sources of Information

This chapter summarizes the locations searched for pollution prevention and control information related to U.S. shipyards. The sections are broken down into locations to get technical publications related to pollution prevention, research programs and facilities doing pollution research and locations to get vendor information on available pollution prevention technologies. Several locations identified are through the Internet; however, where possible phone numbers and addresses are provided as contact information. Overlap occurs between some sections of this chapter since, for example, some locations provide both vendor information and technology summaries. Many locations may provide more detailed references as well as point to other sources for information.

2.1 Publications Related to Pollution Prevention and Control

National Center for Environmental Publications and Information (NCEPI)

Internet Address: http://www.epa.gov/ncepihom/index.html
Phone Number: (800) 490-9198

The NCEPI is a central repository for all EPA documents available for distribution. You can browse and search the National Publications Catalog and order EPA documents on-line at the Internet address provided above. Alternately, the publications can be ordered by phone at the number provided above if you know the title or EPA identification number.

National Technical Information Service (NTIS)

Internet Address:	*http://www.fedworld.gov/ntis/ntishome.html*
Street Address:	*Department of Commerce* *National Technical Information Center* *5285 Port Royal Road* *Springfield, VA 22161*
Phone number:	*(800) 553-NTIS*
Fax Number:	*(703) 321-8547*

NTIS is the nation's clearinghouse for research and development results and other information produced by the U.S. government. It contains publications related to over 375 technical areas including topics related to the environment. More than 200 U.S. government agencies contribute to the NTIS collection, including: NASA; EPA; National Institute for Standards and Technology (NIST); National Institutes of Health (NIH); and the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, Labor, and Transportation. You can search the NTIS database on the Internet or if you know the document title or number you can call or fax NTIS at the phone numbers provided above to purchase the document of interest.

If you are interested in keeping abreast of the latest information being published by NTIS you can receive monthly updates of published material in a

given area of interest (for example: Environmental Pollution and Control) for approximately $175.00 per year.

National Shipbuilding Research and Documentation Center

Internet Address: *http://www.umich.edu/~umtrimsd/docctr/docctr.htm*
Street Address: *NSRP Coordinator*
University of Michigan Transportation Research
Institute Marine Systems Division
2901 Baxter Road
Ann Arbor, MI 48109-2150
Phone Number: *(313) 763-2465*
Fax Number: *(313) 936-1081*

The National Shipbuilding Research and Documentation Center at the University of Michigan Transportation Research Institute provides access to a variety of technical and non-technical shipbuilding information. It contains reports produced by The National Shipbuilding Research Program (NSRP), SNAME (Society of Naval Architects and Marine Engineers) Ship Production Symposium papers, REAPS and IREAPS technical meeting papers, autovisual materials and NSRP statistics. You can order documents from the NSRP Coordinator at the phone number given above or you can browse the Documentation Center on the Internet at the Internet Address provided and download the documents that are available.

Joint Services Pollution Prevention Technical Library

Internet Address: *http://enviro.nfesc.navy.mil/p2library*
Contact: *Charles Sokol*
NFESC, Code 423
1100 23rd Ave.
Port Hueneme, CA 93043-4370
Phone Number: *(805) 982-5318*

The Joint Service Pollution Prevention Technical Library has a wealth of information pertaining to pollution prevention (P2) technologies. It is maintained by the Naval Facilities Engineering Service Center (NFESC) and consists of three sections. The most informative section is **The Joint Service P2 Opportunity Handbook**. This handbook identifies available off-the-shelf pollution prevention technologies, management practices, and process changes that will reduce the amount of hazardous waste and solid waste being generated at industrial facilities. Pollution prevention measures are described for several areas including electroplating and metal finishing, hazardous materials and hazardous waste management, ozone depleting substance replacements, painting, depainting, petroleum, oils and lubricants, solid waste management, solvent alternatives, wastewater, storm water, and preproduction technologies. Each technology is summarized, including advantages and disadvantages, and an economic analysis of the technology is compared to its replacement. Some vendor information is also provided. A sample technology review is provided in Appendix C. The library can

be accessed via the Internet Address provided above or if you work for the DoD or are a DoD contractor you can obtain a hardcopy through the contact above.

EPA Office of Research and Development (ORD) Project Summaries

Internet Address: http://www.epa.gov/ORD/WebPubs/projsum

This listing contains a number of project summaries and environmental research briefs produced by the EPA Office of Research and Development (ORD). These publications are generally 2-10 pages in length and are short synopses of key findings from larger ORD project reports that present the results of recently completed research, development, and engineering work. These summaries convey the essence of a project in terms the technical community at large can understand. The full reports are available for purchase from the National Technical Information Service. At the date of this report project summaries were provided for the period of April 1996 to February 1997.

National Risk Management Research Laboratory (NRMRL) Clean Processes and Products Branch Project Descriptions

Internet Address: http://www.epa.gov/ORD/NRMRL

The Clean Processes and Projects Branch of the NRMRL develops and demonstrates pollution prevention, recycling, and remediation technologies within the following four areas: (1) metal finishing and electronics pollution prevention, (2) green engineering for chemical synthesis, (3) solvent and coatings, and (4) separations and removal and recycling. This Internet site provides a summary of NRMRL Clean Processes and Products Branch projects as of May 1996 and provides contact points. The NRMRL is the principal entity within ORD responsible for environmental risk management research related to characterization of pollutant generation and release; protection of the environment from pollution originating from both anthropogenic and natural sources; remediation of contaminated media; protection of public health from indoor pollutants; and worker protection in industrial environments, agricultural pesticide use, and Superfund site cleanup.

PRO-ACT

Internet Address: http://www.afcee.brooks.af.mil/pro_act/main/proact4.htm

This web site is funded by the United States Air Force Center for Environmental Excellence and is provided to promote crossfeed of environmental information. This includes a feature called Cross Talk that is published twice yearly with information on pollution prevention measures at Air Force installations and provides regulatory reviews.

Enviroene

Internet Address: *http://es.inel.gov*

This Internet site is starting point to obtain a wealth of information pertaining to pollution prevention opportunities. It can be used to implement pollution prevention and solvent substitution programs, ensure compliance with environmental laws and regulations, solve enforcement cases and develop research projects. The search engine can search multiple web servers, and offers assistance in preparing a search. It is funded by the EPA and DoD Strategic Environmental Research and Development Program (SERDP). The following web address provides a list of the web locations searched by Enviroene, http://es.inel.gov/cgi-bin/search.pl?alldb=on.

2.2 Vendor Information Related to Pollution Prevention and Control

SNAP Program (Significant New Alternatives Policy)

Internet Address: http://www.epa.gov/ozone/title6/snap/snaplist.html
Street Address: SNAP Coordinator
U.S. EPA 6205J
401 M St. SW
Washington, DC 20460
Phone Number: (202) 233-9152

This web site provides a list of acceptable and unacceptable substitutes for ozone depleting substances (ODS) and also provides a comprehensive but not all inclusive list of vendors supplying substitute solvents and environmentally acceptable metal cleaning processes. Over 500 vendors are listed with a brief description of their products along with contact information. This list is a result of Section 612 of the Clean Air Act Amendments of 1990 that requires the EPA to publish lists of acceptable and unacceptable alternatives to ODS. If you do not have access to the Internet you can obtain this list from the SNAP coordinator at the address and phone number above.

National Metal Finishing Resource Center

Internet Address: *http://www.nmfrc.org/welcome1.htm*

This site was established under a program jointly funded by the Commerce Department's NIST and the EPA. A vendor database, regulatory interpretations database, and much more information specialized to those working in the metal finishing industry is included in this site.

Joint Services Pollution Prevention Technical Library

Internet Address: *http://enviro.nfesc.navy.mil/p2library*
Contact: *Charles Sokol*
NFESC, Code 423
1100 23rd Ave.
Port Hueneme, CA 93043-4370

Phone Number: *(805) 982-5318*

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Steel Structures Painting Council (SSPC)

Internet Address: *http://www.sspc.org*
Street Address: *4400 5th Ave.*
Pittsburgh, PA 15213-2683
Phone Number: *(412) 268-3327*
Fax Number: *(412) 268-7048*

SSPC is a non-profit professional society concerned with the use of coatings to protect industrial steel structures. Its goals are to conduct research, develop standards, and to disseminate this information through a variety of publications, conferences and educational initiatives. As a result of these goals an Internet site was developed to provide a forum for discussions related to surface preparation and painting, extensive links to other coating web sites including coating manufacturers, distributors of paint application equipment, and facilities performing research for the coatings industry. Publications can also be ordered on-line for a moderate cost.

Journal of Protective Coatings and Linings

Street Address: *2100 Wharton St. Suite 310*
Pittsburgh, PA 15203-9908
Phone Number: *(415) 281-2331*

The *Journal of Protective Coatings and Linings* (ISSN 8755-1985) is published monthly by Technology Publishing Company in cooperation with the Steel Structures Painting Council. There is a fee of $55.00 to subscribe to this SSPC Journal. The subscription includes a yearly Buyer's Guide that is dedicated to suppliers of equipment in the paints and coatings industry. You can purchase the Buyer's Guide alone for $10.00. The journal contains articles pertaining to technologies in the paints and coatings industry and has vendor advertisements.

Environmental Protection

Internet Address: *http://www.eponline.com*
Phone Number: *(815) 734-1208*

Environmental Protection is published monthly and provides management and problem-solving articles for environmental professionals. Once a year a Buyer's Guide is published which is useful to obtain vendor information on environmentally related products. *Environmental Protection* also has an Internet site that can be accessed for on-line searches for vendor information. This site provides a forum for discussions on environmental issues and a section on cutting-edge technologies emerging from the nation's laboratories and universities. The Internet site requires that a user sign on to eponline prior to use. This service is free, however.

Pollution Equipment News

Internet Address: *http://www.rimbach.com*
Street Address: *8650 Babcock Boulevard*
Pittsburgh, PA 15237-9915
Fax Number: *(412) 369-9720*

Pollution Equipment News is published monthly and provides information to environmental managers on pollution equipment for air, water, and hazardous waste. It is a free subscription and comes with a yearly Buyer's Guide full of vendors in the pollution equipment industry.

Parts Cleaning

Street Address: *P.O. Box 3021*
Lowell, MA 01853-9994
Fax Number: *(508) 663-9570*

This is a newly published magazine for the industrial metal cleaning industry. It concentrates on the needs of companies for which cleaning means the degreasing and deburring of metal. The publication is produced six times a year and has articles pertinent to the metal cleaning industry as well as vendor advertisements related to metal cleaning.

2.3 Facilities & Government Programs

DoD Facilities and Programs

Environmental Security Technology Certification Program (ESTCP)
Internet Address: http://estcp.xservices.com

This Internet site provides a listing and description of on-going and completed projects performed by ESTCP. ESTCP demonstrates and validates promising, innovative technologies that target the DoD's most urgent environmental needs. The ESTCP has several research target areas including compliance, pollution prevention, and cleanup.

National Center for Environmental Excellence (NDCEE)
Internet Address: http://www.ndcee.ctc.com

The goal of NDCEE is to transition environmentally acceptable materials and processes to defense industrial activities and private industry, to provide training that supports the use of new environmentally acceptable solutions, and to perform applied research and development, where appropriate, to accelerate the adoption of new technologies. The NDCEE has several project areas including cleaning/coatings removal, inorganic and organic coatings, environmental management, recycle/recovery/reuse, special projects, treatment and remediation and technology transition and insertion. Projects within these areas are summarized along with contact information in the NDCEE web site listed above. The NDCEE is operated by Concurrent Technologies Corporation (CTC), an independent nonprofit organization. NDCEE also has a demonstration factory where experiments can be conducted with new technologies and processes in organic and inorganic finishing, cleaning and stripping, and recycling, recovery and reuse.

Strategic Environmental Research and Development Program (SERDP)

Internet address: http://www.hgl.com/serdp/

This is the DoD corporate environmental Research and Development (R&D) program, planned and executed in full partnership with the Department of Energy (DOE) and EPA, with participation by numerous other federal and non federal organizations. This program focuses on cleanup, compliance, conservation and pollution prevention technologies. The SERDP Internet site has an overview of SERDP's activities and a search feature that allows access to SERDP documentation of program activities. The site also provides summaries on research areas and contacts for additional information.

Joint Technology Exchange Group (JTEG) Joint Depot Maintenance Analysis Group

Contact: *Talmon Perkins/Carl Springle*
Street Address: *Building 280, Door 24*
4170 Hebble Creek Road
Wright-Patterson AFB OH 45433-5653
Phone Number: *(937) 656-2759*

This group was chartered in 1984 to facilitate the introduction of new and emerging technology, processes and equipment into the depot maintenance community. The JTEG has established technology groups to facilitate the management and oversight of depot technologies. These generic groups include laser applications, metallic coatings, paint stripping, flexible computer integrated manufacturing, nondestructive inspection and electronics.

Industrial Ecology Center (IEC)

Address: Department of the Army
Armament Research, Development and Engineering Center
Building 172
Picatinny Arsenal, NJ 07806-5000

The Industrial Ecology Center (IEC), located at Picatinny Arsenal, New Jersey manages the Army's Environmental Quality Pollution Prevention Program. This program includes the Environmental Quality Basic Research and Development (EQBRD) Program, the Army's newly initiated Applied Environmental Research and Development Program, and participation as the Army representative on SERDP Pollution Prevention (P2) Technology Thrust Area Working Group (TTAWG). The IEC is also the program management office for the NDCEE and provides life cycle environmental support to the Army's armament mission.

Naval Facilities Engineering Services Center Environmental Protection Laboratory (DoD and Navy)

Technology Transfer Contact:	*Jerry M. Dummer, Technology Director*
Street Address:	*Code L70PM Port Hueneme, CA 93043-4328*
Phone Number:	*(805) 982-1599*
Fax Number:	*(805) 982-1409*
Email Address:	*jdummer@ncel.navy.mil*

This laboratory was developed and equipped for RDT&E in environmental restoration;, oily-waste disposal and oil-spill removal; water decontamination, solid waste refuse-derived fuel analysis; noise and air pollution abatement; pollution prevention; hazardous waste treatability; and land use management at Navy shore facilities and advanced bases, and other pollution control and abatement requirements identified by changing standards. This summary was obtained from the EPA non-EPA laboratory list provided at the following Internet Address: http://www.nttc.edu/env/nonlabs3.html#21.

Naval Surface Warfare Center, Caderock Division Environmental Protection Facility (Agency: DoD and Navy)

Technology Transfer Contact:	*Dick Bloomquist*
Street Address:	*Code 0117 Bethesda, MD 20084-5000*
Phone Number:	*(301) 227-4299*
Fax Number:	*(301) 227-2138*
Email Address:	*bloomqui@oasys.dt.navy.mil*

This facility performs investigations of processes, operations and systems designed to abate shipboard-generated liquid, solid and gaseous discharges (hazardous or toxic waste, plastics, oily and non-oily fluids, sewage, etc.). Capabilities include development and evaluation of pilot-plant size discharge processing, full-scale waste treatment, solid waste disposal and incineration hardware and systems. This summary was obtained from the EPA non-EPA laboratory list provided at the following Internet Address: http://www.nttc.edu/env/nonlabs3.html#21.

NASA Facilities and Programs

NASA Commercial Technology Network Technology Resources

Internet Address: http://nctn.hq.nasa.gov/nctn/resource.html

This web site is a starting point to find information on NASA-sponsored research, technology, scientific/technical expertise and R&D capabilities. This site was searched to find information on innovative technologies potentially applicable to U.S. shipyards.

Other Laboratories and Facilities

Environmental Engineering Laboratory
(Agency: Tennessee Valley Authority (TVA))

Technology Transfer Contact:	*Tina Tomaszewski*
	Environmental Engineer
Street Address:	*Chattanooga Engineering Services*
	1101 Market Street, CC-1A-C
	Chattanooga, TN 37402-2801
Fax Number:	*(615) 751-3717*

The laboratory provides environmental engineering services including wastewater and waste characterization, development and evaluation of innovative treatment technologies through bench-scale and pilot-scale test work, process modification to reduce or eliminate pollutants at the source, and development of methods to assess the impact of pollutants on the environment. Personnel are skilled in evaluating potential recycling options of wastes and by-products; experimentally generating and characterizing sediment or solid waste leachates; designing and developing less-costly, less energy-intensive treatment technologies such as constructed wetlands for sewage treatment and anoxic limestone drains for acid mine drainage; evaluating sediment oxygen demand (SOD); and using all equipment listed below. Facilities include equipment for bench and pilot scale studies of both physical/chemical and biological treatment systems for liquid, solid and hazardous wastes. Physical/chemical treatment capabilities include neutralization, precipitation, coagulation/flocculation, sedimentation, ozonation, ion exchange (batch and column), activated carbon (batch and column), drying and solidification. Biological treatment capabilities include activated sludge, nitrification and denitrification, anaerobic and aerobic digestion, and wetlands. Facilities include a 200-sq ft walk-in controlled temperature chamber, portable wetland units, and other apparatus for field pilot-testing of innovative wastewater treatment technologies. This summary was obtained from the EPA non-EPA laboratory list provided at the following Internet Address:
http://www.nttc.edu/env/nonlabs1.html#1.

Pacific Northwest National Laboratories Environmental Technology Division (PNNL ETD)

Internet Address: http://terrassa.pnl.gov:2080

Pacific Northwest National Laboratory works in all phases of the technology development cycle from Research and Development to industrial implementation. They specialize in technologies that address existing wastes that promote cleaner operations, and are environmentally safe. The laboratory pollution prevention focus is divided into three areas: design and assessment, recovery and recycle, and inherently clean technology. In the recovery and recycle area technologies that are currently being researched and developed include waste acid detoxification and reclamation, supercritical fluids parts cleaning, based catalyst decomposition, thermochemical environmental energy system, 7 rubbercycling, hydrothermal processing, biosludge hydrolysis, and petroleum sludge treatment. The inherently clean technologies being developed include supercritical fluid processing,

membrane reactors, chemicals from alternative feedstocks, and solid acid catalysis. A more in-depth discussion of the technologies listed above is provided in the PNNL ETD Internet site at the address listed above.

EPA Office of Research and Development (ORD)

Internet Address: *http://www.epa.gov/ORD*

The Office of Research and Development (ORD) is the scientific and technological arm of the U.S. EPA. Comprised of three headquarters offices, three national research laboratories and two national centers, ORD is organized around a basic strategy of risk assessment and risk management to remediate environmental and human health problems. ORD focuses on the advancement of basic peer-reviewed scientific research and the implementation of cost-effective, common sense technology. Fundamental to ORD's mission is a partnership with the academic scientific community, through extramural research grants and fellowships to help develop the sound environmental research necessary to ensure effective policy and regulatory decisions. This Internet site provides the activities of ORD including grants, proposals, technical publications, a description of laboratories and more.

The Center for Advanced Ship Repair and Maintenance (CASRM)

Technical Contact: *Larry Mizelle, Technical Director*
Street Address: *222 E. Main Street*
Norfolk, Virginia 23510
Phone Number: *(757) 622-2137*
Fax Number: *(757) 622-2490*
Email Address: *casrm@infi.net*

The Center for Advanced Ship Repair and Maintenance (CASRM) is a partnership between the private ship repair yards of Hampton Roads (STASR), Old Dominion University, The City of Norfolk and Virginia's Center for Innovative Technology. CASRM, Inc. is a not-for-profit Virginia Corporation. The goal of the Center is to make ship repair operations more cost effective, while meeting or exceeding environmental requirements. You can contact Larry Mizelle at the phone number or Email address above to get more information on the Center's activities.

The Applied Research Laboratory at The Pennsylvania State University
The Environmental Technology Group

Technical Contact: *Robert Keay, Group Leader*
Phone Number: *(814) 865-7222*
Email Address: *rek10@psu.edu*

The Environmental and Technology Group addresses both pollution prevention and compliance issues. In the areas of pollution prevention, investigations are currently being performed in materials and process alternatives. Current research projects involve paint removal and application R&D; laser cladding as a replacement for chromium electroplating; laser surface finishing as a replacement for circuit board coatings; supercritical fluid CO_2 as a solvent substitute for cleaning operations and wastewater treatment; and environmentally friendly lubricants for various applications. In the areas of compliance, research is being performed in air/water pollution control using advanced oxidation processes; membrane and biofiltration for shipboard and industrial applications, metals recovery from aqueous waste streams, incinerator/engine emission treatment (NOx); remediation of toxic-laden solid waste streams; energetics disposal research; analytical monitoring and support. The strengths of this group include manufacturing-related pollution prevention; treatment of airborne, waterborne and solid wastes; and sensor and control technology.

3. Shipyard Survey Results

Surveys were mailed to thirty shipyards ranging in size from full shipbuilding facilities to simple repair yards to determine what measures are currently being implemented or planned to reduce air emissions and wastewater discharges. The shipyards were also asked if they would recommend a technology that they are currently implementing. Out of the thirty surveys mailed out, eleven were received with partial or full response to the questions asked and four were conducted over the phone. A copy of the survey is provided in Appendix A.

The survey responses are provided in Tables 3.1 for the control, collection and treatment of air emissions and in Table 3.2 for the control, collection and treatment of wastewater. The general nature of the questionnaire led to responses that varied considerably; however where possible, shipyards were contacted to make the results comparable.

The general operations covered in the shipyard survey were surface preparation, surface coating, cleaning (tanks, vehicles, parts and equipment), metal finishing, composite material operations, welding and boiler operations. The shipyard survey also covered treatment of storm water, sewage and grey water and ship bilge water. Due to the low number of responses received in the areas of metal finishing and composite material operations these sections will not be covered in this report. However, this section will briefly discuss the methods that were recommended by the shipyards responding to the survey, and provide you with Tables 3.3 and 3.4 which break down by process the number of shipyards using a given technology. The responses in these tables are based on positive responses from given shipyards and do not necessarily reflect actual usage rates throughout the shipbuilding and repair industry. Additional shipyards surveyed may also be using this technology, although, they did not mention it in their responses due to the general nature of the survey questions. Where possible shipyards were contacted to clarify this issue.

Surface Preparation

- In the area of surface preparation, ultra-high pressure (UHP) water blasting was recommended by three shipyards. One of the shipyards felt that the process produced cost savings, less manpower requirements, less waste and less containment controls. On the other hand, another shipyard tried the process once and found it produced excessive wastewater and was not cost effective, while the third simply did not recommend it. Yet another shipyard is transitioning to this technology while another is currently evaluating the process. A summary of UHP water blasting is provided in the Technology Data Sheets of Section 4.1.1.3. along with contact information.
- Another surface preparation technology that was recommended was sponge blast media and equipment distributed by Sponge-Jet^{R} (see the Technology Data Sheet provided in 4.1.1.3 for a summary and contact points). The shipyard using this blasting technology is using it for cleaning the inside of tanks and for the preparation of large flat surfaces. The advantages noted in the survey were the reusability of the media and the reduced dust generated compared to more traditional blasting methods.
- Cryogenic Carbon Dioxide (CO_2) Pellet Blasting was also recommended. A shipyard has just introduced this process and is using it for cleaning applications onboard ships. They requested the help of the National Defense Center for Environmental Excellence

(NDCEE) in evaluating this technology in their shipyard. Again, this technology is summarized along with advantages and disadvantages in the Technology Review Sheets in Section 4.1.1.3.

- The last technology recommended is CAPE and is recommended for the containment and collection of fugitive dust emissions during surface preparation operations and for the collection and containment of paint overspray and VOC treatment during painting operations. Please see the Technology Data Sheets in Section 4.1.1.3 for an overview and for contact points for this technology.

Surface Coating

- All shipyards using airless or air-assisted airless paint guns recommended their use in painting operations. Most shipyards appeared to be using low VOC coating technologies; however most did not specify what low VOC coating technologies they were using or recommend a given technology, such as powder, waterborne or high solids, over another for a given application.

Cleaning Operations

- Two shipyards recommend Safety-Kleen solvents and solvent disposal service (see the Vendor Listing in Appendix B for contact information). This product is a non-hazardous cleaner and is being used in parts cleaning applications.
- Another shipyard recommended their use of Hotsy detergent cleaners as a replacement for vapor degreasers. The vendor information is given in Appendix B.
- Yet another shipyard recommends a new Isoprep 132 parts washer which is a petroleum based solvent that replaces chlorinated and fluorinated or aromatic hydrocarbons. This solvent is recyclable. The vendor information is provided in Appendix B.
- Lastly one shipyard using citric terpenes recommends their use as a replacement for CFCs. Terpenes are summarized in a Technology Review Sheet provided in Section 4.3.1.4.

Wastewater Treatment

- The three shipyards surveyed that currently use Dissolved Air Flotation (DAF) units in the treatment of bilge water recommended this method.
- A different shipyard recommended their method of bilge water treatment that uses ultrafiltration. However, this method was not recommended for the treatment of wastewater from vehicle cleaning operations.
- One shipyard highly recommends treating bilge water using their wastewater treatment system obtained from AFL Industries (see Vendor Listing in Appendix B). This system has a 150 GPM capacity and utilizes both physical and chemical treatment of the wastewater. The plant utilizes a vertical tube coalescing separator for physical separation of the oil and water. Oil is recycled via a waste oil reclaimer off site. The water is then treated with ferric sulfate and lime to adjust pH for metals precipitation. A polymer is then added to form a flocculant that is skimmed off the top of the DAF tank. Once treated the water is discharged to the local publicly owned treatment works and sludge is dried in four hanging bags and is sent off site for disposal.
- Two different recommendations were provided for the treatment of ultra-high pressure wastewater. One shipyard recommends the use of precoat filtration while another

recommends micron filtration and then filtration through an ion exchange resin to remove metal contaminants. The last method was said to result in less containment controls, less manpower, cost savings and the production of less waste that is easier to treat and dispose.

Throughout this report you will find many additional technologies that have potential applications in your shipyard environment. Chapter 4 discusses technologies applicable to surface preparation, surface coating, cleaning operations and welding that reduce air emissions. Chapter 5 provides a brief overview of wastewater treatment methods for bilge water, storm water, and hydroblasting wastewater.

Table 3.1 Air Pollution Control and Treatment Methods in Current Use at Shipyards Surveyed

Shipyard	Surface Preparation	Surface Coating	Cleaning Operations	Welding	Boiler Operations
1	1. control and contain emissions from blasting operations using baghouses and filtration	1. high transfer efficient application equipment 2. low VOC coatings 3. shrouding 4. filtration control for particulates 5. thermal oxidation for VOCs	1. aqueous cleaners	1. lower emission welding processes	1. low-NOx burners
2	1. steel grit abrasives 2. black beauty abrasives 3. no shrouding used in drydock 4. pressure wash ship hulls to remove marine growth	1. HVLP spray guns 2. air-assisted airless spray guns 3. low VOC coatings 4. waterborne paints	1. aqueous cleaners 2. no solvent recycling	1. no capture and filtration of weld fumes	
3	1. garnet abrasives 2. CO_2 blast for cleaning some enclosed ship areas 3. Enviroscreen shrouding in drydock 4. pressure wash ship hull to remove marine growth 5. transitioning to ultra-high pressure blasting (UHP)	1. HVLP spray guns 2. high solids coatings	1. Amicoat 65 2. no solvent recycling		
4	1. black beauty abrasives 2. copper slag abrasives 3. use shrink wrap to encapsulate ships 4. dust collection 5. pressure wash ship hulls to remove marine growth	1. encapsulate ships 2. no VOC treatment system	1. no aqueous or semi-aqueous cleaners are used	1. collection and filtration of weld fumes	
5	1. copper slag abrasives 2. shrouding and encapsulation	1. HVLP spray guns 2. low VOC coatings 3. encapsulation	1. cold solvent degreasers 2. remote reservoir cleaners		

Table 3.1 Air Pollution Control and Treatment Methods in Current Use at Shipyards Surveyed (con't)

Shipyard	Surface Preparation	Surface Coating	Cleaning Operations	Welding	Boiler Operations
6	1. black beauty abrasives 2. sponge blasting inside tanks 3. enclose entire graving dock and have dust collection system	1. airless spray guns 2. air-assisted airless spray guns 3. powder coatings used on small parts	1. Hotsy detergent washers used for parts cleaning 2. use Simple Green aqueous cleaner for hand cleaning 3. PF-145 degreasers for cleaning oxygen lines		1. Burning natural gas approx. 90% of heating season
7	1. black beauty abrasives 2. steel shot inside shops 3. use shrouding and screens in drydock without dust collection 4. pressure wash ship hulls to remove marine growth	1. currently evaluating the use of waterborne and powder coatings 2. high solids coatings 3. paint booths with water curtains for paint overspray control	1. use citric terpene in parts washers 2. use steam cleaning for vehicle washing 3. TSP and citric acid for bilge cleaning	1. no capture and filtration of weld fumes	
8	1. black beauty abrasives 2. tarp shrouding with no dust collection	1. air-assisted airless spray guns 2. low VOC paints 3. 90% painting indoors no VOC control	1. MEK solvents 2. flush and recycle solvents	1. collection and filtration of weld fumes	
9	1. CAPE with Torrit 0.5 µm dust collector 2. use & recycle steel and coal slag abrasives	1. airless spray guns 2. CAPE with DURR regenerative thermal oxidizer	1. Varsol in small parts washers (aqueous cleaner) 2. Varsol recycled through distillation		
10	1. ultra-high pressure water blasting		1. aqueous parts washers		1. natural gas

Table 3.1 Air Pollution Control and Treatment Methods in Current Use at Shipyards Surveyed (con't)

Shipyard	Surface Preparation	Surface Coating	Cleaning Operations	Welding	Boiler Operations
11	1. ultra-high pressure water blasting 2. plastic sheets placed under ship in form of small pool to contain UHP water	1. low VOC coatings	1. new parts washer using Isoprep 132 2. new clean room for Navy oxygen cleaner (NOC)	1. no collection or filtration of weld fumes	
12	1. black beauty abrasives 2. garnet abrasives 3. blasting done in total enclosure with dust control	1. painting done in total enclosure	1. use Safety-Kleen products 2. Safety-Kleen disposes of spent solvent 3. have five MEK cold solvent units. Currently researching replacements for these units 4. hot steam and sometimes TSP to clean bilge tanks 5. some usage of Simple Green aqueous cleaner in bilges and small applications	1. ventilation with some filtration "Smoke Hogs"	1. Bid out to switch to natural gas
13	1. blast containment structures	1. two paint booths with filters			N/A
14	1. tarp shrouding 2. ultra-high pressure water blasting	1. some use of low VOC coatings 2. no VOC control in paint booths	1. recycle solvents using batch distillations	1. no collection or filtration of weld fumes	
15	1. tarp shrouding in drydock (EnviroTarp) 2. dust collectors used to collect small particulate		1. Safety-Kleen Solvent- 2. solvent recycling		

N/A = "Not Applicable"

Table 3.2 Water Pollution Control and Treatment Methods in Currently Used at Shipyards Surveyed

Shipyard	Hydroblasting Wastewater	Storm Water	Ship Bilge/Ballast Water	Ship Sewage and Grey Water	Steam Cleaning of Vehicles
1	1. Dissolved Air Flotation (DAF) treatment system	1. DAF treatment system	1. DAF treatment system	1. not treated	1. DAF treatment system
2	1. no treatment of wastewater	1. not treated	1. treated on-site. Current system uses activated carbon, microfiltration and biological treatment		
3	1. not treated		1. treated on-site		
5*	1. water collected than taken to POTW if meets city requirements	1. collect and treated from high contamination areas	1. collect and pump to baker tank - gravity phase separation and metals separation	1. not treated	1. steam pit collection and then gravity phase oil water separation
6.	Not Applicable	1. not treated	1. treated on-site in bilge water waste treatment facility using ultrafiltration	1. not treated	1. treated on-site in bilge water waste treatment facility using ultrafiltration
7	1. pressure wash water is collected in dock side barge and transported to oil water separator	1. not treated	1. wastewater collected in dockside tanks and transported to on-site oil water separator	1. processed at on-site sewage treatment facility	1. steam clean vehicles and collect wastewater in a sump then transport to an oil water separator
8	Not Applicable		1. steam clean, collect and send for off-site treatment		

* There was no response from Shipyard #4 regarding wastewater treatment

Table 3.2 Water Pollution Control and Treatment Methods in Currently Used at Shipyards Surveyed (con't)

Shipyard	Hydroblasting Wastewater	Storm Water	Ship Bilge/Ballast Water	Ship Sewage and Grey Water	Steam Cleaning of Vehicles
9			1. vertical tube coalescing separator for physical separation of oil and water. Water treated w/ferric sulfate and lime for metals precipitation. Polymer added to form a flocculant which is skimmed off (DAF) tank. 2. oil recycled via a waste oil reclamier off site		
10	1. simple filtration for non TBT paints	N/A	1. DAF unit with oily water separator	1. not treated	
11	1. wastewater collected in plastic sheets and filtered through a micron filter and then through an ion exchange resin to remove metal contaminants	1. not treated	1. wastewater collected in portable tanks or SWOBS (sludge waste oil barge) and transported via tanker to Public Works Center for treatment	1. not treated	N/A
12	N/A		1. treated on-site. with gravity oil water separator, acid cracking of the emulsion layer and parallel plate separator and filtration plate for solids separation		N/A
13	N/A			N/A	
14	1. precoat filtration of wastewater				
15	N/A				1. steam pit collection and then oil water separation

Table 3.3 Review of Shipyard Responses by Technology

Technology	Number of Shipyards Surveyed that are Currently Using the Technology	Number of Shipyards Surveyed that are Transitioning to the Technology
Surface Preparation		
- Ultra-high Pressure Water Blasting	3	1
- CO_2 Pellet Blasting	1	
- Sponge Blasting	1	
- Plastic Media Blasting	1	
- Shrouding in dry dock	5	
- Shrouding or complete enclosures with dust collection	6	
Surface Coating		
High Transfer Efficient Spray Equipment		
- Air-Assisted Airless	3	
- High Volume Low Pressure (HVLP)	3	
- Airless	2	
Low VOC Coatings		
- Powder Coatings	2	
- High Solids Coatings	2	
- Waterborne Coatings	1	
VOC Treatment in Paint Booths	2	
Cleaning Operations		
- aqueous cleaners	5	
- terpenes	1	
- solvent recycling	4 yes and 2 no	
Welding		
Treatment of Weld Fumes	3 yes and 4 no	

Table 3.4 Review of Shipyards Responses to Treatment of Wastewater

Waste Stream	Number of Shipyards Treating this Waste Stream	Number of Shipyards not Treating this Waste Stream
Hydroblast Wastewater	5	3
Storm Water	2	4
Ship Bilge/Ballast Water	9 on-site and 2 off-site	-----
Ship Sewage and Grey Water	1 treated on-site	5

4. Air Pollution Prevention and Control Methods

4.1 Surface Preparation Methods

4.1.1 Pollution Prevention

One of the major pollution prevention opportunities in U.S. shipyards is in reducing fugitive dust emissions from surface preparation operations. There have been numerous studies performed in the literature comparing different surface preparation methods being developed and utilized in both the DoD and NASA operations. These are environmentally friendly alternatives to current methods. NASA is currently conducting a technical assessment of alternative technologies for aerospace depainting (surface preparation) on behalf of the EPA and the United States Air Force (USAF). They are evaluating technologies that are environmentally friendly and specifically do not use methylene chloride. They are studying carbon dioxide (CO_2) pellet blasting, FLASHJET^{TM} coating removal, laser paint stripping, plastic media blasting, sodium bicarbonate wet stripping, water blasting and wheat starch blasting. These studies are complimented by another study conducted by the Joint Technology Exchange Group (JTEG) which is evaluating alternative paint removal processes that have potential use within the DoD. JTEG studied the use of five paint removal techniques including plastic media blasting (PMB), laser paint stripping, sodium bicarbonate blasting, CO_2 pellet blasting and high-pressure water blasting.

The methods discussed in these two studies are summarized in the Technology Data Sheets in Section 4.1.1.3; also included are methods disclosed in shipyard surveys, Sponge-Jet^{R} media and CAPE, those mentioned by colleagues, Blastox^{R}, CASRM Bottom Blaster, and those that were discovered through literature search, ALUMAGLASS^{TM}. The Technology Data Sheets provide a brief summary of the technology, advantages, disadvantages, pollution prevention benefits, contact points and references. Key technical reports that provide additional information on surface preparation techniques is provided in Section 4.1.1.1. Section 4.1.1.2 provides a summary of ongoing research projects in the area of surface preparation. Where applicable a contact person and vendor information is provided with each technology. For some surface preparation methods such as hydroblasting, there are numerous vendors available so a reference that lists several of these vendors is provided in lieu of repeating what is already summarized in available literature.

4.1.1.1 Technical Reports

This section provides a listing of pertinent reports that are worth ordering if more detailed information on a given technology or group of technologies is desired, or if you are interested in pollution prevention measures to reduce pollution at your shipyard.

U.S. EPA. **"Guide to Cleaner Technologies - Organic Coating Removal"** EPA/625/R-93/015. February 1994.

This document identifies new approaches for pollution prevention in paint removal. The objectives of the guide are to help identify potentially viable cleaner technologies to reduce waste by using alternative organic coating removal methods, and to provide more detailed engineering information about the technologies. Information on pollution prevention benefits, operating features, application and limitations is provided for each technology discussed. The following currently available technologies are discussed: plastic media blasting, wheat starch blasting, burnoff coating removal, molton salt coating removal, sodium bicarbonate wet blasting, CO_2 pellet blasting, high-pressure water blasting, medium-pressure water blasting and liquid nitrogen cryogenic blasting. Three emerging technologies are also discussed: laser heating, flashlamp heating and ice crystal blasting. This report can be ordered from NCEPI (see Section 2.1) at no cost.

U.S. EPA. **"Alternate Control Techniques Document: Surface Coating Operations at Shipbuilding and Ship Repair Facilities".** EPA 453/R-94-032. April 1994.

This report provides alternative control techniques (ACT) for State and local agencies to consider for incorporating in rules to limit emission of volatile organic compounds (VOCs) and particulate matter, including PM_{10}, that otherwise result from surface coating operations at shipbuilding and ship repair facilities. This document contains information on emissions, controls, control options, and associated costs. This document has been amended by an additional document to make it the "**Control Techniques Guidelines (CTG) for Shipbuilding and Ship Repair Operations (Surface Coating)"**.

You can download both documents from the EPA Technology Transfer Network (TTN). Dial (919) 541-5742 for data transfer of up to 14,400 bits per second, or access via the Internet at http://www.epa.gov/oar/ttn_bbs.htm. Another option is to order the document from NTIS (see section 2.1) at a cost of $38.00.

The CTG establishes VOC content restrictions on as-supplied and as-applied marine coatings. The control measures outlined in The Control Techniques Guidelines must be implemented by the states by August 1997. Additionally, major shipyard sources must be in compliance with the new State VOC rules by August 1998.

U.S. EPA. "**Manual - Pollution Prevention in the Paints and Coatings Industry"**. EPA/625/R-96/003. September 1996.

This manual presents recommended practices for minimizing the generation of pollution in the paints and coatings industry. The information in this manual can help operators access operations and processes for pollution prevention options in using "cleaner" technologies and more efficient management practices. The manual has three major sections: 1) an overview of the industry and an introduction to pollution prevention for paints and coating operations, 2) pollution prevention considerations, and 3) case studies emphasizing approaches for reducing process waste. This is a very good summary that would be useful to environmental managers looking for pollution prevention technologies and practices to implement in shipyard coating operations. This report can be ordered from NCEPI (see Section 2.1) at no cost.

4.1.1.2 On-going Research Projects

This section gives a brief listing of on-going research projects, their objectives and a point of contact if you are interested in the results of their studies.

The following project reviews are obtained from the following reference:

U.S. Army Tank-Automotive and Armaments Command Industrial Ecology Center. **"Pollution Prevention Environmental Technology"**. Picatinny Arsenal, NJ 07806-5000. February 1997.

1. Waterjet Paint Stripping

The objective of this project is to eliminate or significantly lower the generation of hazardous and toxic materials during metal surface treatment. This project will combine state-of-the-art robotics with Waterjet Paint Stripping and simultaneously apply a waterbased nonhazardous material that will produce a continuous barrier between the metal oxide and the primer paint. This project is funded by SERDP and is being performed by TACOM
Contact: Carl Handsy, TACOM at (810) 574-7738

2. Automated Ultrahigh-Pressure Work Cell

The objective of this project is to evaluate ultrahigh-pressure waterjet technology using activated surface treatment agents (hydrolized silane coupling agents with abrasive) for coatings removal as well as surface priming. NDCEE will demonstrate the automatic high pressure waterjet to replace chemical and manual paint stripping, rubber removal and pretreatment of metal parts. The program funding source is DEM/VAL and the program is being executed by NDCEE.
Contact: Carl Handsey, TACOM at (810) 574-7738

4.1.1.3 Technology Data Sheets

The following technologies are summarized in the Technology Data Sheets that follow: ALUMAGLASS™ abrasive, Blastox®, CO_2 pellet blasting, CASRM bottom blaster, FLASHJET™, laser paint stripping, high pressure water blasting, plastic media blasting (PMB), Sponge-Jet® blast media, sodium bicarbonate blasting, ultra-high pressure water jetting, wet abrasive blasting, and wheat starch blasting.

Surface Preparation Pollution Prevention Data Sheets

Technology

ALUMAGLASS Abrasive

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

ALUMAGLASS is a relatively new abrasive that was developed by researchers at Conversion Technologies, in conjunction with scientists at Alfred University's Center for Advanced Ceramic Technology. The goal of the development team was to develop an abrasive that was reclaimable, capable of high speed cleaning and have exceptional performance in both coarse and loose grain forms. The final product contains approximately 20% alumina (attributes to the abrasives hardness of 6-7 Mohs) and 54% silica (provides fracture characteristics) and other components including calcia and soda. This formulation is a low density abrasive which has high cleaning rates and low energy usages. Its hardness is 6-7 Mohs with an angular/blocky shape and is comparable to the hardness of coal slag and steel shot/grit. Its cleaning rate is quoted as being faster than coal slag and steel shot/grit [1].

The abrasive is attractive from a pollution prevention standpoint because it is rated as low dusting compared to coal slag, and is re-usable and recyclable. It can be re-used approximately four to six times in the field. Once the abrasive has been broken down and is no longer re-usable it can be collected and remelted into new abrasives at the ALUMAGLASS manufacturing facility [2]. This eliminates disposal costs associated with spent abrasives.

ALUMAGLASS has been successful in removing paint from locomotives, removing powder coatings from rejected parts and from powder coating equipment, blasting stainless steel and steel aircraft parts and numerous other blasting applications.

The N.T. Ruddock Company is this distributor of this abrasive and will come and demonstrate the effectiveness of ALUMAGLASS in meeting the cleaning and depainting needs at your facility. Please see the contact information below.

Technology (con't)

ALUMAGLASS Abrasive

Pollution Prevention Benefits

- low dusting abrasive that is reclaimable and recyclable

Advantages

- high cleaning speed
- low energy usage
- non-flammable and non-sparking
- no free silica content

Disadvantages

- still an abrasive blast media which results in particulate emissions during blasting operations

Contact:

Jim Ruddock/N. T. Ruddock Company
600 Golden Oak Parkway
Cleveland, Ohio 44146
(216) 439-4976

References:

[1] Conversion Technologies International, Inc. "ALUMAGLASS Product Development and Positioning".
[2] Ruddock, Jim. Conversation regarding ALUMAGLASS at the Applied Research Laboratory at The Pennsylvania State University. June 1997.

Technology

Blastox

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Blastox is a blasting additive introduced into the blasting and coatings industry in 1991 to render otherwise toxic spent blast media as non-hazardous. It is a silicate based technology that contains no iron or steel with a chemical composition that limits the solubility of a wide range of toxic metals by both chemical and physical means. It is effective in reducing the leachability of many heavy metals including lead, chromium, cadmium, mercury, zinc, etc.

This media can aid the shipbuilding and repair industry by reducing the cost of disposing lead contaminated abrasives as a hazardous waste. Blastox is purchased premixed with the abrasive of your choice and is guaranteed to reduce leachable lead levels from up to 100 mg/l to below 5 mg/l. The effectiveness of Blastox in removing the leachability of other metals will have to be discussed with the vendor.

Technology (con't)

Blastox

Pollution Prevention Benefits

- produces a non-hazardous spent abrasive waste which might otherwise be hazardous.

Advantages

- non-combustible
- effective in reducing the leachability of many heavy metals including lead, chromium, cadmium, mercury, zinc
- reduces lead concentration in air when removing coatings containing lead

Disadvantages

- designed to break-up when it hits the surface so may have some additional dust generated
- need to keep Blastox abrasive mixture off horizontal flat surfaces in presence of heavy fog, mist or light rain. Some material may adhere to the steel or freshly painted surface and need removal
- caution required if used in medium to high wind conditions. Blastox is lighter than the abrasive and may separate from the abrasive and potentially reduce treatment efficiency

Contact:

TDJ Group, Inc.
760-K Industrial Drive
Cary, IL 60013
Phone: (847) 639-1113

References:

[1] Discussion with Lon Meneer of the TDJ Group, Inc. July 1997.

Technology

Carbon Dioxide (CO2) Pellet Blasting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Carbon dioxide pellet blasting is a paint removal and/or cleaning technology that turns liquid carbon dioxide into pellets and blasts them through a nozzle or centrifugally towards the surface being cleaned. The CO2 pellets remove a coating or contaminant by a combination of impact, embrittlement, thermal contraction, and gas expansion. CO2 pellet blasting is effective in removing some paints, sealants, carbon and corrosion deposits, grease, oil, and adhesives [1].

A carbon dioxide pellet blasting system is described in the following paragraph. The carbon dioxide is stored under pressure (approx. 850 psig) and fed to a pelletizer which converts the liquid CO2 into solid CO2 snow and then compresses the dry ice flakes into pellets at about -110 F. The pellets are metered into a compressed air stream and applied to a surface by manual or automated cleaning equipment with specially designed blast nozzles or are blasted centrifugally with a turbine wheel. The CO2 pellets are projected onto the target surface at high speed. As the dry ice pellets strike the surface, they induce an extreme temperature difference between the coating and the underlying substrate, weakening the chemical and physical bonds between the surface materials and the substrate. Immediately after impact, the pellets begin to sublime, releasing CO2 gas at a very high velocity along the surface to be cleaned. The subsequent kinetic energy associated with this process dislodges the coating system, resulting in a clean surface. The main process parameters for CO2 cryogenic stripping when using a blast nozzle are pellet size, pellet density, blast pressure, angle of impingement, media flow rate, blasting standoff distance, and nozzle design.

The National Defense Center for Environmental Excellence (NDCEE) is currently doing research with carbon dioxide blasting using a turbine wheel as the CO2 pellet propelling device (see Contact Section). The project goal is to demonstrate the manipulation of a centrifugally accelerated carbon dioxide pellet turbine wheel device on Navy products. One shipyard surveyed used the NDCEE to aid in their evaluation of this technology and have now implemented CO2 pellet blasting in cleaning operations.

The Joint Services P2 Technical Library provides an economic analysis of CO2 pellet blasting in comparison to chemical stripping and provides vendor contacts (see Contact Section of this Technology Data Sheet). Other references of interest are [2], [3] and [4].

Technology (con't)

Carbon Dioxide (CO_2) Pellet Blasting

Pollution Prevention Benefits

- generates a smaller amount of waste compared to all of the other available paint stripping technologies
- no VOCs or fugitive dust generated
- no wastewater to dispose

Advantages

- introduces no new contaminants
- only disposal is coating residue
- no liquid waste because CO_2 dissipates after use
- pre- or post-stripping cleanup requirements are typically minimal
- no size limitation on parts to be stripped
- benign to most substrates
- time required for cleaning/stripping processes is reduced by 80-90 %
- can selectively remove individual coating layers

Disadvantages

- CO_2 blasting is not always a one pass operation
- operators should wear respiratory, eye and hearing protection equipment
- nonautomated systems quickly fatigue operators, due to cold, weight and thrust of blast nozzles
- static energy can build up if grounding not provided
- can have high capital costs
- rebounding pellets may carry coating debris and contaminate work area
- some coating debris may redeposit on substrate

Contact:

- Joint Services P2 Opportunity Handbook-Depainting-CO_2 Blasting Internet Address: http://enviro.nfesc.navy.mil/p2library
- see NDCEE project summary and technical contacts at the following Internet Address: http://www.ndcee.ctc.com/n045.htm
- see vendor listing in Appendix B

References:

[1] Joint Services P2 Opportunity Handbook. "Carbon Dioxide Blasting Operations". September 1996.
[2] NASA. "Joint EPA/NASA/USAF Interagency Depainting Study Second Progress Report". NASA George C. Marshall Space Flight Center. Huntsville, AL, April 1995.
[3] U.S. EPA. "Guide to Cleaner Technologies - Organic Coating Removal". EPA/625/R-93/015. February 1994.
[4] Tinker Air Force Base. Technologies and Coalitions - Pollution Prevention. "Carbon Dioxide (CO_2) Blast Booth". Internet Address: http://137.240.85.40/tcppr9.htm

Technology

CASRM Bottom Blaster

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	no

Technology Description

The CASRM bottom blaster is a closed cycle rotating wheel blaster. It projects steel abrasive or shot at a surface from a 16" diameter blast wheel rotating at 3500 rpm. The abrasive impacts the bottom of a ship hull at high speed in a pattern approximately 20" wide by 4" deep. Rubber seals between the blast machine and the hull ensure that all the abrasive, dust, paint chips, etc. from the blast process are directed back into the machine, where it is collected in a hopper. The abrasive is then separated from the lighter dust and paint chips by a strong jet of air which is directed through a stream of falling abrasive. The heavy abrasive continues to fall while the lighter dust and paint is carried by the air stream into a dust collector.

The blast head is connected in a frame mounted on the end of a lift arm in such a way that the blast head can pivot in two directions. The lift arm is powered hydraulically and can raise the blast head to the bottom of the ship; the pivoting arrangement allows it to adjust to the angle of the hull. The blast head and lift arm are mounted on a support vehicle which is controlled by a single operator who sits in a cab at the front of the vehicle. This technology is still in the development phase and completed its first test performed on the USS Portland at NORSHIPCO in December 1996.

The information contained in this summary is from reference [1].

Technology (con't)

CASRM Bottom Blaster

Pollution Prevention Benefits

- eliminates fugitive dust emissions
- spent abrasive and paint chips collected at the source

Advantages

- provision to collect all spent abrasive, clean it and reuse it
- dust collection system to trap all dust, fumes and paint chips
- rotating wheel blasters are a proven technology
- blast cost per square foot of area cleaned is 10x lower than open air blasting
- abrasive consumption much less than with open air abrasive blasting
- solid waste production 100 times lower than open air abrasive blasting

Disadvantages

- only blasts the bottom of ships

Contact:

Larry Mizelle, Technical Director
CASRM, Inc.
222 E. Main Street
Norfolk, VA 23510
Phone Number: (757) 622-2137, Email Address: casrm@infi.net

References:

[1] Center for Advanced Ship Repair and Maintenance (CASRM) Report. January 1997.

Technology

FLASHJET

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

This technology is being developed by McDonnell Douglas. The FLASHJET process uses a simultaneous pulse of light energy and a low pressure CO2 particle stream to remove surface coatings while containing paint residue with a vacuum recovery head. As the FLASHJET head is moved across the surface to be cleaned, a xenon lamp emits pulses of light that are absorbed by the coating. This absorption of photon energy heats the coating to the point of pyrolysis and changes it into fine ash particles and previously trapped volatiles. At the same time, a blast stream of CO2 pellets cools the surface while sweeping away coating residue. The paint residue is collected in pre-HEPA and HEPA filters. The remaining effluent vapors are collected in an activated charcoal air scrubber.

The paint systems stripped with the FLASHJET process include epoxy, polysulfide, polyurethane primers and polyurethane, high solids and unicoat topcoats [1]. The FLASHJET technology has been transitioned from a laboratory-proven process to an operationally ready system controlled by a robot. The operator of the system observes the stripping process on a video screen at a cell controller. The FLASHJET system variables include transverse speed, strip width (max. of 12 inches), flashlamp power, flashlamp energy, dry ice pellet blast pressure and flow rate, flash frequency and nominal standoff distance.

This paint stripping system has been designed for and proven effective in depainting aircraft but may be applicable to shipyard use with the development of a new mobile manipulator concept which includes a boom truck, robotic arm, manipulator controller and manipulator software. A review of FLASHJET technology is discussed in several references including [1], [2], [3] and [4], and the Market Development Manager at McDonnell Douglas for this technology is provided in the Contact Section of this Technology Data Sheet.

Technology (con't)

FLASHJET

Pollution Prevention Benefits

- no VOC or particulate emissions
- no wastewater to treat or dispose
- no blast media to dispose
- only toxic waste to dispose is the paint residue trapped in the HEPA filters

Advantages

- no pre-cleaning, masking, or post-strip work required
- low operating costs
- strips up to 4 sq. ft. per minute
- allows for concurrent maintenance activities
- captures particulates at the source
- will not damage aluminum or composites
- minimum operator protection required

Disadvantages

- safety requirements include ultraviolet light filtering glasses, ear plugs and CO2 venting
- high capital investment

Contact:

Thomas Neid, Jr. - Manager - Market Development Aerospace Support
McDonnell Douglas Aerospace
Mailcode S1064360
P.O. Box 516
St Louis, MO 63166-0516 Phone: (314) 232-5761

References:

[1] Nied, T. "FLASHJET Production Plans and Experiences". Proceedings of the 1996 DoD/Industry Aerospace Coatings Conference. Orlando, Florida. May 14-16 1996.
[2] Nied, T. "FLASHJET Coatings Removal Process: Transition from Dev. to Production". Proceedings of the 1995 DoD/Industry Adv. Coatings Removal Conf.. Albuquerque, N.M.May 23-25, 1995.
[3] NASA. 1995. "Joint EPA/NASA/USAF Interagency Depainting Study Second Progress Report". NASA MSFC, HSV, AL, April 1995.
[4] Schmitz, W. and Breihan, D. "Stripping Clean with FLASHJET". Aerospace Digest Volume 40, Number 2, September 1993.

Technology

High Pressure Water Blasting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

High pressure water blasting (also called high pressure water jetting) relies entirely on the energy of water striking a surface to achieve its cleaning effect. Water pressures in the range of 10,000 to 25,000 psi (there exists some discrepancy in the literature regarding this range, some sources claim a 15,000 to 30,000 psi range) are used in this cleaning process without the addition of abrasives. The process can be used for extremely aggressive stripping or used to selectively remove single layers of paint at one time by using rotary nozzles. These high pressure systems generate high operator back thrust which has to be resisted and leads this technology toward automation rather than manual operation. This introduces a high capital cost for use of this process.

The Navy is developing a high pressure waterjet system which is described in a separate Technology Data Sheet. The Joint Technology Exchange Group (JTEG) is also evaluating this technology through three prototypes; the Aqua Miser, the Water-Jet depaint system, and the Large Aircraft Robotic Paint Stripping (LARPS) system [1]. In addition there is an evaluation of this technology being performed as a Joint effort between NASA, EPA and USAF [2].

The Joint Services Pollution Prevention Library can also be accessed (see Section 2.1 of this report for the Internet Address of the Library and view the Joint Services P2 Opportunity Handbook under Depainting). The Library provides an overview of high pressure water blasting, an economic analysis of this process, and some vendor contacts [3]. A data sheet is also provided in the Joint Services P2 Opportunity Handbook for a hydroblasting wastewater recycling system.

Technology (con't)

High Pressure Water Blasting

Pollution Prevention Benefits

- significantly reduces hazardous waste generated compared to chemical stripping
- no disposal of spent abrasives required
- no particulate emissions
- no VOC or HAP emissions

Advantages

- high stripping rate. NASA has achieved stripping rates above 250 ft2/hr [3]
- no size limitation on parts to be stripped
- can selectively remove individual coating layers
- pre-washing and masking is not needed in most applications
- wastewater easily filtered and reused [3]

Disadvantages

- workers need to be protected from direct impingement of water jet due to extreme danger from >15,000 psi water jet
- high noise levels generated during the process; hearing protection required
- robotic applications are required due to high reaction forces and high hazard from water jet [4]
- requires wastewater containment system
- high capital investment
- a misaligned water jet can damage the surface being cleaned
- water can penetrate and/or damage joints, seals, and bonded areas

Contact:

- see vendor listing in Appendix B for a partial list of vendors
- for contact information pertaining to the reports below see the Bibliography under SURFACE PREPARATION - High Pressure Water Blasting

References:

[1] Joint Policy Coordinating Group on Depot Maintenance Tasking Directive 1-90. "Joint Paint Removal Study. Final Report High Pressure Water Blasting". February 1995.
[2] NASA. "Joint EPA/NASA/USAF Interagency Depainting Study Second Progress Report". NASA MSFC, HSV, AL, April 1995.
[3] Joint Services Pollution Prevention Library. "High and Medium Pressure Water Paint Stripping Processes". August 1996.
[4] U.S. EPA. "Guide to Cleaner Technologies Organic Coating Removal". EPA/625/R-93/015. February 1994.

Technology

Laser Paint Stripping

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Laser paint stripping removes paint by "ablation" which means to remove by cutting, eroding, melting, evaporating or vaporizing. The laser energy directed at the surface is absorbed by the coating being stripped resulting in oxidation of the organics in the coating and subsequent volatilization of the products.

Laser systems generally consist of CO2 pulsed lasers used with automatic process control systems, which can be used to selectively strip surface coatings to specific depths or layers [1]. Laser systems have been demonstrated to operate efficiently on metal and composite substrates. Several development projects have been performed by the Navy, Air Force, Army and NASA which have resulted in many different applications and laser system configurations.

A description of each laser development program, Navy ALPS (Automated Laser Paint Stripper), Air Force LADS (Laser Automated Decoating System) and Army ALPS (Automated Laser Paint Stripping Cell) are provided in [2] while a description of NASA MSFC efforts described in [3].

The Navy ALPS program found that pulsed laser radiation with relatively low peak power was the most effective and controllable means of removing paint with lasers. Using this concept, a small quantity of coating is removed with each pulse and the target area is allowed to cool before being processed again. This system uses real time vision feedback for control of the laser eliminating the need for precision robotics. This system is being developed to strip coatings from fighter-size aircraft. The Air Force is developing the use of lasers to remove rain erosion coatings from composite aircraft radomes and flight control surfaces. A 1200-Watt pulsed laser system that generates a square laser beam of about two square centimeters with a Raleigh range of about 18 inches is used. The Army procured a turn-key automated laser paint stripping cell for use at Corpus Christi Army Depot (CCAD). This system is designed to handle medium to large components, employing both a robotic arm and rotational parts positioner. It is being used to strip helicopter blades. Another study using laser paint stripping was performed by NASA, USAF, and the EPA [3]. The NASA study demonstrated the use of a CO2 laser at MSFC on metal and composite substrates.

Technology (con't)

Laser Paint Stripping

Pollution Prevention Benefits

- eliminates the use of toxic chemical paint strippers and generates less disposal waste than the initial volume of paint applied [2]

Advantages

- effective method for composite structures [3]
- provides reliable and repeatable paint stripping results [3]
- substrate undergoes minimal increase in temperature [3]
- laser cleaned substrates show good coating adhesion and corrosion resistance [1]
- contains and potentially reduces the costs associated with paint stripping operations [2]

Disadvantages

- requires large capital investment
- difficult to focus and control laser beam to allow stripping of curved or complex parts [1]
- coating removal efficiency is affected by coating color and gloss [1]
- requires use of Class 1 laser enclosure to ensure worker protection [1]

Contact:

- see the contact points in the the Bibliography cooresponding to the references below for more information

References:

[1] U.S. EPA. "Guide to Cleaner Technologies Organic Coating Removal". EPA/625/R-93/015. February 1994.

[2] Joint Policy Coordinating Group on Depot Maintenance Tasking Directive 1-90. "Joint Paint Removal Study. Final Report Laser Paint Removal". February 1995.

[3] NASA. "Joint EPA/NASA/USAF Interagency Depainting Study Second Progress Report". NASA George C. Marshall Space Flight Center. Huntsville, AL, April 1995.

Technology

Navy High-Pressure Waterjet Demonstration System

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	no

Technology Description

The Navy Waterjet Demonstration System is a closed cycle high pressure waterjet that is incorporated into a self contained mobile unit for cleaning coatings from ship hulls. The waterjet system includes a high pressure water pump, a teleoperated transporter with a 5 axis telescoping arm, a 6 axis manipulator with specialized end effector, a recovery process trailer and a system remote control console.

Paint is stripped from the paint hull by directing the energy of high pressure water against the surface being treated. The waterjet nozzle in this design is 6 inches wide incorporated into an end effector mounted in a frame that is mechanically guided along the surface being stripped. The end effector includes a vacuum recovery shroud which is designed to capture virtually 100% of the process water, the suspended particles and the fouling residue. As the shroud removes the process effluent, it simultaneously dries the substrate, leaving a rust free surface.

The end effector, which is moved through a 4.5 by 6.5 ft envelope, is connected to a manipulator subsystem which provides the interface between the end effector and the ship surface. The manipulator is accurately positioned against the ship using an off-the-shelf mobile telescoping transporter subsystem. A single operator commands this automatic process through a remote control console mounted on a roll-around cart.

This system has been successfully demonstrated on several ships including the USS Nimitz underwater hull and flight deck, the USS Sturgeon, the USS Leftwich and the USS Paul Foster.

The information for this summary has been obtained from two references on this project [1] and [2]. Copies of these summaries can be obtained for more details or contact Robert Price at the phone number listed in the Contact Section of this Technology Data Sheet.

Technology (con't)

Navy High-Pressure Waterjet Demonstration System

Pollution Prevention Benefits

- complete effluent recovery at the source eliminating airborne particulates
- paint is the only waste product

Advantages

- reduces waste, disposal costs and dry dock cleanup
- reduces dry dock time for ship
- lowers manpower requirement
- ability to selectively strip layers of a coating or entire coating in one pass
- operates independently on a dry dock without external utilities
- other operations can be performed in dry dock simultaneously
- provides cleaner surface for recoating
- provides a grit-free environment for workers and equipment
- bare metal does not flash rust

Disadvantages

- cannot access all areas of a ship hull (hand held unit in development)

Contact:

Robert Rice
Pratt & Whitney Waterjet Systems
(205) 721-2531

References:

[1] Envirosense. " Naval Paint Stripping Operations". June 1995. Internet Address: http://es.inel.gov/program/p2dept/defense/navy/navpaint.html

[2] Williams, J. and Rice, R.. "Navy High-Pressure Waterjet Closed-Loop Paint Stripping System", 1995 Ship Production Symposium; The Society of Naval Architects and Marine Engineers: Seattle, January 25-27,1995. NSRP 0439.

Technology

Plastic Media Blasting (PMB)

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Plastic media blasting (PMB) is a dry stripping process that projects plastic media at a surface through either low-pressure air (10 to 60 psi) or centrifugal wheels. The blast particles have sufficient impact energy through their hardness and geometry to chip away or erode the coating. After the coating has been dislodged, the substrate can be prepared for recoating by removing paint debris and blast dust via air pressure and/or vacuuming. Plastic media are manufactured in six types and a variety of sizes and hardnesses. A military specification has been developed (MIL-P-85891) which provides general information on the types and characteristics of plastic media. The order of media aggressiveness from mild to aggressive is Type I, Type VI, Type V, Type II, and Type III. DoD facilities using PMB typically use either a Type II or a Type V media [2]. Type V is a durable media for general stripping of coatings from metal sheeting. Type II, like Type V, is applied for general stripping. Type II gives faster stripping rates more likely to damage the substrate if the operator deviates from stripping parameters.

PMB is performed in a ventilated enclosure such as a small cabinet (glove box), a walk-in booth, or a large room. This enables recovery and reuse of the plastic media. Media reuse systems separate contaminants such as coating chips and undersized media fragments, from the intact media. Separation can be done by cyclone separators, vibrating screens, magnetic separators, or similar equipment. The number of reuse cycles that can be achieved is variable. Generally large media and lower operating pressures allow more reuse cycles.

There are several parameters that affect the performance of the PMB process using air pressure. These parameters include: blasting pressure (10-60 psi), angle of impingement (30 to 80 degrees), media flow rate (250 to 500 lb/hr with 1/2 in nozzle), blasting standoff distance (6" to 30"), stripping rate (0.5 to 5 ft2/min), type of coating to be removed, nature of substrate material and its thickness, media type and size, nozzle size, masking requirements, types and capabilities of commercially available PMB systems. The requirements for a PBM system include compressed air to propel the blast media and energy for media recovery and recycle, dust collection, and ventilation.

An economic analysis of this process is provided in [1] where the costs are compared to conventional chemical stripping. This reference also provides a list of vendors.

Technology (con't)

Plastic Media Blasting (PMB)

Pollution Prevention Benefits

- no VOC or HAP emissions
- no wastewater generated
- spent media can be cleaned and reused several times
- some spent media are recyclable to make plastic products

Advantages

- can selectively remove individual coating layers
- fully automated robotic systems available
- no size limitation on parts to be stripped
- uses nontoxic media

Disadvantages

- spent plastic media contains paint chips which may cause waste to be hazardous
- fugitive dust emissions which are a possible explosion hazard
- requires respiratory and eye protection equipment for operators
- generates high noise levels so hearing protection required
- quality of stripping dependent on skill and experience level of the operator
- may cause metal substrate damage
- may not remove corrosion
- uses flammable media

Contact:

- see the Joint Services P2 Opportunity Handbook at the following Internet Address: http://enviro.nfesc.navy.mil/p2library/depaint6.htm to obtain a list of vendors and view an economic analysis of this technology

References:

[1] Joint Services Pollution Library. "Plastic Media Blasting (PMB) Paint Stripping". October 1996.
[2] U.S. EPA. "Guide to Cleaner Technologies Organic Coating Removal". EPA/625/R-93/015. February 1994.

Technology

Sodium Bicarbonate Blasting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Sodium bicarbonate abrasives can be used in either a dry or wet abrasive blasting process. Old coatings are removed through abrasive action by propelling the abrasive at high velocities toward the surface being cleaned. In the dry abrasive blasting process compressed air is used to propel the blast media, in a manner similar to conventional sandblasting equipment. Water can be injected into this process for dust control (air abrasive wet blasting technique). In a pressurized water abrasive blasting process a special sodium bicarbonate formula is used which is injected into low pressure water streams operating between 2,500 to 4,000 psi. Either technique can be used in a blast cabinet for use on small parts where visibility can be improved and waste is contained and treated.

There exists several sodium bicarbonate formulations designed to meet most coating removal problems. The process will remove paints from a variety of metal substrates and remove heavy accumulations of grease and dirt from mechanical equipment. The effectiveness of the sodium bicarbonate stripping process is dependent on a number of operating parameters including air pressure, air, media and water flow rates, blasting standoff distance, angle of impingement, and transverse speed. These operating parameters coupled with the type of coating to be removed, coating thickness, substrate type and sodium bicarbonate formula affect the removal and cleaning rates.

Sodium bicarbonate is an inelastic media which typically fractures upon impact, breaking into smaller pieces. This behavior is unlike conventional abrasives which maintain their shape upon impact and subsequently rebound at approximately the same velocity as at impact (elastic behavior). This results in a three to four time reduction in the required media flowrate compared to elastic media (plastic or sand) [1].

Several studies have been performed using the sodium bicarbonate blasting process including a joint study by EPA/NASA/USAF for use on aircraft/spacecraft needs [2] and by the Joint Policy Coordinating Group on Depot Maintanence (tasked to JTEG) on various aircraft, ground vehicles, and other components [3]. These references include contact names and phone numbers for additional information as does the Joint Services P2 Technical Library.

Technology (con't)

Sodium Bicarbonate Blasting

Pollution Prevention Benefits

- no VOC or HAP emissions
- fugitive dust emissions are reduced compared to dry abrasive blasting if used in wet abrasive process
- blast media is nontoxic

Advantages

- can selectively remove individual coating layers
- stripping media costs less than plastic abrasives
- simple stripping equipment
- no size limitation on parts to be stripped
- can reduce prewashing and masking of surface prior to stripping
- use less blast media per square foot compared to other blast media
- low start-up and operating costs

Disadvantages

- requires respiratory and eye protection equipment for operators
- generates high noise levels so hearing protection required
- if used in a dry process a cloud of dust results which requires monitoring and may require containment
- generates wet sodium bicarbonate sludge containing coating debris
- paint removal rates slower than conventional methods [3]
- system should be operated in an isolated area outdoors or indoors in an abrasive blast room- due to noise and dust [3]

Contact:

- see vendor listing in Appendix B for a partial listing of vendors
- see the Joint Services P2 Opportunity Handbook for an economic analysis and vendors. Internet: http://enviro.nfesc.navy.mil/p2library
- for contact information regarding references [2] and [3] given below see the Bibliography

References:

[1] Spears, E. and Shank, J. "ARMEX Blast Cabinet System with Waste Treatment". DoD/Industry Advanced Coatings Removal Conference, Albuquerque, New Mexico. May 23-25, 1995.

[2] NASA. "Joint EPA/NASA/USAF Interagency Depainting Study Second Progress Report". NASA MSFC Huntsville, AL. April 1995.

[3] Joint Policy Coordinating Group on Depot Maintanence Tasking Directive 1-90. "Joint Paint Removal Study. Final Report Sodium Bicarbonate Paint Stripping". February 1995.

Technology

Sponge Blasting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

With sponge blasting the blast media is chemically bonded into an open cell water based polyurethane sponge and blasted at the surface being cleaned using compressed air. This process significantly reduces the dust generated compared to conventional dry abrasive blasting processes. On impact to the surface, the sponge media flattens out and transfers its energy to the surface being blasted without breaking down the abrasive. As the sponge rebounds from the surface the open cell structure of the sponge traps the freed contaminants in the matrix of the sponge, suppressing 94% of the dust generated in comparison to traditional abrasive blasting procedures.

The sponge media is reusable. The sponge particles contain the abrasive aggregate so the abrasive is protected from premature breakdown. The aggregrate only begins to breakdown after it has been reused several times. In industrial applications, the sponge can typically be recycled 6-8 times. A media classifier is used for the recycling process after the spent media is vacuumed from the surrounding area. It is an electronically powered sifter which uses progressively smaller screens to sort used media into 3 categories: large contaminants, reusable media, and fines (spent media and dust).

A variety of surface preparation jobs and cleaning can be performed with Sponge-Jet including the removal of grease, oil, industrial coatings, lead paint, soot and mill scale. Depending on the degree of surface cleaning desired there are six different sponge media types: blue, green, white, brown, silver and red. Sponge blasting is currently being utilized in one shipyard for cleaning tanks and large flat surfaces.

An economic analysis of this technology compared to chemical paint stripping is provided in the Joint Services P2 Opportunity Handbook which can be accessed via the Internet [1].

Technology (con't)

Sponge Blasting

Pollution Prevention Benefits

- up to 94% reduction in dust generation compared to conventional dry abrasive blasting processes
- reusable abrasive reducing spent abrasive wastes
- no wastewater stream to treat and dispose

Advantages

- a safer working environment for operators
- bounceback significantly reduced with sponge media
- better visibility for blast operator
- can blast in close proximity to operating equipment and other workers
- reduced containment requirements
- blast media reusable so less media to be purchased and disposed

Disadvantages

- foam media costs are more expensive than traditional sandblasting media so a complete economic evaluation of the process needs to be performed
- relatively slow removal rates

Contact:

Dick Rieley
Sponge-Jet & Trade
Phone: (207) 439-0211
Internet Address: http://www.spongejet.com

References:

[1] Joint Services Pollution Prevention Library. "Sponge Blasting". July 1996. Internet Address: http://enviro.nfesc.navy.mil/p2library. Then go to Depainting Section or search for Sponge Blasting.
[2] Conversation with Dick Rieley as well as Sponge-Jet & Trade product literature and video

Technology

Ultra-high Pressure Water Jetting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

An ultra-high pressure waterjet process utilizes 25,000 + psi water pressure to remove surface coatings. This technology can provide a gentle, layer-by-layer removal of organic paints to removal of tough, flame sprayed coatings from superalloy substrates [1]. The waterjet can also be used for cleaning parts. It is efficient at removing oil and greases from parts with simple geometries and can remove particulates from parts with complex geometries down to precision clean levels [1].

The National Defense Center for Environmental Excellence (NDCEE) currently has a closed-loop robotically controlled ultrahigh-pressure waterjet system, which is described below, for demonstration of this technology.

The following is a quote from the NDCEE brochure describing the ultrahigh-pressure waterjet: "The waterjet is a robotically controlled, closed-loop system that uses a low-volume stream of pure water at high pressures. The stream is manipulated by a 6-axis, GM-Fanuc high-precision, industrial pedestal robot. This stream is fine tuned by various rotating blast nozzles specifically designed to provide the correct energy pattern. Water is supplied to the nozzle assembly by an ultahigh-pressure, dual-intensifier pump. An operator controls the robot, pump, and turntable with a user-friendly, menu-driven computer workstation and programs the robot's motion through a remote control pushbutton "teach pendant". A water filtration system filters out particles larger than 0.35 microns before the water is used again for stripping or cleaning" [1]. Please contact the NDCEE for more information or see the vendor listing in Appendix B.

At least three of the shipyards surveyed are successfully using this technology for their surface preparation needs and recommend the process to others.

Technology (con't)

Ultra-high Pressure Water Jetting

Pollution Prevention Benefits

- eliminates fugitive dust emission problems associated with abrasive blasting
- eliminates the disposal of spent abrasive associated with abrasive blasting
- eliminates VOC and HAP emissions

Advantages

- high stripping rate

Disadvantages

- potential operator safety concerns due to the high pressures utilized in the process

Contact:

- NDCEE
  (814) 269-6425
  Internet Address: http://www.ndcee.ctc.com
- see Appendix B for a partial listing of vendors

References:

[1] Concurrent Technologies Corporation. "Cleaning and Coating Removal - Ultrahigh-Pressure Waterjet" brochure.

Technology

Wet Abrasive Blasting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Three basic classifications are given for wet abrasive blast systems: air abrasive wet blasting, air/water/abrasive slurry blasting and pressurized water abrasive blasting. An NSRP study was performed and reported in [1] which compares the three major classes of wet abrasive blasting techniques through field demonstrations of 10 commerical units. The field demonstrations were conducted on steel surfaces typically encountered in marine, highway and water works maintanence, such as rusted and pitted steel, mill scale covered steel, and painted steel. This study determined the cleaning rates and effectiveness of wet blast units, determined the safety and reliability of wet blast units and developed guidelines for the use of wet blast equipment for cleaning various types of structural steel for repainting. This report provides a good comparison of the 10 commercial units evaluated, a checklist for surface preparation requirements, and a list of 100 vendors providing wet abrasive blasting equipment and blasting services.

Basically, wet abrasive blasting is a technique whereby water or a water/air mixture is used to project the abrasive toward the surface being cleaned. In the air abrasive wet blasting method water is used primarily for dust control and units closely resemble existing air dry abrasive blasting in their operation and use. With air/water/abrasive slurry blasting, compressed air is used to propel the abrasive to the surface being cleaned. In this process, air is mixed with water at a control unit upstream of the nozzle which is claimed to permit a better mixing of the abrasive and water and hence better dust control and ability to selectively remove paint layers. The third method, pressurized water abrasive blasting, uses a high velocity stream of water to clean a surface. Water pressures for this process range from 2,000-15,000 psi. The addition of abrasive in the water stream enhances the cleaning capability of the waterjet. One abrasive that is used in the pressurized water stream is sodium bicarbonate which is discussed as a separate Technology Data Sheet.

Technology (con't)

Wet Abrasive Blasting

Pollution Prevention Benefits

- reduces particulate emissions compared to dry abrasive blasting processes

Advantages

- substantially reduces particulate emissions compared to air abrasive blasting
- can selectively remove paint layers
- for specific advantages for each classification see [1]

Disadvantages

- generates wastewater containing paint residue
- for specific disadvantages for each classification see [1]

Contact:

- see vendor list in Appendix B for a partial listing of wet abrasive blasting vendors.

References:

[1] U.S. Department of Transportation Maritime Administration and Avondale Shipyards. "Evaluation of the Effectiveness of Wet Blast Cleaning Methods of Surface Preparation". NSRP 0218. June 1985.

Technology

Wheat Starch Blasting

Applicable Shipyard Process	Surface Preparation
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Wheat starch blasting uses a nontoxic, biodegradable media which is a crystalline form of wheat starch made from renewable sources. The media is similar in appearance to plastic blast media, except that it is softer. The wheat starch blast media strips away a coating by a combination of impact and abrasion while being propelled to a surface using low-pressure air. It is used in a dry stripping process and is reusable, although not indefinately.

It can remove a variety of coatings ranging from resilient rain-erosion resistant coatings found on radomes and radar absorbing materials to tough polyurethane and epoxy paint systems [1]. It is well suited for stripping paints without risking damage to the substrate due its relatively soft nature and the low blast pressures used. Examples would include the stripping of coatings from aluminum alloys and composites like graphite, fiberglass, and aramid.

Wheat starch can be used in systems specifically designed for plastic media blasting or in systems specifically designed for its use. Several components are required including a moisture control system to control the storage conditions of the media. The next component required is a system to reclaim the media after use. To do this the spent wheat starch residue is dissolved in water and then either filtered or separated in a dense particle separator/centrifuge. The wheat starch is recycled in the system and may be used up to 15 to 20 times. The waste stream generated from this process is sludge generated from the wheat starch recycling system.

The Joint Services P2 Technical Library can be accessed via the Internet to obtain an economic analysis of this process compared to chemical paint stripping and to obtain a list of vendors. Please see the Contact Section of this Technology Data Sheet.

Technology (con't)

Wheat Starch Blasting

Pollution Prevention Benefits

- eliminates VOCs and HAPs
- no wastewater because it is a dry stripping process
- spent media can be reused several times

Advantages

- can be used to remove coatings from both composite and metallic materials
- provides controlled coating removal
- can selectively remove coating layers
- media is inexpensive
- medium is nontoxic and biodegradable
- no size limitation on parts to be stripped
- waste generated from this process can be treated in a bioreactor

Disadvantages

- dense contaminants in recycled media may damage delicate substrates
- stripping rate generally slow to moderate
- workers required to wear respiratory and eye protection equipment
- process produces airborne dust
- media is moisture sensitive
- high capital investment
- requires complex subsystems for media recovery and recycling and dust collection and control
- due to contamination with paint chips spent blast media may require hazardous waste disposal

Contact:

- contact the Joint Services P2 Opportunity Handbook for an economic analysis of this process and a vendor listing
  Internet Address: http://enviro.nfesc.navy.mil/p2library then choose the Depainting Section and then see the title below

References:

[1] Joint Services Pollution Prevention Technical Library. "Paint Stripping Using Wheat Starch Blasting". August 1996.
[2] U.S. EPA. "Guide to Cleaner Technologies Organic Coating Removal". EPA/625/R-93/015. February 1994.

One capture and treatment method is discussed in the Technology Data Sheets of this section. It is the CAPE system developed and currently utilized by Metro Machine to enclose and capture emissions from blast cleaning and painting ship hulls in dry dock. Please see the Technology Data Sheet for a description of this system. Another form of pollution control is dry dock covers. A Technology Data Sheet for dry dock covers is not included but dry dock covers are essentially a form of tarping or cover that can supply some measure of dust suppression during surface preparation and coating operations, and are moveable from one ship area to the next. Some systems involve dust collection whereas others just help prevent dust from flying out of the enclosure. A vendor listing is enclosed in Appendix B that lists a series of vendors that supply dry dock covers for containment of blast debris. Several of the shipyards surveyed were using some form of tarping or covers. Names of the vendors mentioned in the surveys are included in the vendor listing including the vendors of Envirotarp and Shrink Wrap.

Surface Preparation Treatment Data Sheets

Technology

CAPE- Compliant All Position Enclosure

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

CAPE is a unique air pollution control system which encloses and captures emissions from blast cleaning and painting of ship hulls in dry dock. It is a series of 15 structural steel staging towers, covered at the back, then connected and sealed side to side, top and bottom around one quadrant of a ship's hull. Each tower has a base module which is 20 feet long, 5 feet deep and 5 feet high. A top unit, which contains a hoist winch with electrical control panels, is 20 feet high. All of the modules are erected with a crane, a spreader lifter bar, and secured at four corners with Interbox connectors. Each tower contains a moveable blaster and spray painter platform, capable of preparing and coating the hull from top to bottom. The moveable work platform carries the workers or automated equipment the height of the tower, and scissors in and out for constant proximity to the hull surface.

The environmental conditions within the enclosure are controlled with equipment mounted on the CAPE support barge. The CAPE support barge is self-sufficient and contains equipment to circulate, filter, dehumidify, and heat the air inside the enclosure. Two barge mounted blowers draw 60,000 cfm of air from the enclosure. The air first passes through a dust collector which filters 99.91 percent of the particles larger than 0.5 microns. From there 11,000 cfm is vented to the atmosphere. During painting and while the paint dries, the vented air passes through a VOC oxidizer. The VOC oxidizer heats the VOC air mixture to 1,450 degrees F oxidizing the paint solvents to carbon dioxide and water. The remaining 49,000 cfm of air passes through fans to a dehumidifer and a heating coil before returning to the enclosure. Forcing air leakage inward at the boundary of the enclosure creates a negative pressure thereby containing contaminants inside the enclosure.

The CAPE enclosure system has been used successfully in production on two ships, USS Seattle and the USS Scott. You can contact Jim McMichael at the address and phone number provided in the Contact Section of this Technology Data Sheet for more information or check reference [1]. The information in this summary was obtained from references [1] and [2].

Technology (con't)

CAPE- Compliant All Position Enclosure

Pollution Prevention Benefits

- collection and destruction of VOCs during paint application and curing
- collection of fugitive dust emissions from blasting operations

Advantages

- improved coating quality due to temperature and humidity control
- eliminates negative weather effects
- eliminates blast dust contamination of paint coats
- towers set up easily and quickly
- CAPE automation systems permit fewer workers to accomplish more work in less time
- weather does not interrupt work on ship hulls
- other operations can be performed in dry dock simultaneously

Disadvantages

- potential high capital investment

Contact:

Jim McMichael
MMC Compliance Engineering, Inc.
(757) 494-0721

References:

[1] Metro Machine Internet Web Page at http://www.memach.com
[2] Garland, C. and Lukey, M. "An Innovative Permanent Total Enclosure for Blast Cleaning and Painting of Ships in Drydock". MMC Compliance Engineering, Inc. Product Literature.

4.2 Surface Coating Operations

4.2.1 Pollution Prevention

Approximately 35 shipyards in the United States are estimated to be major sources of HAP emissions from surface coating operations and are subject to NESHAP regulations that require shipyard compliance by December 16, 1997. These emissions result from the use of solvents such as toluene, xylene, ethylbenzene, methanol, methyl ethyl ketone, methyl isobutyl ketone, ethylene glycol, and glycol ethers in surface coating operations. In general the regulation specifies VOHAP content limits on marine coatings, work practice standards, record keeping and reporting. This section focuses on pollution prevention methods that can be implemented in work practice standards. The EPA manual "A Guide Book on How to Comply with the Shipbuilding and Ship Repair (Surface Coating) Operations National Emission Standards for Hazardous Air Pollutants" [1]mentions six pollution prevention options which can be included as work practice standards in a facility-specific implementation plan:

- more efficient paint application equipment
- operator training,
- reformulated marine coatings
- recycling cleaning solvents
- alternate cleaning materials
- containment around storage areas for VOC/VOHAP-containing materials

This section will provide technology summaries of high transfer efficiency paint equipment, and low VOC coating technologies[2]. Alternate cleaning materials and recycling of cleaning solvents will be discussed in Section 4.3.

4.2.1.1 Technical Reports

The following is a list of valuable reports that provide information on regulations and pollution prevention technologies related to the surface coating industry. Some of these documents are used as references in the Technology Data Sheets but all technologies mentioned are not included, therefore it is worth obtaining these documents for review.

U.S. EPA. **"Guide to Cleaner Technologies Organic Coating Replacements".** EPA/625/R-94/006. September 1994.

This guide is designed to provide sufficient information to users to help in selecting one or more candidate cleaner technologies (i.e. lower VOC content or no VOC

[1] U.S. EPA. "A Guidebook on How to Comply with the Shipbuilding and Repair (Surface Coating Operations) National Emission Standards for Hazardous Air Pollutants". EPA/453/3-97-001. January 1997.
[2] Transfer efficiency is defined as either the mass of solid coating deposited divided by the mass of solid coating used or by the volume of solid coating deposited divided by the volume of solid coating used.

content) for further analysis and in-plant testing. Several available as well as emerging coating technologies are discussed, including the following:

Available	Emerging
high solids coatings, solvent borne	vapor injection cure coatings
powder coatings	supercritical carbon dioxide as solvent
waterborne coatings	radiation induced thermally-cured coatings
electrodeposition	
UV/EB radiation-cured coatings	

Discussions on these technologies are broken down into several areas including: pollution prevention benefits, how the technology works, operating features, curing, applications, cost, benefits, limitations, state of development and references. Once the technologies have been reviewed one can go to the list of trade and technical organizations in the last section of the EPA Guide to obtain additional information and vendor contacts. The guide can be ordered for free from the National Center for Environmental Publications and Information (see Section 2.1 of this report for ordering information).

U.S. EPA. **"A Guidebook on How to Comply with the Shipbuilding and Ship Repair (Surface Coating) Operations National Emission Standards for Hazardous Air Pollutants".** EPA 453/B-97-001. January 1997.

This guidebook provides a straightforward overview of NESHAP regulations and provides facilities with the basic information needed to comply with the regulation. Specific areas covered are discussed at the beginning of this section. This document was ordered from National Technical Information Service at a cost of $32.00 (see Section 2.1 of this report for ordering information).

U.S. EPA. **"Alternate Control Techniques Document: Surface Coating Operations at Shipbuilding and Ship Repair Facilities".** EPA 453/R-94-032. April 1994.

This report provides alternative control techniques (ACT) for State and local agencies to consider for incorporating in rules to limit emission of volatile organic compounds (VOCs) and particulate matter including PM_{10} that otherwise result from surface coating operations at shipbuilding and ship repair facilities. This document contains information on emissions, controls, control options, and associated costs. This document has been amended by an additional document to make it the "**Control Techniques Guidelines (CTG) for Shipbuilding and Ship Repair Operations (Surface Coating)"**.

You can download both documents from the EPA Technology Transfer Network (TTN). Dial (919) 541-5742 for data transfer of up to 14,400 bits per second, or access via the Internet at http://www.epa.gov/oar/ttn_bbs.htm. You can also order the ACT document from NIST for a cost of $38.00 (see Section 2.1 of this report for ordering information).

The CTG establishes VOC content restrictions on as-supplied and as-applied marine coatings. The control measures outlined in The Control Techniques Guidelines must be implemented by the states by August 1997. Additionally, major shipyard sources must be in compliance with the new State VOC rules by August 1998.

U.S. EPA. "**Manual Pollution Prevention in the Paints and Coatings Industry"**. EPA/625/R-96/003. September 1996.

This manual presents recommended practices for minimizing the generation of pollution in the paints and coatings industry. The information in this manual can help operators access operations and processes for pollution prevention options in using "cleaner" technologies and more efficient management practices. The manual has three major sections: 1) an overview of the industry and an introduction to pollution prevention for paints and coating operations, 2) pollution prevention considerations, and 3) case studies emphasizing approaches for reducing process waste. This is a very good summary that would be useful to environmental managers looking for pollution prevention technologies and practices to implement in shipyard coating operations. The guide can be ordered for free from the National Center for Environmental Publications and Information (see Section 2.1 of this report for ordering information).

U.S. EPA. **"Proceedings: Pollution Prevention Conference on Low- and No-VOC Coating Technologies".** EPA-600/R-94-022. February 1994.

This report documents a conference that provided a forum for the exchange of technical information on coating technologies. It focused on improved and emerging technologies that result in fewer volatile organic compound (VOC) and toxic air emissions than traditional coating emissions. Several excellent papers and presentations are provided that cover powder coatings, supercritical fluid spray coatings, and radiation curing technology, to name a few. This document can be ordered from NIST at a cost of $61.00 (see Section 2.1 of this report for ordering information).

4.2.1.2 Vendor Information

Steel Structures Painting Council

The Steel Structures Painting Council (SSPC) can be contacted to obtain vendor information and additional information on coating technologies. The SSPC contact information is provided in Section 2.2 of this report.

Journal of Protective Coatings and Linings

This Journal has vendor information as well as articles pertinent to the paintings and coatings industry. See Section 2.2 of this report to find out how to obtain a subscription.

4.2.1.3 On-going Technology Projects

This first three project reviews are obtained from the following reference:

U.S. Army Tank-Automotive and Armaments Command Industrial Ecology Center. **"Pollution Prevention Environmental Technology".** Picatinny Arsenal, NJ 07806-5000. February 1997.

1. **Unitized Coating Application Facility: E-Coat and Powder Coat**

This project is funded by NDCEE to investigate paint application technologies that reduce VOC emissions and improve coating quality. The project will first identify present processes and perform research on state-of-the-art techniques. Then a demonstration facility will be developed and transitioned to Letterkenny Army Depot. A more detailed review of this project is provided at the NDCEE Internet site at http://www.ndcee.ctc.com/n002-6.htm.

2. Supercritical CO_2/ Replacement for Solvent in Spray Applied Coatings

This project is also funded by NDCEE. The goal is to develop UNICARB coatings, using existing Military Specifications, and application equipment for DoD applications that would include antifouling coatings, epoxy primers and urethanes. They are interested in implementing the UNICARB system in shipyards, maintenance facilities, and depots as well as transitioning this technology into the commercial industry.
Contact: NDCEE for more information. See Section 2.3 of this report.

3. Paint Handling and Spray Equipment Testing, Evaluation and Training

The objective of this project is to evaluate and test advanced paint handling and spray equipment for use in military industrial facilities that will reduce environmental discharges associated with painting operations, comply with EPA regulations, and improve productivity. The NDCEE will act as a non-biased third

party to evaluate the various technologies against DoD requirements using latest industry innovations. This project is funded by NDCEE. A more complete review of this project is provided on the NDCEE web site at http://www.ndcee.ctc.com/n023.htm.

4. SERDP Proposal ID# 756 **"Fluorinated Ship-Hull Coatings for Non-Polluting Fouling Control"**
Internet Address: http://es.inel.gov/new/funding/serdp/p2proj005.html

The specific objective of this project is to develop a nontoxic, zero discharge coating that protects ship-hulls from marine fouling organisms. The technical objectives are to:

- Simulate adsorbed fluorinated monolayers either by grafting perfluoroalkyl molecule to surfaces, by embedding perfluoroalkyl compounds into the surface of polymeric matrices, or by synthesizing comb type polymers with perfluorinated side-chains for maximum effectiveness;
- Determine the minimum amount of perfluorinated additive needed for optimum performance;
- Reduce the amount of the expensive perfluorinated moiety by polymerization of block-polymerization with non-fluorinated monomers to reduce cost;
- Verify the effectiveness of the perfluorinated polymeric materials against the adhesion of marine fouling organisms.

5. SERDP Proposal ID# 065 **"Organic Protective Coatings and Application Technology"**
Internet Address: http://es.inel.gov/new/funding/serdp/p2proj006.html

The project objective is to develop high performance, non-toxic, low volatile organic compound (VOC) content coatings for Navy use. The investigation in low VOC polymer technology will be used to produce low VOC binder systems. Reactive monomers/oligomers and diluents will be developed to obtain low viscosity, low VOC binder systems for future organic coatings. In addition, recent advances in water-borne resin technology will allow for the development of high performance water-borne topcoats that are compliant with these regulations. Coating corrosion resistance, physical performance properties and VOC content will be evaluated to develop the best materials. Furthermore low/no VOC protective coatings (such as electrocoatings, powder coatings, bearing adhesives, fuel cell repair, NDI penetrants, etc.) will be investigated for potential aerospace applications. Several recently developed VOC compliant, non-toxic alternative materials will be investigated for this program. These compliant coating systems include Unicoat (a non-lead, non-chromate, low VOC self-priming topcoat); compliant lacquer topcoats and non-toxic inhibitor systems. The non-toxic inhibitor systems will be used to develop replacements for the current lead and chromate containing materials. These materials will be optimized, service evaluated and implemented for Navy use. Finally, conventional air spray equipment used to apply these materials, has a transfer efficiency of only about 28%. Therefore, implementing high transfer efficient spray equipment would significantly reduce the

amount of air emissions from painting operations. Application equipment such as air-assisted airless, electrostatic, and high volume low pressure (HVLP) will be evaluated.

4.2.1.4 Technology Data Sheets

These Technology Data Sheets cover both low VOC coating technologies and high transfer efficiency paint application equipment. The coating technologies summarized include powder coatings and the UNICARB^{R} coating system. The high transfer efficiency spray equipment summarized are airless, air-assisted airless, electrostatic and high volume, low pressure (HVLP).

Surface Coating Pollution Prevention Data Sheets

Technology

Powder Coatings

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Powder technology, as a group, is the fastest growing coating technology in the organic coatings market. In fact, in some industry sectors it is rapidly competing with and penetrating the liquid coatings applications market [1]. Powder coatings use no solvents and essentially do not contribute to air, water, or hazardous waste pollution. They also offer cost advantages over either solvent or waterborne liquid technologies for many applications [1].

In powder coatings each discrete powder particle contains the entire coating formulation which includes the resins, pigments, fillers and modifiers. The powder coating process has two steps: (1) applying the coating onto a pretreated part and (2) curing the coated part in an oven. There are four different methods to apply the powder coating: electrostatic attraction by corona discharge, electrostatic attraction using tribo-charging guns, fluidized bed and flame spraying. The parts are then cured in either a convection oven at a temperature between 325 to 400 deg F or in an infrared oven.

In general, powder coatings are ideal for metal parts that have relatively simple geometries and surfaces that are all reasonably accessable and small enough to fit into an oven [1]. The final coating is extremely hard and abrasion resistant, and exhibits excellent physical properties. Depending on the coating system, the coating can also be resistant to chemicals, solvents, sunlight, and most of the other chemical properties that are associated with high-performance coatings [1].

NDCEE has a powder coating facility to demonstrate the feasability of using powder coating for your application. Operators and engineers will study process parameters for finish quality, film thickness, edge coverage, corrosion resistance, and mechanical properties such as impact resistance, hardness, and abrasion resistance to find the best coating application for your parts [2]. You can contact NDCEE at the phone number listed below.

References [1] and [3] in the Contact Section of this Technology Data Sheet provide additional information regarding powder coatings including costs associated with powder coatings and profiles of the economic impact of switching to powders.

Technology (con't)

Powder Coatings

Pollution Prevention Benefits

- up to 99% of overspray is recycled (NDCEE demonstration unit)
- emissions of almost zero VOC content (0.5 to 5% by weight)
- minimum generation of hazardous waste

Advantages

*- excellent physical performance properties
- many powders have excellent machinability
- excellent salt spray resistance
- operators can coat sharp edges and cut ends
- can provide thin to heavy film builds in one application (usually requires no primer)
- masking may not be required

*All advantages obtained from [1]

Disadvantages

* - high energy usage
- requires skilled operator
- often requires manual touch-up
- difficult to achieve high film thicknesses (greater than 5 mil) unless part heated
- capital equipment more expensive than conventional equipment

* All disadvantages obtained from [1]

Contact:

- contact NDCEE if you are interested in their assistance in evaluating this technology for your shipyard (814) 269-6425
- see Joint Services P2 Technical Library for vendors
  Internet Address: http://enviro.nfesc.navy.mil/p2library then goto Painting then to Powder Coatings

References:

[1] U.S. EPA. "Manual - Pollution Prevention in the Paints and Coatings Industry". EPA/625/R-96/003. September 1996.
[2] Concurrent Technologies Corporation. "Equipment Demonstrations- Organic Finishing - Powder Coating". Promotional Literature.
[3] Brown, L. "Aerospace Applications for Powder Coating at Hughes Aircraft Company." In Proceedings: Pollution Prevention Conference on Low and No-VOC Coating Technologies. EPA-600/R-94-022. February 1994.

Technology

UNICARB System

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

This is a new alternative spray painting technique developed by Union Carbide that uses supercritical carbon dioxide (CO2) as a replacement to traditional hazardous solvents in paint formulations. This technique not only reduces VOC emissions released during painting operations but increases the paint transfer efficiency over traditional methods [1]. Supercritical CO2 when heated to its critical temperature (approximately 31 deg C) and compressed to its critical pressure (approximately 1070 psi) acts like solvent and can be used for thinning viscous coatings to the desired level for application. VOC emissions can be reduced by up to 80% using this method [2].

Supercritical CO2 is compatible with a wide variety of thermoplastic and thermosetting polymers, and can be used with ultraviolet coatings, waterborne coatings, and two-package systems (vehicle plus curing agent). The CO2 process has been used on metal, wood, plastics, and in some commercial applications, including automotive topcoats and components, aircrafts, and appliances [1].

The supercritical carbon dioxide system requires investment into new equipment for paint mixing, handling, and spraying. The application equipment includes a mixing unit, where the gaseous CO2 is heated to supercritical temperature and pressurized immediately prior to being added to the paint. The liquid CO2 is mixed with the paint and applied immediately by manual or automatic electrostatic and nonelectrostatic spray guns or robots [1].

NDCEE is currently funded to develop the UNICARB system for use in DoD applications. Their goal is to implement the UNICARB system into shipyards, maintenance facilities, and depots. Please see Section 2.3 of this report for information on how to contact NDCEE for more information.

The Institute of Local Self-Reliance (ILSR) also has a POLLUTION SOLUTIONS Fact Sheet (Fact Sheet 28) describing the costs of the UNICARB system and sample studies where this process has been used in industry. At the time of this report this Fact sheet was not yet available via the Internet but you can email Michelle Carstensen at michelle@ilsr.org to obtain the fact sheet and additional information or check the ILSR Internet Address to see if this Fact sheet has come online. The Internet Address is http://www.ilsr.org. Also check reference [3] for more detailed information on this technology.

Technology (con't)

UNICARB System

Pollution Prevention Benefits

- reduces the emissions of VOCs into the atmosphere
- increases paint transfer efficiency thus reducing solid waste generation
- less toxic than conventional organic solvents

Advantages

- creates more uniformly sized paint particles that are more evenly distributed through the spray fan, yielding higher quality films and minimizing overspray [1]
- allows for a high film build without running or sagging or a low film build that is uniform and continuous [1]
- more economical because it provides more coverage per gallon than conventional solvents
- nonflammable and mostly inert

Disadvantages

- N/A

Contact:

- Rick Woods
  Union Carbide
  (203) 794-2522
- see Section 2.3 for NDCEE project contact for this technology

References:

[1] The Institute for Local Self-Reliance. POLLUTION SOLUTIONS. "UNICARB System for Spray Paint Applications in the Automotive Industry". 1997. Internet Address http://www.ilsr.org.
[2] U.S. EPA. "Guide to Cleaner Technologies Organic Coating Replacements". EPA/625/R-94/006. September 1994.
[3] Miller, P. and Morrison, T. "Supercritical Fluid Spray Application of Low-Pollution Coatings for Plastic Substrates." In Proceedings: Pollution Prevention Conference on Low- and No-VOC Coating Technologies. EPA-600/R-94-022. February 1994.

Technology

Air-assisted Airless Spray

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

"The principle of this spray gun is very similar to that of the airless gun in that high fluid pressures force the coating through a small orifice in the spray gun cap. The gun differs from the airless spray gun in that the fluid pressures are only 300 to 1,000 psi. These pressures, however, poorly atomize the top and bottom of the fan. Morover, streaks or "tails" appear at the extremities. To eliminate the "tails", low-pressure air emerges from separate orifices in the horns of the cap to force the "tails" back into the main portion of the pattern. The low-pressure air, 10 to 20 psi, does not atomize the coating particles, and therefore the gun differs considerably from the conventional air atomizing gun. The air-assisted airless gun is currently the most popular type used in a wide range of industries. While it can handle relatively high fluid flow rates and therefore keep up with fast moving conveyor lines, it can also be adjusted for slow moving lines. Operators commonly use this gun to coat medium- and large-size targets, and in some cases to coat small parts, providing suprisingly appealing finishes." [1]

Technology (con't)

Air-assisted Airless Spray

Pollution Prevention Benefits

- reduces air, water and hazardous waste pollution due to improved paint transfer efficiency

Advantages

*- low coating usage
- fair to good operator control on air pressure
- few runs and sags in painted surface
- good atomization

*All advantages obtained from [2]

Disadvantages

*- high equipment maintenance
- expensive fluid tips
- poor operator control on fluid pressure
- not suitable for high-quality surface appearance"

*All disadvantages obtained from [2]

Contact:

- see the vendor list in Appendix B for a partial list of vendors or view the vendor references given in Section 4.2.1.2.

References:

[1] U.S. EPA. "Manual: Pollution Prevention in the Paints and Coatings Industry". EPA/625/R-96/003, pages 80-81. September 1996.
[2] U.S. EPA. "Alternative Control Techniques Document: Surface Coating Operations at Shipbuilding and Repair Facilities". EPA/453/R-94-032, page 2-28. April 1994.

Technology

Airless Spray Systems

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

"With an airless spray system a hydraulic pump siphons the coating out of a reservoir such as a 55 gallon drum and then pumps the coating, usually under pressures of 1,000 to 3,000 psi, to the spray gun. The coating atomizes as it passes through the small orifice (0.011 to 0.074 inches) in the cap of the gun. The size and shape of the orifice determine the degree of atomization and the shape and width of the fan pattern. Moreover, a large orifice permits a higher fluid flow rate than a small orifice" [1]. The EPA associates a transfer efficiency of approximately 40% with this gun but considerably higher values are obtainable [1]. This method is most effective on large objects because high fluid pressures in the system are effective in depositing large quantities of coating quickly.

Technology (con't)

Airless Spray Systems

Pollution Prevention Benefits

- reduces air, water and hazardous waste pollution due to improved transfer efficiency

Advantages

*- most widely used
- low air usage (uses hydraulic pressures)
- high-volume material output
- limited overspray fog
- large spray patterns and high application speeds
- can apply heavy viscous coatings
- excellent for large surfaces
- good transfer efficiency on large surfaces

*All advantages obtained from [2]

Disadvantages

*- uses high volume of air
- expensive fluid tips
- high equipment maintenance
- difficult to mix some high viscosity materials
- min. operator control during operation
- system not very flexible
- not suitable for high-quality surface appeaerance
- pressurized system can cause injuries to operator if not used w/adequate caution

*All disadvantages obtained from [2]

Contact:

- see vendor listing in Appendix B for a partial listing of vendors or view the vendors references given in Section 4.2.1.2.

References:

[1] U.S. EPA. "Manual: Pollution Prevention in the Paints and Coatings Industry". EPA/625/R-96/003, page 80. September 1996.
[2] U.S. EPA. "Alternative Control Techniques Document: Surface Coating Operations at Shipbuilding and Repair Facilities". EPA/453/R-94-032, page 2-28. April 1994.

Technology

Electrostatic Paint Spray Process

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

In an electrostatic spray system the gun imparts an electric charge to the coating particles as they emerge from the spray gun nozzle. Prior to painting, the workpiece must be well grounded. The negatively charged atomized paint particles and the grounded workpiece then create an electrostatic field that draws the paint particle to the workpiece. This process minimizes overspray and results in a typical transfer efficiency of 75% [1].

Electrostatic guns can utilize one of the following conventional atomizing technologies in their design: conventional air, airless, air-assisted airless and HVLP [2]. High-speed discs can also be used to atomize the paint. This technology atomizes the coating more finely than air atomization and directs more paint to the target [1].

One potential problem with electrostatic paint spray systems is the Faraday cage effect which is a tendancy for charged coating particles to deposit around entrances to cavities [1]. High particle momentum can help overcome Faraday cage effects but this results in lower transfer efficiency.

Electrostatic spray systems can work with any material that can be atomized, regardless of the coating conductivity. The workpiece must be groundable such as metal. Some wooden pieces can be painted electrostatically but plastic, rubber, ceramic, and glass cannot [1].

An economic analysis of this technology and a vendor listing is provided by the Joint Services Pollution Prevention Library at the Internet address provided in the Contact Section of this Technology Data Sheet.

Technology (con't)

Electrostatic Paint Spray Process

Pollution Prevention Benefits

- reduces air, water and solid waste due to improved paint transfer efficiency

Advantages

- high transfer efficiency so less paint used and wasted
- less maintenance required for pollution control equipment serving a paint booth employing this process

Disadvantages

- high capital cost
- more spray equipment maintenance required compared to other methods
- electric charges tend to repel on complicated surfaces
- Faraday cage effect
- surface imperfections are possible due to air molecules being trapped in the coating surface

Contact:

- see the Joint Services P2 Technical Library for vendors and for an economic analysis of this technology
  Internet Address: http://enviro.nfesc.navy.mil/p2library then look under Painting for Electrostatic Paint Spray System

References:

[1] Joint Services P2 Technical Library. "Electostatic Paint Spray System". September 1996.
[2] U.S. EPA. 'Manual: Pollution Prevention in the Paints and Coatings Industry". EPA/625/R-96/003. September 1996.

Technology

HVLP Air Atomizing Spray Guns

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

The high volume, low pressure (HVLP) gun atomizes the coating through a high volume of air delivered at a low pressure (less than 10 psi). There are several methods which are used to generate the high volume, low pressure air. Traditionally, the most common method used a high speed turbine that drew large volumes of air directly from the surrounding space. This turbine pushed the high volume of air though a large diameter hose to the spray gun. Air was heated during the process which benefited the coating application. More recently, a new version is available that does not require a turbine to generate the high volume of air. Low volume, high pressure shop air is now converted directly by means of venturies or regulators. Typically, the incoming shop air is 80 to 100 psi, while the air emerging from the cap of the spray gun is less than 10 psi [1]. These new guns can directly replace conventional air atomizing spray guns without any new capital expenditures [1]. Sometimes in-line heaters are included with the new systems to heat the air as the old systems did.

These guns are very effective at coating small, medium and large parts. There is potential concern if used in high-production lines due to its slow paint application rate but HVLP can successfully atomize a wide range of coatings (some rheologies do not atomize well) [1]. Transfer efficiencies on the order of 50-65% are quoted [2].

An economic analysis for using HVLP sprayers compared to other methods is provided in the Joint Services P2 Technical Library as well as a list of vendors of this equipment. See the Contact Section of this Technology Data Sheet to obtain the Internet Address to view this data.

Technology (con't)

HVLP Air Atomizing Spray Guns

Pollution Prevention Benefits

- reduces air, water and hazardous waste pollution due to improved paint transfer efficiency

Advantages

*- low blowback and spray fog
- good transfer efficiency
- portable (totally self-contained equipment)
- easy to clean
- overall time and cost savings
- can be used for intricate parts
- good operator controls on gun

*All advantages obtained from [3]

Disadvantages

*- high initial cost
- slower application speed (controversial)
- does not finely atomize some high-solids coating materials (controversial)
- high cost for turbine maintenance
- requires more operator training than conventional
- still relatively new to the market
- some very high solids products not sprayable by HVLP

*All disadvantages obtained from [3]

Contact:

- see Joint Services P2 Technical Library for vendors and for an economic analysis of this technology
  Internet address: http://enviro.nfesc.navy.mil/p2library then look for Painting then High Volume Low Pressure Paint Spray System

References:

[1] U.S. EPA. "Manual: Pollution Prevention in the Paints and Coatings Industry". EPA/625/R-96/003. September 1996.
[2] Joint Services P2 Technical Library. "High Volume Low Pressure Paint Spray System". September 1996.
[3] U.S. EPA. "Alternative Control Techniques Document: Surface Coating Operations at Shipbuilding and Repair Facilities". EPA/453/R-94-032, page 2-28. April 1994.

4.2.2 Pollution Treatment Methods

A reduction of VOC emissions during surface coating operations can be achieved through three main methods: using low VOC coatings, using improved paint transfer equipment and by installing add-on control equipment that captures and then destroys or reclaims VOCs. Section 4.2.1 discussed the first two options while this section covers innovative treatment and capture devices. Unfortunately most surface coating operations in U.S. shipyards do not lend themselves to efficient capture and treatment of VOCs during coating operations. This coupled with high cost has led the industry toward improved coatings and better paint transfer equipment[1]. However, U.S. shipyard coating operations performed in paint booths can potentially utilize the technologies discussed in this section if VOC treatment is necessary in your area.

There are several innovative treatment technologies that have been identified through a joint study by the Air Force Engineering Services Center (AFESC) and the EPA's Air and Energy Engineering Research Laboratory (AEERL) for minimizing emissions of VOCs and HAPs from paint spray booths. The technologies that will be discussed in this section include Regenerative Thermal Oxidation (RTO), regenerative incineration, carbon adsorption/incineration, Carbon Paper Adsorption/Carbon Incineration (CPACI) and Fluidized Bed Catalytic Incineration (FBCI). These summaries are provided along with the well known technologies carbon adsorption and catalytic incineration. These standard technologies are included because several of the innovative technologies mentioned above include these as a portion of their hybrid systems. Much of the information provided in the technology summaries is from the joint AFESC and AEERL study report described below in Section 4.2.2.1.

One other capture and treatment method is applicable to this section. It is the CAPE system developed and currently utilized by Metro Machine to enclose and capture emissions from blast cleaning and painting ship hulls in dry dock. Please see the CAPE Technology Data Sheet on page 58 for a description of this system.

4.2.2.1 Technical Reports

Ritts, D., Garretson, C., Hyde, C., Lorelli, J., Wolbach, D. **"Evaluation of Innovative Volatile Organic Compound and Hazardous Air Pollutant Control Technologies for U.S. Air Force Paint Spray Booths",** ESL-TR-89-51. October 1991.
This document can be obtained from NTIS at the contact information provided in Section 2.1 of this report.

This report summarizes information gathered on innovative emission control technologies that can cost effectively lower or eliminate VOC and HAP emissions from a typical United States Air Force (USAF) paint spray booth[2]. The study

[1] U.S. EPA. "VOC Emission Control Technologies For Ship Painting Facilities - Industry Characterization", page iv, EPA/600/2-81-131. July 1981.

[2] A technology was considered innovative if it combined two or more separate technologies, or it incorporated new designs that allowed it to achieve greater VOC and HAP removal or destruction, as well as higher efficiences that conventional treatment technologies.

focused on controlling emissions from paint booths in which solvent-based epoxy primers and polyurethane topcoats are normally used. The primary VOCs treated were methyl ethyl ketone, ethyl acetate, methoxyacetone, 4-methyl-2-pentanone (MIBK), toluene, butyl acetate, ethylbenzene, xylenes, 2-ethoxyethyl acetate, and 2-methoxyethoxy-ethanol. Although the study was performed for emissions from USAF paint booths the results are applicable to commercial booths.

Information gathered from a vendor survey indicated RTO, regenerative incineration, membrane vapor separation/condensation, carbon adsorption/incineration, CPACI and FBCI technologies might successfully be applied to USAF paint booths. Of these, CPACI and FBCI were field tested and found to achieve VOC destruction and removal efficiencies of 99% during normal operating conditions and were recommended to be used for economically and effectively controlling VOC emissions from USAF paint booths.

Review this report if you would like more information comparing the costs of the technologies mentioned above and if you would like more detailed information on CPACI and FBCI technologies and the field-tests that were performed with them.

U.S. EPA. **"Handbook - Control Technologies for Hazardous Air Pollutants".** EPA/625/6-91/014. June 1991.

This handbook presents a methodology for determining the performance and cost of air pollution control techniques designed to reduce or eliminate the emissions of potentially hazardous air pollutants from industrial/commercial sources. This document provides general technical guidance on controls but does not provide guidance for compliance with specific regulatory requirements for HAPs. The design and cost of the following HAP control techniques is provided: thermal incineration, catalytic incineration, flares, boiler/process heaters, carbon adsorption, absorption, condensers, fabric filters, electrostatic precipitators, and venturi scrubbers. Although this is written to be used by EPA personnel in evaluating air quality permits it is a useful guide describing the important design factors of these technologies and their associated costs. You can obtain a copy of this handbook from NCEPI for no cost (see Section 2.1 of this report for ordering information).

Snider, T. **"An Analysis of Air Pollution Control Technologies for Shipyard Emitted Volatile Organic Compounds (VOCs)"**. NSRP 0376. March 1993.

This report describes air pollution control techniques that can be implemented in shipyards to reduce VOC emissions and evaluates the application of these devices to shipyard operations. Incineration, oxidation, adsorption, absorption, condensation and hybrid systems (including FBCI and CPACI) are discussed along with specific examples and applications. A cost comparison of these technologies is also provided. A copy of this document can be obtained from the National Shipbuilding Research and Documentation Center (see Section 2.1 for ordering information).

4.2.2.2 Vendor Information

Environmental Protection

Environmental Protection is published monthly and provides management and problem-solving articles for environmental professionals. Once a year a Buyer's Guide is published which is useful to obtain vendor information on environmentally related issues. See Section 2.2 for contact information.

Pollution Equipment News

Pollution Equipment News is published monthly and provides information to environmental managers on pollution equipment for air, water, and hazardous waste. It is a free subscription and comes with a yearly Buyer's Guide full of vendors in the pollution equipment industry. See Section 2.2 for contact information.

4.2.2.3 Technology Data Sheets

The following technologies are summarized in the technology data sheets:, carbon adsorption, carbon adsorption/incineration, CPACI, catalytic incineration, FBCI, regenerative incineration, RTO.

Surface Coating VOC Treatment Data Sheets

Technology

Carbon Adsorption

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Adsorption is a removal technology that involves the physical adhesion of molecules to adsorbant surfaces. During the adsorption process organic molecules collect onto the sorbant surface as the gas stream passes through the adsorbant bed. Adsorbed VOCs are removed from the carbon bed by heating to a sufficiently high temperature (usually via steam) or by reducing the pressure to a sufficiently low value (vacuum desorption) [1]. These desorbed VOCs are then destroyed (e.g., destruction in an incineration device) or reused (e.g., reuse of solvents to clean equipment used in the coating operation).

At equilibrium, the quantity of HAP in a gas stream that is adsorbed on activated carbon is a function of the adsorption temperature and pressure, the specific compound being adsorbed, and the carbon characteristics (e.g., pore size and structure). The size of a carbon adsorption system depends on four parameters: (1) the volumetric flow rate of the VOC laden gas stream, (2) the mass loading of VOC, (3) the adsorption time and (4) the working capacity of the carbon bed.

A carbon adsorption system may have difficulties when controlling emission streams containing ketones (e.g., acetone, methyl ethyl ketone). Ketones exothermically polymerize on the carbon bed, clogging the pores on the surface of the carbon contained in the vessel. This decreases the system efficiency and may cause fire if carbon is dry [1].

Carbon adsorption is usually a batch operation and can involve multiple beds. The most common adsorption systems are fixed regenerative beds and disposal/rechargable canisters. Fixed bed regenerative units are used to control continuous VOC laden streams with flow rates ranging from about 2,000 acfm to 200,000 acfm. These units can efficiently operate at concentrations in the low ppmv range or as high as 25% of the compound's lower explosion limit (LEL). Carbon canister systems are normally used for control of intermittant lower volume air streams and are generally employed on sources where the expected volume of VOC recovered is small [1]. Carbon canister systems cannot be desorbed at the site, and must be either land filled, or shipped back to the vendor's central facility for desorption.

For cost evaluations please refer to reference [1] which will guide you through calculations to determine the costs associated with carbon adsorption systems for your waste stream treatment.

Technology (con't)

Carbon Adsorption

Pollution Prevention Benefits

- removes VOCs emitted during surface coating operations

Advantages

*- potential for high control efficiencies with optimal blend of VOCs and high concentration of VOCs
- lower fuel cost compared to incineration systems
- ability to recover and reuse VOC solvents

*advantages have been obtained solely from [2]

Disadvantages

* - adsorption media can become fouled and ineffective w/o the knowledge of the operator
- humidity can alter the efficiency of the adsorption media and can generate organic acids that effect the system
- keytones in the airstream present a fire hazard due to their high heat of adsorption. If heat not dissipated, bed of carbon might ignite.

*disadvantages have been obtained solely from [2]

Contact:

- see the vendor list in Appendix B for a partial list of vendors or view the vendor references given in Section 4.2.2.2

References:

[1] U.S. EPA "Control Technologies for Hazardous Air Pollutants". EPA/625/6-91/014. June 1991.
[2] Snider., J. "An Analysis of Air Pollution Control Technologies for Shipyard Emitted Volatile Organic Compounds (VOCs)". NSRP 0376. March 1993.

Technology

Carbon Adsorption/Incineration

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Carbon adsorption/incineration is an innovative solvent destruction technology that combines the following technologies together: adsorption with granular activated carbon, thermal regeneration with hot gases and controlled oxidation. These systems can treat hydrocarbons and chlorinated hydrocarbons as well as oxygenated solvents. The overall emission control efficiency of these systems is 95-99% while operating at design temperatures from 1450 to 1650 deg F. The residence time is on the order of regenerative thermal oxidation systems at 1.0 second. Flow rates from 1,000 to 50,000 scfm and VOC concentrations ranging from 1 to 500 ppmv can be treated with these systems. Lastly, these systems require natural gas, electric power, air and activated carbon for operation. A comparison of capital, installation, total and annual operating costs for this system compared with FBCI, RTO, CPACI and regenerative incineration is provided in [1]. The information contained in this summary is solely obtained from [1].

Technology (con't)

Carbon Adsorption/Incineration

Pollution Prevention Benefits

- destroys VOCs emitted during surface coating operations

Advantages

- can handle flucuations in VOC loadings
- low energy costs

Disadvantages

- needs additional air pollution control equipment for treatment of halogenated solvents
- system is large
- system is expensive

Contact:

- vendor sources to search for this technology are given in Section 4.2.2.2

References:

[1] Ritts, D., Garretson, C., Hyde, C., Lorelli, J., and Wolbach, D. "Evaluation of Innovative Volatile Organic Compound and Hazardous Air Pollutant Control Technologies for U.S. Air Force Paint Spray Booths", ESL-TR-89-51. October 1991.

Technology

Carbon Paper Adsorption/Catalytic Incineration

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Carbon Paper Adsorption/Catalytic Incineration (CPACI) is a hybrid system that combines carbon adsorption and catalytic incineration. This system can treat waste gas streams of hydrocarbons and oxygenated solvents. The carbon cleans the air stream while the catalytic incinerator is used to destroy the VOCs desorbed from the carbon adsorption system. Full-scale CPACI units are available in sizes that treat waste gas flow rates from 350 to 105,000 scfm and VOC concentrations from 5 to 500 ppmv. This technology includes the following equipment: rotating carbon paper adsorber, a catalyst bed, heat exchangers and a natural gas burner. Other equipment includes fans, burners, valves, control panels, safety devices and other miscellaneous items common to incineration devices.

Air emissions from the paint booth are first passed through a particulate filter, then through a granular activated carbon filter. Next, the air flows through a carbon paper filter that is fashioned into a cylindrical, continuously turning rotor. The honeycombed structure of the filter allows for a high VOC removal efficiency. Paint spray booth emissions pass through one end of the cylinder. However, air passes through only about seven-eighths of the area at the end of the carbon paper rotor before exhausting to the atmosphere. The remaining one-eighth of filter area is used in the incineration loop of the CPACI technology. The design operating temperature for the device is 700 degrees F with a residence time of 0.25 seconds at that temperature.

CPACI was found to be effective and economical in controlling VOC emissions from a USAF paint spray booth at McClellan Air Force base through field testing of a Metro-Pro Corporation pilot-scale unit. This technology has been in operation over 10 years and has over 30 units installed worldwide. CPACI treatment systems will require periodic filter and catalyst replacement, and regeneration of carbon adsorption paper and granular activated carbon. The treatment costs per lb of VOCs destroyed is lower than that of standard air pollution control technogies such as recuperative thermal incineration and regenerable carbon adsorption with catalytic incineration. A comparison of capital, installation, total and annual operating costs for this system compared with FBCI, RTO, carbon adsorption/incineration and regenerative incineration is provided in [1]. The information contained in this summary is solely obtained from [1].

Technology (con't)

Carbon Paper Adsorption/Catalytic Incineration

Pollution Prevention Benefits

- destroys VOCs from surface coating operations

Advantages

- high VOC destruction removal efficiency
- low operating costs
- installation quick and inexpensive

Disadvantages

- needs additional air pollution control devices for treatment of halogenated solvents

Contact:

- see the vendor listing in Appendix B for a partial list of vendors or view the vendor references given in Section 4.2.2.2

References:

[1] Ritts, D., Garretson, C., Hyde, C., Lorelli, J., and Wolbach, D. "Evaluation of Innovative Volatile Organic Compound and Hazardous Air Pollutant Control Technologies for U.S. Air Force Paint Spray Booths", ESL-TR-89-51. October 1991.

Technology

Catalytic Incineration

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Catalytic incineration destroys HAPs by chemically altering them with the aid of a catalyst. The catalyst accelerates the rate of chemical reaction without undergoing a chemical change itself. This accelerated rate of reaction results in reduced residence time (which is on the order of a few hundreds of a second) and lower operating temperatures (500-900 deg F) in comparison to thermal incineration methods. It is very suitable to waste gas streams containing low to moderate concentrations of HAPs. Materials such as arsenic, mercury, phophorous, sulfur and halogens can poison catalytic metals [1] so catalytic incineration is not recommended if these materials are present in the waste stream unless treatment for these materials is provided upstream of the catalytic incinerator. With catalytic incineration the waste gas stream is heated prior to entering the catalyst bed (requiring supplemental fuel). This is done to bring the gas stream temperature to that required by the catalyst to be effective at oxidizing the constituents in the gas stream.

Catalytic incinerator performance is affected by several factors including operating temperature, space velocity, VOC concentration and composition, catalyst properties, and the presence of poisons/inhibitors in the emission stream.

Typical catalysts used for VOC incineration include platinum and palladium, among others [2]. Catalysts beds come in many different forms including metal mesh-mat, ceramic honeycomb or in the form of spheres or pellets [2]. Advances in catalyst research has broadened the applicability of catalytic incineration to treat sulfurs and chlorine containing compounds [2]. These new catalysts are often single or mixed metal oxides and are supported by a mechanically strong carrier. Catalysts such as chrome/alumina, cobalt oxide, and copper oxide/manganese oxide have been demonstrated to control emission streams containing chlorinated compounds.

In some designs, the energy in the waste stream exiting the catalytic incinerator is recovered and used to heat the incoming waste stream. Catalytic incineration is also used in hybrid air pollution control systems to treat desorbed contaminants off carbon adsorption beds.

Reference [2] can be utilized to determine the costs and performance of a catalytic incinerator to meet your waste stream needs.

Technology (con't)

Catalytic Incineration

Pollution Prevention Benefits

- destroys VOCs and HAPs emitted during surface coating operations

Advantages

- lower operating temperatures than thermal incineration
- shorter residence times than thermal incineration
- destruction of many HAPs
- reduced supplemental fuel requirements compared to thermal incineration [1]
- low capital and operating costs

Disadvantages

- potential for catalyst poisoning if incompatible materials are introduced into the waste stream being treated [1]
- potential for catalyst sintering
- requires periodic catalyst replacement [1]
- may need to remove particulates from waste gas stream prior top entry into catalyst incinerator

Contact:

- see the vendor listing in Appendix B for a partial list of vendors or view the vendor references given in Section 4.2.2.2

References:

[1] Snider., J. "An Analysis of Air Pollution Control Technologies for Shipyard Emitted Volatile Organic Compounds (VOCs)". NSRP 0376. March 1993.

[2] U.S. EPA "Control Technologies for Hazardous Air Pollutants". EPA/625/6-91/014. June 1991.

Technology

Fluidized-bed Catalytic Incineration (FBCI)

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Fluidized-Bed Catalytic Incineration (FBCI) combines catalytic incineration and thermal oxidation to accomplish VOC destruction. The VOC-laden gas stream is brought into the incinerator by a forced-draft fan. The gas is preheated by a heat exchanger and put in direct contact with a natural gas burner. 20 to 50 percent of the total destruction of VOCs occurs in this step. The heated gas then flows through a baffled distribution grate and into a bed of fluidized spheres. These spheres consist of proprietary metal oxide coated on proprietary solid pellets. The exhaust from the catalyst bed is vented to the atmosphere. Units also incorporate a heat exchanger into the design to recoup heat from the exhaust gas before the gas is vented. Operating temperatures range from 550 to 1250 degrees F, but are generally maintained between 550 and 700 degrees F. The FBCI needs electric power, compressed air and natural gas for its operation.

FBCI was found to be effective and economical in controlling VOC emissions from a USAF paint spray booth at McClellan Air Force base through field testing of an ARI Technologies pilot-scale unit [1]. The field tests showed destruction efficiencies in excess of 99% for 19 of 21 tests performed. Full-scale FBCI are available in sizes that treat waste gas flow rates ranging from 500 to 75,000 scfm and VOC concentrations ranging from 1 to 1500 ppmv. A comparison of capital, installation, total and annual operating costs for this system compared with regenerative incineration, carbon adsorption/incineration, RTO, and CPACI is provided in [1]. The information contained in this summary is solely obtained from [1].

Technology (con't)

Fluidized-bed Catalytic Incineration (FBCI)

Pollution Prevention Benefits

- destroys VOCs from surface coating operations

Advantages

- high VOC destruction and removal efficiency
- base metal catalyst is resistant to poisoning
- base metal lowers oxidation temperature
- fluidized-bed design lowers power consumption
- self-sustaining: low fuel consumption if VOC concentration high enough

Disadvantages

- needs additional air pollution control devices for treatment of halogenated solvents

Contact:

- see the vendor list in Appendix B for a partial list of vendors or view the vendor references given in Section 4.2.2.2

References:

[1] Ritts, D., Garretson, C., Hyde, C., Lorelli, J., and Wolbach, D. "Evaluation of Innovative Volatile Organic Compound and Hazardous Air Pollutant Control Technologies for U.S. Air Force Paint Spray Booths", ESL-TR-89-51. October 1991.

Technology

Regenerative Incineration

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Regenerative incineration is a solvent destruction technology that is a combination of thermal oxidation (incineration) with internal energy recovery. The wastes treated with this technology include hydrocarbons and chlorinated hydrocarbons. The VOC emission control efficiency is 90-95% with a design operating temperature of 1400 deg F and a residence time of 0.5 seconds. Air flow rates from 1000 to 500,000 scfm and VOC concentrations from 1 to 2500 ppmv can be treated with this system. The system requires electric power and natural gas for operation. A comparison of capital, installation, total and annual operating costs for this system compared with FBCI, RTO, CPACI and carbon adsorption/incineration is provided in [1]. The information contained in this summary is solely obtained from reference [1].

Technology (con't)

Regenerative Incineration

Pollution Prevention Benefits

- destroys VOCs emitted during surface coating operations

Advantages

- high VOC destruction and removal efficiency
- self-sustaining: low fuel consumption if VOC concentration is high enough
- excellent for multiple sources
- employs indestructable media

Disadvantages

- system is large
- needs additional air pollution control devices for halogenated solvents

Contact:

- vendor sources to search for this technology are given in Section 4.2.2.2

References:

[1] Ritts, D., Garretson, C., Hyde, C., Lorelli, J., and Wolbach, D. "Evaluation of Innovative Volatile Organic Compound and Hazardous Air Pollutant Control Technologies for U.S. Air Force Paint Spray Booths", ESL-TR-89-51. October 1991.

Technology

Regenerative Thermal Oxidation (RTO)

Applicable Shipyard Process	Surface Coating
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Regenerative Thermal Oxidation (RTO) destroys VOCs by high temperature thermal oxidation. These designs consolidate the oxidation chamber with a heat exchanger. Multiple beds of ceramic heat transfer media are used to store and release thermal energy generated by the oxidation reaction. These systems can treat hydrocarbons, oxygenated solvents and very dilute chlorinated hydrocarbons. The systems have an overall destruction efficiency between 90-98 % while operating at a design temperature of 1800 degrees F. The residence time at the operating temperature is 1 second. These systems handle flow rates ranging from 3000 to 200,000 scfm and a concentration range from 1 to 1500 ppmv. The only operation and maintenance requirement is electric power. A comparison of capital, installation, total and annual operating costs for this system compared with FBCI, carbon adsorption/incineration, CPACI and regenerative incineration is provided in [1].

Technology (con't)

Regenerative Thermal Oxidation (RTO)

Pollution Prevention Benefits

- destroys VOCs from surface coating operations

Advantages

- high heat recovery efficiency
- proven VOC destruction capability
- compact design
- low maintenance requirements
- destruction of most HAPs

Disadvantages

- needs additional air pollution control devices for treatment of halogenated solvents

Contact:

- see the vendor list in Appendix B for a partial list of vendors or view the vendor references given in Section 4.2.2.2

References:

[1] Ritts, D., Garretson, C., Hyde, C., Lorelli, J., and Wolbach, D. "Evaluation of Innovative Volatile Organic Compound and Hazardous Air Pollutant Control Technologies for U.S. Air Force Paint Spray Booths", ESL-TR-89-51. October 1991.

4.3 Shipyard Cleaning Operations

Cleaning methods are used throughout shipbuilding and repair for various types of contaminants and substrates and from large objects such as vehicles and tanks to smaller parts in the manufacturing process. EPA regulations are forcing the industry to use cleaners that reduce HAP and VOC emissions but no one cleaner can replace the solvents currently in use today. The environmentally friendly cleaning alternatives available are numerous and the choices can be overwhelming. Section 4.3.1 provides a few key EPA guides that discuss cleaning alternatives, documents that discuss EPA regulations concerning cleaning operations, and documents summarizing case studies where clean technologies have been implemented in industry. Section 4.3.2 provides excellent references for obtaining vendors, and Section 4.3.3 provides Technology Data Sheets that describe the types of environmentally friendly cleaners that are available commercially.

There are a few aids available to narrow down your search for a cleaning process and solvent replacement. One such aid is the Solvent Alternative GuidE (SAGE) developed by the EPA and summarized in a Technology Data Sheet in this section. A sample of SAGE information is provided in Appendix D. The Joint Services Pollution Prevention (P2) Technical Library is also a valuable source in evaluating environmentally friendly substitutes. The library has over 34 data sheets describing solvent and cleaning process alternatives including alternatives for cleaning and degreasing, paint removal, rust and corrosion, heat scale removal, carbon and carbonaceous deposit removal, general metal cleaning, and engine degreasing, to name a few. In each Technology Data Sheet a list of alternatives are provided including its application, what it replaces, its ingredients, cost, and manufacturer data and chemical property data. The cleaning processes summarized in the Joint Services P2 Technical Library include chemical, immersion, mechanical, and ultrasonics to name a few. Please see Section 2.2 for information on how to gain access to this library.

4.3.1 Technical Reports

U.S. EPA. '**Guide to Cleaner Technologies: Alternatives to Chlorinated Solvents for Cleaning and Degreasing**". EPA/625/R-93/016. February 1994.

This guide describes cleaning and degreasing alternatives to chlorinated solvents. For each technology discussed, the guide addresses its pollution prevention benefits, operating features, applications and limitations. The guide covers aqueous cleaners, semi-aqueous cleaners, petroleum hydrocarbons, hydrofluorocarbons (HCFCs), miscellaneous organic solvents, supercritical fluids, carbon dioxide snow, catalytic wet oxidation cleaning and absorbant media cleaning. This guide can be ordered for free from NCEPI at the address or phone number listed in Section 2.1.

U.S. EPA. "**Guide to Cleaner Technologies: Cleaning and Degreasing Process Changes"**. EPA/625/R-93/017. February 1994.

This guide describes cleaning and degreasing process changes that reduce pollution generation. For each technology discussed, the Guide addresses its pollution prevention benefits, operating features, applications and limitations. The technologies discussed include completely enclosed vapor cleaner, automated aqueous cleaning, aqueous power washing, ultrasonic cleaning, low-solids fluxes, inert atmosphere soldering, vapor storage technology, vacuum furnace, laser cleaning, plasma cleaning, fluxless soldering and replacement for tin-lead solder joints. This guide can be ordered for free from NCEPI at the address or phone number listed in Section 2.1

U.S. EPA. **"Guidance Document for the Halogenated Solvent Cleaner NESHAP".** EPA-453/R-94-081. April 1995.

This document gives owners and operators of solvent cleaning machines the information required to determine whether the halogenated solvent cleaning regulation applies to them, and the options available to comply. The document is divided into the following three parts: (1) determining if you are required to comply with the Federal halogenated solvent cleaner requirements, (2) available compliance options, and (3) alternative cleaning solvents or technologies that can be used in lieu of complying with the standards. This document can be ordered from NIST at a cost of $39.00. Please see Section 2.1 for ordering information.

U.S. EPA. **"Demonstration of Alternative Cleaning Systems".** EPA/600/SR-95/120. August 1995.

This report represents the first demonstration of cleaner technologies to support the 33/50[1] program to find substitutes to the use of chlorinated organic solvents. Technical, environmental, and economic evaluations were performed to determine the merits of using an aqueous wash system, no-clean technology and a hot water wash system implemented at Calsonic Manufacturing Corporation. The demonstration strongly supports the implementation of these alternative cleaning technologies. The aqueous cleaning alternative reduced cleaning cycle times by 50% and part reject rates by 77% with improved cleaning characteristics as well as offering significant financial advantages. This report can be obtained from NIST at the contact information provided in Section 2.1.

[1] 33/50 is also known as EPA 17 toxic chemicals. Mostly chlorinated solvents and heavy metals

4.3.2 Vendor Information and Solvent Alternatives Listings

SNAP (Significant New Alternatives Policy)

SNAP provides a list of acceptable and unacceptable substitutes for ozone depleting substances (ODS) and also provides a comprehensive but not all inclusive list of vendors supplying substitute solvents and environmentally acceptable cleaning processes. Over 500 vendors are listed with a brief description of their products along with contact information. This list is a result of Section 612 of the Clean Air Act Amendments of 1990 which requires the EPA to publish lists of acceptable and unacceptable alternatives for ozone depleting substances (ODS). If you do not have access to the Internet you can obtain this list from the SNAP coordinator at the address and phone number provided in Section 2.2.

Joint Services Pollution Prevention Library

The Joint Services Pollution Prevention Library has a wealth of information pertaining to cleaning operations that are organized based on your cleaning need. Sample topics include cleaning and degreasing, paint removal, general metal cleaning, carbon and carbonaceous deposit removal, paint removal and cleanup, etc. Under several of the topics, such as general metal cleaning, tables are provided which include items such as product names, application, cleaner replacing, method of use, chemical ingredients, safety and health, cost, disposal, recycling options, manufacturer and contact information. See section 2.1 for information on how to obtain this source.

4.3.3 Pollution Prevention Projects

This first project review is obtained from the following reference:

U.S. Army Tank-Automotive and Armaments Command Industrial Ecology Center. **"Pollution Prevention Environmental Technology"**. Picatinny Arsenal, NJ 07806-5000. February 1997.

1. **SERDP Proposal ID #067 "Solvent Substitution and Low VOC Cleaners**
Internet Address: http://es.inel.gov/new/funding/serdp/p2prj017.html

The project goal is to identify low VOC content cleaning solvents for use on Navy aircraft, weapons systems, and ground support equipment and to identify replacements for methylene chloride based chemical paint strippers. This project will develop solvent blend formulations and aqueous cleaners that will be evaluated with laboratory performance and cleaning efficiency tests. Enzyme cleaners, lubricant cleaners, low VOC solvent, and supercritical CO_2 cleaning methods will also be evaluated in this program. This is an on-going project that is scheduled to

be completed in 9/99 and is being performed by the Naval Air Warfare Center Aircraft Division Warminster.

2. **SERDP Proposal ID #116 "Solid State Metal Cleaning"**
Internet Address: http://pprc.pnl.gov/pprc/rpd/fedfund/DoD/serdp/solidst.html
Primary Research Contact: *Dr. Phil Mykytiuk*
WL/MLSE Building 652
2179 12th Street, Suite 1
Wright Patterson, AFB, OH 45433-7718
Phone: (513) 255-3953
Fax (513) 476-4378
Email: *mykytipd@ml.wpafb.af.mil*

The goal of this project is to develop innovative metal cleaning processes that do not require the use of water or volatile organic compounds. Research and development is currently being performed to study the mechanisms and kinetics of solid state oils (oils, waxes, particulates and metallic oxides) removal processes. Various processes being studied include activated particulates or polymers, starch, CO_2 and various inorganic particulates including carbonates and phosphates. This research is being organized by the US Air Force Material Command and being primarily funded by SERDP. Research was scheduled to be complete in February of 1997.

4.3.4 Technology Data Sheets

The Cleaning Technology Data Sheets cover the following cleaners: aqueous, semi-aqueous, petroleum hydrocarbons, supercritical carbon dioxide, terpenes and PC/BA for cleaning paint application equipment. There is also a Technology Data Sheet describing an interactive system called SAGE that can be used to evaluate alternative cleaners and processes to meet your cleaning needs.

Cleaning Technology Data Sheets

Technology

SAGE (Solvent Alternatives GuidE)

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

SAGE is a software system that was developed by the EPA to aid in the selection of environmentally friendly solvent and process alternatives in cleaning and degreasing operations. A user of the system can either:

(1) answer questions about their product and cleaning needs which allows SAGE to suggest the best alternatives

(2) go to the descriptions of alternative solvents and cleaning processes

If option (1) is chosen, the user is asked a series of questions about the part to be cleaned including information such as part size, complexity, and material, present processing chemistry, part cost, production rate and contaminants to be removed. Based on the answers provided, SAGE ranks a number of recommended options and provides important technical parameters for implementing the options. An alternate solvent and/or an alternate cleaning process may be recommended.

If option (2) is chosen the user can obtain summary infomation for a given process including equipment costs, automation possibilities, safety precautions, compatible cleaning solutions and particular applications. The solvent summaries include Material Safety Data Sheets (MSDS) and describe the solvent substitute. SAGE also has summaries of case studies, references and vendor lists.

The process alternatives considered in SAGE include abrasives, brushing, CO2 pellets, CO2 snow, fiberglass molds, high pressure spray, immersion, laser ablation, low pressure sprays, megasonics, paint stripping, plasma, power washers, printed circuit boards, semi-aqueous, steam, supercritical fluids, ultrasonics, UV/Ozone, wiping and xenon flash lamp. The solvent alternatives include acetone, acidic, alkaline and neutral aqueous, alcohol, aqueous additives, dibasic esters (DBE), ethyl lactate, glycol ethers, N-methylpyrollidone (NMP), petroleum distillates, pure water and terpenes.

SAGE can be accessed via the Internet at the following Internet Address:

http://clean.rti.org. The EPA Control Technology Center (CTC) can also provide assistance with downloading and running the program from other sources. You can call them at (919) 541-0800 or (919) 541-5384.

Technology (con't)

SAGE (Solvent Alternatives GuidE)

Pollution Prevention Benefits

- reduce ozone depletion by recommending chemical alternatives to ozone depleting chemicals

Advantages

- provides a quick but detailed reference for a variety of EPA approved chemical and process alternatives

Disadvantages

- can't make final selection of a process, pay for it and install it in your facility

Contact:

EPA Control Technology Center
Phone: (919) 541-0800 or (919) 541-5384

References:

[1] U.S. EPA. "Project Summary SAGE 2.1, Solvent Alternatives GuidE: User's Guide". May 1995.

Technology

PC/BA for Cleaning Paint Spray Equipment

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

The EPA evaluated and demonstrated a replacement solvent for Methyl Ethyl Ketone (MEK) in cleaning paint application equipment. A blend of of 40% propylene carbonate and 60% benzyl alcohol (PC/BA) was successfully used to replace MEK for cleaning paint application equipment (pumps, hoses and guns). Results of the EPA demonstration showed that PC/BA cleans green Chemical Agent Resistant Coating (CARC) from the pumps as well as MEK, and cleans epoxy primers from the pumps better than MEK [1].

A summary of this research, "Project Summary Pollution Prevention Demonstration and Evaluation of Paint Application Equipment and Alternatives to Methylene Chloride and Methyl Ethyl Ketone" can be downloaded from the EPA Office of Research and Development (ORD) project summaries database at the following Internet Address: http://www.epa.gov/ORD/WebPubs/projsum/#Air.

Technology (con't)

PC/BA for Cleaning Paint Spray Equipment

Pollution Prevention Benefits

- reduced VOC emissions
- replacement for Methyl Ethyl Ketone in cleaning spray application equipment

Advantages

- lowered inhalation hazard to workers
- reduced cleaner usage
- reduced labor time for cleaning
- PC/BA is not regulated by the Source Conservation Recovery Act
- significantly decreases downtime of primer pumps

Disadvantages

- The only disadvantage noted was the increased cost to purchase this solvent. However, this cost may be offset by cleaner recovery and reclamation, and further waste reduction associated with using this solvent [1].

Contact:

- contact NTIS and order the full report for more information. The report name and document numbers are provided below in the Reference Section.

References:

[1] U.S. EPA. "Pollution Prevention Demonstration and Evaluation of Paint Application Equipment and Alternatives to Methylene Chloride and Methyl Ethyl Ketone". EPA/600/SR-96/117. October 1996.

*This document (NTIS # PB97-104632) can be ordered from NTIS at the address and phone number provided in Section 2.1 of this report.

Technology

Aqueous Cleaners

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Aqueous cleaners are defined as those that are typically comprised of at least 95% water [1]. To be effective, aqueous cleaning solutions have to be chemically compatible with the part being cleaned, provide appropriate surfactants to enhance removal of the specific contaminants on the parts, and contain additives needed to prevent problems such as excessive solution foaming or part corrosion [1]. The most important factors in successful aqueous cleaning operations are proper choice of cleaner solution, obtaining adequate mechanical force on the part being cleaned and increased temperature over ambient to improve cleaning efficiency [1]. Adequate rinsing and drying steps are also key factors and are required to protect the part being cleaned.

Aqueous cleaners come in acidic, alkaline or neutral solutions depending on the contaminants to be removed. The most commonly used aqueous solutions are alkaline which are used to remove greases, coolants, cutting oils, shop dirt, fingerprints, cosmolene, petrolatum, and some water soluble paints [2]. These alkaline cleaners can be used with all types of liquid processes including sprays, ultrasonics, immersion and power washers. They also can clean to a very high level of cleanliness with good filtration and rinsing capabilities [2]. Neutral aqueous solutions clean well where a high degree of chemical solvency is not required [2]. They are good at removing light oils, particles, chlorides, and other salts. They can be used in spray and ultrasonic applications and in steam equipment but they are not good for immersion processes without agitation. Acidic aqueous cleaners are used to remove scale, rust and oxides from metals. The choice of acid and additives used in the cleaner depends on the type of metal to be cleaned and the type of soil to be removed [2].

There are several excellent references available that summarize aqueous cleaning in more depth. Please see the bibliography of this report. SAGE and SNAP provide vendor information while economics are covered in SAGE and the Pollution Prevention Technology Reviews. There are also several closed loop aqueous systems available commercially that will help eliminate the wastewater treatment and disposal problems associated with aqueous cleaning. Some of these vendors are included in the vendor listing in Appendix B.

Technology (con't)

Aqueous Cleaners

Pollution Prevention Benefits

- non-ozone-depleting
- few if no VOCs
- many cleaners are reported to be biodegradable

Advantages

- less hazardous

Disadvantages

- generates wastewater stream
- cleaning process becomes more complicated because it requires more steps than traditional solvent cleaning
- contaminant and/or spent cleaner may be difficult to remove from blind holes and crevices
- often used at high temperatures (120 to 200 F)
- metals may corrode if part not dried quickly

Contact:

- See vendor listing in Appendix B, SNAP Section 2.2 or Joint Services P2 Technical Library in Section 2.1 of this report for vendor information
- Contact NDCEE to see if they can demonstrate cleaning processes for your needs (see Section 2.3 of this report for contact information).

References:

[1] Pacific Northwest Pollution Prevention Research Center. "Pollution Prevention Technology Reviews: 1996 Review Series: Cleaning for Manufacturing - Aqueous Cleaning". March 1996.
Internet Address: http://pprc.phl.gov/pprc/p2tech/p2tech.html
[2] U.S. EPA. "Solvent Alternatives GuidE - SAGE".
Internet Addess: http://clean.rti.org

Technology

Semi-aqueous Cleaners

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Semi-aqueous cleaners are a group of cleaning solutions that are composed of natural or synthetic organic solvents, surfactants, corrosion inhibitors, and other additives. They are designed to be used in process equipment much like aqueous cleaners. The commonly used semi-aqueous cleaners include water-immiscible types (terpenes, high-molecular-weight esters, petroleum hydrocarbons, and glycol ethers) and water-miscible types (low-molecular weight alcohols, ketones, esters, and organic amines) [1]. Terpenes, petroleum hydrocarbons and N-methylpyrrolidone (NMP) can be used in semi-aqueous cleaners or used alone. A summary of these solvents are provided in separate review sheets.

Semi-aqueous cleaners generally have excellent solvency for a number of difficult contaminants such as heavy grease, tar, and waxes. The cleaners also have low surface tension which allows them to penetrate small spaces such as crevices and blind holes.

The semi-aqueous cleaning process generally consists of washing, rinsing, and drying stages that include features such as mechanical agitation via direct pressure spray, spray under immersion, immersion, and ultrasonic immersion [2]. These cleaners are readily available but care must be taken in choosing a semi-aqueous cleaner and process to ensure it meets your needs. There are many variables in the semi-aqueous process which can be optimized to meet your cleaning needs. These include temperature, pressure, cycle times and agitation settings. The NDCEE Advanced Cleaning Center can be utilized to determine if an aqueous or semi-aqueous cleaner and associated system can meet your part cleaning needs.

The Advanced Cleaning Center has aqueous and semi-aqueous methods to clean a wide variety of large or small metal and nonmetal parts [2]. They have an advanced immersion system, dual-use ultrasonic system, a honeycomb system, a power washer and a rotary basket system [2] which can be used to evaluate these technologies for cleaning your parts.

Technology (con't)

Semi-aqueous Cleaners

Pollution Prevention Benefits

- non-ozone-depleting
- most are biodegradable

Advantages

- may be more aggressive in removing heavy organic contaminants compared to aqueous cleaners
- may have lower corrosion potential with water sensitive parts than aqueous cleaners
- lower surface tensions than aqueous cleaners so can penetrate small spaces more easily

Disadvantages

- maybe partly composed of VOCs
- mists of concentrated semi-aqueous cleaners can be ignited at room temperature

Contact:

- See SNAP vendor list in Section 2.2 and The Joint Services P2 Technical Library at the address given in Section 2.1 for vendors selling semi-aqueous cleaners and processes
- Contact NDCEE at Phone Number: (814) 269-6425 or view Internet Site at http://www.ndcee.ctc.com for more information

References:

[1] U.S. EPA. Guide to Cleaner Technologies "Alternatives to Chlorinated Solvents for Cleaning and Degreasing". EPA/625/R-93/016. February 1994.

[2] Concurrent Technology Corporation. "Equipment Demonstration - Advanced Cleaning Center". Product Literature. NDCEE Advanced Cleaning Center Promotional Literature.

Technology

Petroleum Hydrocarbons

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

There are two grades of petroleum hydrocarbons, basic petroleum distillates and a specialty grade of synthetic paraffinic hydrocarbons. Petroleum distillates, which have been used for a long time, are produced from crude oil and include solvents such as mineral spirits, kerosene, white spirits, naptha, Stoddard Solvent and PD-680 (military designation: Types I, II and III). Paraffinic hydrocarbons are a more recent grade available due to improved separation and synthesis techniques [1]. These solvents have higher solvency, very low aromatic content and low evaporative loss rates compared to petroleum distillates. These paraffinic hydrocarbons are more expensive but their expense is offset because less solvent can be used for a given job due to lower evaporative loss rates compared to petroleum distillates [2].

Petroleum hydrocarbons are typically used when water contact with parts is undesirable. They lend themselves to simple, inexpensive, one-step cleaning processes where a high level of cleanliness is not essential [1]. They are effective in removing "hard-to-clean" organic soils, including heavy oil and grease, tar and waxes. They can penetrate and clean small spaces because of their low liquid surface tensions (approx. 22 to 28 dynes/cm) [1]. They are compatible with most metals and plastics, and with some elastomers [1]. Lastly, they can also be used as the solvent portion of semi-aqueous cleaning solutions [3].

Immersion baths and manual hand wiping operations are the most widely used methods of cleaning with petroleum hydrocarbons. These cleaners dry more slowly than common chlorinated solvents [2] so parts may need to be dried by forced air or oven drying. When the cleaning power of the immersion bath is exhausted the entire bath needs to be replaced. The spent solvent can be incinerated or recycled through distillation. Contaminated solvents will tend to leave a residue on parts, so they should be replaced when slow drying or residue becomes a problem. If the residues are unacceptable, a second level of cleaning may be needed [1].

Please see SAGE [3] for case studies pertaining to petroleum hydrocarbon usage and ecomomics for this alternative.

Technology (con't)

Petroleum Hydrocarbons

Pollution Prevention Benefits

- if used alone there is no wastewater
- recyclable by distillation
- the synthetic paraffinic hydrocarbons have low evaporative loss
- the synthetic paraffinic hydrocarbons have low toxicity

Advantages

- if used in pure form (ie. not in a semi-aqueous process) there is no potential for water corrosion or for water to become trapped in cavities
- have high solvency for "hard-to-clean" organic soils, including heavy oil and grease, tar and waxes [1]
- low liquid surface tension so permits cleaning in small spaces

Disadvantages

- flammable, and some have flash points as low as 105 deg F
- process equipment has to be designed to eliminate explosion hazard
- are VOCs and may require recovery of VOCs from exhaust equipment
- may see restrictions on their use in the future
- slower drying times than chlorinated solvents

Contact:

- See Section 2.2 to obtain SNAP list of vendors or visit the Joint Services P2 Technical Library at the Internet Address provided in Section 2.1.

References:

[1] U.S. EPA. "Guide to Cleaner Technologies Alternatives to Chlorinated Solvents for Cleaning and Degreasing". EPA/625/R-93/016. February 1994.
[2] Enviroene. "Fact Sheet: Hydrocarbon Based Cleaners used for Industrial Cleaning". Internet Address: http://es.inel.gov/techinfo/facts/florida/hydro-fs.html
[3] U.S. EPA. "Solvent Alternatives GuidE- SAGE". Internet Address: http://clean.rti.org

Technology

Terpenes

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Terpenes are natural hydrocarbons usually derived from sources such as pine trees or citrus fruit (orange, grapefruit, and lemon). The most common ingredient in terpene cleaners is d-limonene, a derivative of orange peels. A-pinene is also a common terpene. Other terpenes included in the EPA interim list of CFC substitutes are: anethole, beta-pinene, alpha-terpene, beta-terpene, terpinolene, and dipentene.

Terpenes have high solvency and often clean better than chlorinated solvents [1]. Greases, oils (such as cosmoline), rosin fluxes, fingerprints, and adhesives are easily removed with terpenes, and blends have been developed that remove resins, paints and carbon deposits [1]. Terpenes are generally not recommended for cleaning polystyrene, PVC, polycarbonate, low-density polyethylene, and polymethylpentene. They are also not compatible with the eastomers natural rubber, silicone, and neoprene [2].

They can be used alone or in semi-aqueous cleaning processes. Dilution in semi-aqueous processes reduces the cleaning performance but decreases usage, reduces expense (purchase less terpene), and lowers vapor pressure which decreases vapor emissions [2]. Reclamation of an aqueous/terpene mixture, however, is more difficult and may not be economically feasible. Straight terpene cleaners can be vacuum distilled and reclaimed more easily. Disposal of terpene cleaners is by incineration or discharge to sewers. Terpenes are biodegradable with high biological and chemical oxygen demands (BOD/COD) which may lead to sewer surcharges so beware before purchasing this cleaner [1].

Immersion baths are typically used with terpenes and some form of agitation is usually employed. Terpenes also have low volatility so a rinse and/or dry step may be necessary in the cleaning process. Terpenes are highly flammable so extra care must be taken if used in spray application systems.

Technology (con't)

Terpenes

Pollution Prevention Benefits

- non-ozone-depleting
- biodegradable
- pure terpenes recyclable by distillation

Advantages

- good solvent for removing rosin fluxes, fingerprints, heavy petroleum greases, and oils
- low volatility so evaporative losses are minimum

Disadvantages

- are VOCs
- may see tighter regulations for these compounds in the future [3]
- need to consider wastewater treatment methods if using this solvent in semi-aqueous solutions
- relatively low flash points (approx. 115 to 120 deg F)
- mildly neurotoxic
- highly photolytically reactive
- strong odor

Contact:

- see SNAP list in Section 2.2 for vendor information or go to the Joint Services P2 Technical Library at the Internet Address provided in Section 2.1

References:

[1] Enviroene. "Fact Sheet: Terpene Cleaners Used for Industrial Cleaning"
Internet Address: http://es.inel.gov/techinfo/facts/florida/terpclfs.html.
[2] U.S. EPA. "Guide to Cleaner Technologies Alternatives to Chlorinated Solvents for Cleaning and Degreasing".
EPA/625/R-93/016. February 1994.
[3] U.S. EPA. "Solvent Alternatives GuidE - SAGE".
Internet Address: http://clean.rti.org

Technology

Supercritical Carbon Dioxide Cleaning (SCCO2)

Applicable Shipyard Process	Cleaning Operations
Pollution Prevention or Treatment Method?	Pollution Prevention
Commercially Available?:	yes

Technology Description

Supercritical carbon dioxide (SCCO2) has considerable promise for solvent replacement [1]. When CO2 is heated under pressure to a point above its critical temperature (approximately 31 deg C) and critical pressure (approximately 1070 psi) it becomes a supercritical fluid where it has properties of both a liquid and a gas. Like a liquid, SCCO2 can dissolve and suspend chemical compounds. At the same time, SCCO2 can penetrate porous surfaces like a gas. These properties make it an excellent solvent.

SCCO2 is superior to other solvents when you need to clean substrates with intricate geometry, have water and/or heat sensitive substrates or have substrates that have drying times that are too long using aqueous cleaning methods [2]. SCCO2 is compatible with metals, ceramics and polymers such as Teflon, high density polyethylenes, epoxies and polyimides. However SCCO2 causes swelling in acrylates, styrene polymers, neoprene, polycarbonates and urethanes [3]. It removes silicone oils, flux residues, petroleum oils, machining oils, dielectric oils, lubricants, adhesive residues, plasticizers, fats and waxes [4]. SCCO2 is not effective in removing inorganic and polar organic soils, loose scale or other particulates [3].

A basic SCCO2 cleaning system is a batch process which consists of a cleaning chamber where the "dirty" parts are placed. The process begins by drawing CO2 from a gas cyclinder and compressing it above its critical pressure using a pump. Then the compressed CO2 is heated (either in a heater or inside the cleaning chamber) above its critical temperature thus creating the SCCO2. The parts in the cleaning chamber are cleaned through exposure to the SCCO2. Often times mechanical mixing is used to enhance the cleaning process. Once the parts are cleaned the SCCO2-containing the dissolved contaminants is bled off to a separator vessel, where the SCCO2 is decompressed and returned to a gaseous state. The contaminants remain in liquid form and are collected out the separator bottom, while the gaseous CO2 is either discharged to the atmosphere or sent through a chiller to return it to a liquid form for reuse.

Please see the references in this Technology Data Sheet for additional information regarding case studies, economics and a more complete description of the process. A vendor list is also included in Appendix B of this report.

Technology (con't)

Supercritical Carbon Dioxide Cleaning (SCCO2)

Pollution Prevention Benefits

- non-ozone-depleting
- only waste stream generated is contaminants removed from parts being cleaned

Advantages

- non-flammable
- virtually inert
- high solvency for many "hard-to-clean" organic soils, including heavy oil and grease, tar and waxes
- operational costs are reasonable and often lower than vapor degreasers and aqueous cleaning methods [2]
- CO2 can be reused and is inexpensive

Disadvantages

- high pressures used to reach SCCO2 state
- high capital costs compared to other cleaning methods [2]
- batch process only
- not good for removing inorganic and polar organic soils, loose scale or other particulates [3].

Contact:

- see vendor listing in Appendix B
- a case study implementing this technology in industry is provided at the following Internet Address: http://es.inel.gov/program/p2dept/energy/nice3/nice3-5.html

References:

[1] Institute for Local Self-Reliance. "Fact Sheet 12 - Supercritical Carbon Dioxide: Uses as an Industrial Solvent". Internet Address: http://www.ilsr.org/carbo/factsh12.html

[2] Pacific Northwest Pollution Prevention Research Center. "Cleaning for Manufacturing - Supercritical Carbon Dioxide". March 1996. Internet Address: http://pprc.pnl.gov/pprc/p2tech/p2tech.html

[3] U.S. EPA. "Guide to Cleaner Technologies- Alternatives to Chlorinated Solvents for Cleaning and Degreasing". EPA/625/R-93/016. February 1994.

[4] U.S. EPA. "Solvent Alternatives GuidE - SAGE". http://clean.rti.org

4.4 Welding Operations

Collection and filtration equipment for weld fumes was studied thoroughly under a separate NSRP project, project N-3-93 "Air Toxic Emissions Evaluations". In lieu of repeating what was already accomplished by this project the information available in the following NSRP report (NSRP 0457), "Characterizing Shipyard Welding Emissions and Associated Control Options" is summarized below. This report can be obtained from the NSRP Project Coordinator (contact information provided in Section 2.1).

Jacobs, Z**. "Characterizing Shipyard Welding Emissions and Associated Control Options"**. NSRP 0457. August 1995.

This report presents an introduction to shipyard welding processes, summarizes federal regulations pertaining to welding emissions, provides available information on welding emission factors, options for collection and filtration of welding fumes in the shipyard production environment including advantages and disadvantages of different designs and a list of vendors of fume collection and filtration equipment.

Our current study is concerned with pollution prevention and treatment options so I will summarize the technologies mentioned in this study for collection and treatment of weld fumes. Welding processes produce weld fumes which contain particulate in the sub-micronic range (i.e. 0.01-1.0 micron in diameter) and the PM-10 range (<10 microns) which require specialized filtration equipment. Two types of filtration equipment are mentioned in NSRP 0457 to treat particulates of this size, electrostatic precipitation and mechanical media filters. Before the weld fumes can be filtered, however, they need to be collected. Two options are available but the recommended option in NSRP 0457 is source capture which collects weld fumes at the point of generation. This is recommended because it achieves a higher rate of collection efficiency and the ability to keep potentially harmful emissions away from the workers breathing area. There are several configurations and designs available depending on the location of the welding process. I refer you to NSRP 0457 to obtain specific information on these collection systems and their applicability to your shipyard welding processes.

5. Wastewater Treatment Methods

5.1 Hydroblast Wastewater

Rather than rehash what has already been summarized in the literature, a few pertinent reports will be summarized on this topic and the locations to find them will be provided. The first document presents the results of a study performed for the National Shipbuilding Research Program on the treatment of hydroblast wastewater in U.S. shipyards. The second report is a guide developed by the Municipality of Metropolitan Seattle Water Pollution Control Department Industrial Waste Section to help shipyards select wastewater discharge options and wastewater treatment systems that will provide compliance to NPDES permits in Washington State.

1. National Steel and Shipbuilding Company (NASSCO). **"Filtration of Runoff from Pressure Washing Vessel Hull in Dry dock"**. NSRP 0452. September 1995.

This report can be obtained from the NSRP coordinator at the address, phone or Internet address listed in Section 2.1.

This report discusses the chemical characteristics of hydroblast waste streams and identifies the most practical and cost effective methods to filter or treat run-off water from hydroblasting operations in dry dock to meet Federal and State water quality requirements or local public owned treatment works (POTW) standards. A vendor survey of 126 vendors was conducted which identified the currently available pretreatment technologies for treating hydroblast wastewater. A summary table of the vendors contacted, including contact information is provided along with the vendor wastewater treatment products. Five commercially available wastewater treatment technologies are identified and discussed which have the potential to treat hydroblast wastewater:

- gravity separation and clarification
- filtration-plate and frame pressure
- filtration with mono- and multi-media
- precoat filtration
- membrane ultrafiltration

This report provides a summary of the technologies above as well as providing a cost analysis of each technology.

2. Municipality of Metropolitan Seattle Water Pollution Control Department Industrial Waste Section. **"Shipyard Waste Treatment Guidelines".** December 1991.

This report can be obtained from: *Municipality of Metropolitan Seattle*
Water Pollution Control Department
Industrial Waste Section
130 Nickerson Street, Suite 200

Seattle, WA 98109-1658
(206) 689-3000

This publication is a guide to help shipyard operators select wastewater discharge options and wastewater treatment systems that will provide compliance with NPDES permits in Washington State. The guide mainly focuses on the hardware of wastewater collection and treatment. Much of the information contained within the document is provided by a study, called the Maritime Industrial Waste Project, conducted by the Municipality of Metropolitan Seattle (Metro). The Maritime Industrial Waste Project characterized wastewater from the maritime industry and identified potential treatment methods so that pollutant discharges from the maritime industry could be reduced. A major effort of the study was to pilot-test wastewater treatment equipment at shipyards and boatyards.

Guidelines for the collection and treatment of hydroblasting wastewater and the treatment and disposal of bilge and ballast water is included in the report. There is also an appendix with descriptions of the treatment systems that were pilot-tested during the Maritime Industrial Waste Project. The systems that were pilot tested during the project included:

- mixed media filtration
- membrane ultrafiltration
- media precoat filtration
- settling and filtration - manufactured mixed media, system 1
- settling and filtration - manufactured mixed media, system 2
- chemical flocculation and settling - alum and lime
- chemical flocculation and settling - iron and lime
- chemical flocculation and settling - proprietary dry chemical
- chemical flocculation and settling - cationic polymer
- dissolved-air flotation (DAF) - continuous alum flocculation system
- induced-air flotation - alum batch system

5.2 Bilge and Ballast Water

This section contains technology data sheets that summarize two treatment technologies which are the Bilge Oily Waste Treatment System (BOWTS) and a Supercritical CO_2 wastewater treatment system. The second report “Shipyard Waste Treatment Guidelines” in Section 5.1 can also be referenced for treatment methods of bilge and ballast water.

Wastewater Treatment Methods

Technology

BOWTS

Applicable Shipyard Process	Bilge Wastewater Treatment
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

BOWTS (Bilge and Oily Wastewater Treatment System) is a system for treating bilge and other oily wastewater which was developed by the Naval Facilities Engineering Service Center. The system removes free and emulsified oils, dissolved heavy metals and suspended solids. Several BOWTS systems at 150 gpm capacity are in operation at Naval bases but the BOWTS system can also be used to treat bilge from commerical ships and other oily wastewater [1]. The treatability of bilge water to remove oil and grease is dependent on the type of materials used to clean the bilge and will vary from ship to ship. A description of this system given below is taken from the Joint Services P2 Technical Library. Please reference this source for additional information including an economic analysis of the process and contact information.

"The BOWTS hardware is a stationary system with secondary containment equipped with redundant (duty/standby) intake pumps, each fitted with upstream strainers. After the ship's bilge water is transferred to a large holding tank, the feed is then passed through a first stage oil/water separator, and is then introduced into a series of three chambers for performing chemical treatment. Two chemical metering pumps feed a reverse emulsion breaker and sodium hydroxide, respectively into this subsystem, resulting in removal of the emulsified oil and precipitation of the heavy metals. The effluent is then pumped into an induced-air flotation unit, where the generated residues are removed. Two slop oil tanks are provided for collecting the free oil separated in the oil/water separator, and a sludge tank is provided for holding the sludges collected in the oil/water separator and the induced-air flotation device. The water fraction leaving the system will be of a quality that can be discharged directly into the sanitary sewer." [2].

Additional information on the BOWTS system can also be obtained from T2 Environmental Inc. at their Internet address http://www.t2einc.com/default.html.

Technology (con't)

BOWTS

Pollution Prevention Benefits

- potential to reduce the amount of bilge water disposed at a site by as much as 95% [2]

Advantages

- BOWTS operation is completely automated but requires one person to monitor the process
- proven off-the-shelf technology
- system is flexible to accomodate a wide range of concentrations and flow ranges and each system is designed to site specific requirements

Disadvantages

- N/A

Contact:

T2 Environmental Incorporated
2596 North Star Cove
Port Hueneme, CA 93041
Phone: (805) 984-7260

References:

[1] T2 Environmental, Inc. "Bilge and Oily Wastewater Treatment Systems"
[2] Joint Services P2 Technical Library. "Bilge and Oily Wastewater Treatment System (BOWTS)" November 1995. Internet Address: http://enviro.nfesc.navy.mil/p2library

Technology

Critical/Supercritical Carbon Dioxide System

Applicable Shipyard Process	Wastewater Treatment
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

There is currently one company which commerically builds near supercritical carbon dioxide (CO2) wastewater treatment plants. Basically, organic material from wastewater using carbon dioxide which has been raised to near its critical point which is approximately 1070 psi and 31 deg C. The commercial system pressurizes the wastewater and then pumps it to the top of an extractor, a three-story cylindrical tank where it is mixed with liquid CO2 under pressure. The extractor contains eighteen metal packing plates, circular plates with small holes that act to keep the bubbling CO2 uniform. As the wastewater flows down from the top of the extractor, it comes into contact with the CO2 being bubbled from the bottom of the extractor. Organics in the wastewater have an affinity for, and are effectively extracted by the CO2. After bubbling, the CO2 is phased out of the solution and sent to a separator tank where it is depressurized, removed, and recycled for reuse, leaving behind the organics extracted from the wastewater. The organic material is then collected and used as incinerator fuel [1]. This process can treat alcohols, ketones, halogenated organics and aromatics. A system currently in operation in Baltimore, Maryland treats up to 30,00 gallons of wastewater per day and produces cleaned water suitable for discharge to POTW (< 2 ppm BTEX (Benzene, Toluene, Ethylbenzene, Xylene) and 2 ppm Total Toxic Organics (TTO)) [2].

The Applied Research Laboratory (ARL) at The Pennsylvania State University is currently evaluating critical/supercritical CO2 (C/SCCO2) for the treatment of contaminated bilgewater. This project is funded by The United States Navy and is tasked to evaluate C/SCCO2 for treating contaminated bilgewater in deployed Navy Ships. The ARL investigation is using a laboratory scale C/SCCO2 system to extract contaminants from simulated bilgewater. Their major tasks are to demonstrate and characterize the counterflow extraction process, including the effects of temperature, pressure, agitation, and column geometry, to evaluate the effects of surfactants on the extraction process, and to develop techniques to reduce surfactant interference. The ultimate goal is the development of an automated system that can meet the 5 ppm discharge criterion with lower manpower requirements and lower life-cycle costs than other alternatives.

Technology (con't)

Critical/Supercritical Carbon Dioxide System

Pollution Prevention Benefits

- commerical system treats alcohols, ketones, halogenated organics, and aromatics
- CO_2 is recovered and recycled in the process

Advantages

- ARL research goal is lower manpower requirements and life-cycle costs than other methods
- environmentally friendly

Disadvantages

- high operating pressures
- special equipment required

Contact:

- contact Clean Harbors for additional information on the commercially available system (see vendor list under wastewater treatment)
- contact Jon Peters at The Applied Research Laboratory at Penn State for information on the laboratory scale system.
  Phone: (814) 865-4229 and Email: pnu@psu.edu

References:

[1] Clean Harbors Technology Corporation. "A breakthrough in Treatment CES Technology" Product Literature.
[2] Peters, J. "Supercritical Carbon Dioxide Bilgewater and Wastewater Treatment". Environmental Technology Focus. Applied Research Laboratory The Pennsyvania State University.

5.3 Storm Water

Currently, there are two research projects being conducted by the National Shipbuilding and Research Program that address storm water collection and treatment. The goals of these projects will be described below as well as three storm water treatment methods; sand filters, vortex solids separators and wet detention ponds. These last three methods are summarized in the Joint Service Pollution Prevention Opportunity Handbook which is described in Section 2.1.

1. Storm Water Collection, Treatment, Recycling, and Reuse
Task Number N1-96-7

Contact: *Larry Mizelle*
CASRM
222 E. Main Street
Norfolk, Virginia 23510
(757) 622-2137

This project started in December 1996. The objectives are to provide environmentally sound and cost-effective recommendations on the management of storm water runoff, to identify scientific approaches and options for storm water management, and to review regulatory limitations for storm water management. You can contact Mr. Mizelle for more information.

2. Heavy Metal Adsorbants for Storm Water Pollution Prevention
Task Number N1-96-4 Subtask 27

Contact: *Dr. William Burgos*
Department of Civil and Environmental Engineering
The Pennsylvania State University
(814) 863-0578

The objectives of this project are to evaluate the potential use of porous adsorbants for the removal of heavy metals from storm water and to examine common storm water collection and distribution systems to determine the most effective location(s) for adsorber placement. The project is schedueled for completion in December 1997.

Storm Water Treatment Methods

Technology

Sand Filter

Applicable Shipyard Process	Storm Water Runoff
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Basically, sand filters are composed of at least two components: a sedimentation chamber for removing floatables and heavy sediments, and a filtration chamber which filters flow through a sand bed to remove additional pollutants. A sand filter system effectively removes suspended solids, biochemical oxygen demand (BOD) and fecal coliform bacteria. It also removes other pollutants such as nitrogen, phosphorus, and some metals.

The Joint Services Pollution Prevention Opportunity Handbook provides an overview of sand filters for storm water quality control and managing storm water runoff volumes. You can obtain a copy of the handbook if you are a DoD contractor (see Section 2.1 under Joint Services Pollution Prevention Library) or view the sand filter datasheet through the Internet Address provided in the Contact Section of this Technology Datasheet. The Joint Services datasheet will provide a more detailed technology summary, contacts and an economic analysis. The information contained in this datasheet is obtained from the Joint Services Pollution Prevention Library datasheet on sand filters.

Technology (con't)

Sand Filter

Pollution Prevention Benefits

- high removal efficiencies for suspended solids, BOD and fecal coliform bacteria
- removal of hydrocarbons

Advantages

- see pollution prevention benefits

Disadvantages

- nitrites are not removed
- ineffective at removing dissolved pollutants

Contact:

- Joint Services P2 Technical Library
  Internet Address: http://enviro.nfesc.navy.mil/p2library then goto "Storm Water" and then "Sand Filters for Treating Storm Water Runoff"

References:

Joint Services P2 Technical Library. "Sand Filters for Treating Storm Water Runoff". February 1997.

Technology

Vortex Solids Separators

Applicable Shipyard Process	Storm Water Runoff
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

A vortex solids separator physically removes solids and floatables from wastewater or storm water using no moving parts. They are used for both combined sewer overflows (CSOs) and separate storm events. Data from solids removal studies indicate that vortex solids separators are effective at removing gritty materials, heavy particulates, and floatables from storm water, but ineffective in removing materials with poor settling capability [1].

The Joint Services Pollution Prevention Opportunity Handbook provides an overview of vortex solids separators. You can obtain a copy of the handbook if you are are a DoD contractor (see Section 2.1 under Joint Services Pollution Prevention Library) or view the vortex solids separator datasheet through the Internet Address provided in the Contact Section of this Technology Datasheet. The Joint Services datasheet will provide a more detailed technology summary, contacts and an economic analysis.

Technology (con't)

Vortex Solids Separators

Pollution Prevention Benefits

- ability to separate solids and floatables from storm water and wastewater

Advantages

- good in instances where a separations technology is limited by space or land constraints, such as surface slope or soil composition
- no moving parts so not maintenance intensive

Disadvantages

- limited effectiveness in use with wet weather flows
- may not meet water quality treatment objectives for some locations
- limited information available for vortex solids separators treating pollutants other than solids

Contact:

- Joint Services P2 Technical Library
  Internet Address: http://enviro.nfesc.navy.mil/p2library then goto "Storm Water" then "Vortex Solids Separators for Treating Storm Water Runoff"

References:

[1] Joint Services P2 Technical Library. "Vortex Solids Separators for Treating Storm Water Runoff". February 1997.

Technology

Wet Detention Pond

Applicable Shipyard Process	Storm Water Runoff
Pollution Prevention or Treatment Method?	Treatment Method
Commercially Available?:	yes

Technology Description

Basically a wet detention pond is a constructed pond that maintains a permanent pool of water within a designated area, and relies on physical, biological, and chemical processes to remove pollutants from storm water runoff. Sediment, organic matter, dissolved metals and nutrients are removed with this method.

The Joint Services Pollution Prevention Opportunity Handbook provides an overview of wet detention ponds to treat storm water runoff. You can obtain a copy of the handbook if you are a DoD contractor (see Section 2.1 under Joint Services Pollution Prevention Library) or view the wet detention pond datasheet through the Internet Address provided in the Contact Section of this Technology Datasheet. The Joint Services datasheet will provide a detailed technology summary, contacts and an economic analysis.

Technology (con't)

Wet Detention Pond

Pollution Prevention Benefits

- provide improved downstream water quality through removal of suspended solids, metals, and dissolved nutrients using natural biological and physical processes

Advantages

- can decrease the potential for downstream flooding and streambank erosion

Disadvantages

- should not construct pond near land constraints such as utilities or underlying bedrock
- sediments from upstream industrial or highly contaminated runoff areas may be hazardous waste requiring special disposal and treatment

Contact:

- Joint Services P2 Technical Library
  Internet Address: http://enviro.nfesc.navy.mil/p2library then goto "Storm Water" and then "Wet Detention Ponds to Treat Storm Water Runoff"

References:

[1] Joint Services P2 Technical Library. "Wet Detention Ponds to Treat Storm Water Runoff". February 1997.

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Internet Address: http://www.ilsr.org/carbo/factsh12.html

U.S. EPA. "Solvent Alternatives GuidE - SAGE".
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Internet Address: http://es.inel.gov/techinfo/facts/florida/terpclfs.html

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Contact: Jim Ruddock at (216) 439-4976

CO2 Pellet Blasting

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Contact Mr. Dave Frederick, Ogden Air Logistics Center (801) 775-2992

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Contact Ms. Jeannie Warnock, Sacramento Air Logistics Center (916) 643-2892

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Contact Mr. Darrel Tenney Jr., Naval Aviation Depot (804) 444-3550

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Contact Mr. Dave Frederick, Ogden Air Logistics Center (801) 775-2992

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Contact Mr. Mike Haas, San Antonio Air Logistics Center (512) 925-8541

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Appendix A Shipyard Survey

April 16, 1997

I am from The Pennsylvania State University Applied Research Laboratory and I am working with Janice Schneider on a project funded by the NSRP (National Shipbuilding Research Program) Facilities and Environmental Effects Panel (SP-1). The goal of this project is to determine the current technologies being implemented at shipyard facilities for controlling or reducing air and water emissions. I will then write a report summarizing the survey results, and detailing the currently available and emerging technologies to treat and control air and water emissions at shipyard facilities.

Your participation is very important and much appreciated. I expect that only some sections of the enclosed tables will be applicable to your shipyard and therefore do not expect fully completed tables. We tried to include all the potential processes occurring at shipyards but would appreciate any information on important processes at your yard that we have not included (these can be included in the sections marked *Other* in the enclosed survey tables). When I receive your responses I may call to discuss any questions that I have regarding your answers and to obtain more information about your air emissions and waste streams.

I would also like to know if there are pollution prevention or treatment methods you have heard of that you would like to see detailed in my report. You can use the last page of the survey, which is blank, to provide this information and you can use this page for questions and comments regarding the survey.

It is very important that I receive your responses as soon as possible and at the latest by May 12, 1997. Please use the enclosed envelope to return your responses to me. Thank you again for your time.

If I can be of assistance or if you have any questions please contact me at (814) 865-3536.

Sincerely,

Meryl R. Mallery
Environmental Engineer
The Applied Research Laboratory
The Pennsylvania State University
P.O. Box 30
State College, PA 16804-0030

Survey of Air and Water Pollution Prevention and Control Technology

Instructions

Please fill in the shipyard information and fill in the following tables. These tables request information on the treatment and control of air emissions and wastewater for several processes identified in shipyards. Please include any additional processes that have not been mentioned that contribute to air emissions or waste streams at your facility. Below is a list of typical questions that I am looking for answers to in the tables below. This is not intended to give you an exhaustive list but to give you an idea of the information that I am seeking.

Shipyard Information

Shipyard _____
Location _____
Contact Person _____
Phone _____
Fax _____
Email _____

Questions

Process Modifications

In this field I am looking for answers to questions such as those provided below:

1) Have your blasting techniques been modified to include dust reducing measures such as the use of slurry blast or hydroblasting or have you switched to the use of new blast media?
2) Are you using new surface coatings with lower VOC solvents or have you switched to new spray technologies for coating applications?
3) Have you replaced vapor degreasers with new cleaning methods such as semi-aqueous or aqueous cleaning?
4) Have you switched to more efficient welding methods that reduce air emissions from your welding processes?

Air and Water Treatment Technologies

1) Do you use blast enclosures or containment structures for outdoor blasting and if so what kind?
2) Do you perform blasting in a booth and if so, how do you treat air emissions?
3) Do you control VOC emissions from coating operations?
4) What do you use to collect and treat welding fumes, machining particulates, VOCs from metal finishing operations?
5) Are you using new methods to treat cooling tower water (i.e. to replace the use of hexavalent chromium)
6) Do you treat waste solvents on site and if so how do you treat them?

Note: If you do not have enough room for responses in the enclosed tables please use the last page of the survey to provide the remainder of your responses.

Table 1 Control, Collection and Treatment of Air Emissions

Process		Process Modifications			Air Treatment Technologies			
Process	Does your shipyard perform this process?	If yes, have you modified this process to reduce air emissions?	If you have modified this process, what process modifications have you made? Please describe the process modification or alternate material and provide vendor names, if applicable.	Would you recommend this process modification to to other shipyards? Please explain.	Do you treat air emissions from this process?	If you treat air emissions, what treatment method do you use? Please describe what method and provide vendor names, if applicable.	Would you recommend this treatment method to other shipyards? Please explain.	Is your shipyard currently considering any alternative technologies for this process or considering any air treatment methods. Please describe briefly.
Surface Preparation	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Surface Coating	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Welding	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Parts or Equipment Cleaning	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Metal Finishing	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no

Table 1 Control, Collection and Treatment of Air Emissions (continued)

Process		Process Modifications			Air Treatment Technologies			
Process	Does your shipyard perform this process?	If yes, have you modified this process to reduce air emissions?	If you have modified this process, what process modifications have you made? Please describe the process modification or alternate material and provide vendor names, if applicable.	Would you recommend this process modification to to other shipyards? Please explain.	Do you treat air emissions from this process?	If you treat air emissions, what treatment method do you use? Please describe what method and provide vendor names, if applicable.	Would you recommend this treatment method to other shipyards? Please explain.	Is your shipyard currently considering any alternative technologies for this process or considering any air treatment methods. Please describe briefly.
Composite Material Operations	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Boiler Operations	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Internal Combustion Engines	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Other (Please Specify)	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no

Table 2 Control, Collection and Treatment of Waste Water

Process		Process Modifications			Water Treatment Technologies			
Process	Does your shipyard perform this process?	If yes, have you modified this process to reduce the waste stream generated?	If you have modified this process, what process modifications have you made? Please describe the process modification or alternate material used and provide vendor names, if applicable	Would you recommend this process modification to to other shipyards? Please explain.	Do you treat the waste stream generated from this process?	If you treat the waste stream, what collection and treatment method do you use? Please describe what methods and provide vendor names, if applicable.	Would you recommend this treatment method to other shipyards? Please explain.	Is your shipyard currently considering any alternative technologies for this process or considering any water treatment methods? Please describe.
Parts or Equipment Cleaning	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Metal Finishing	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Surface Preparations Using Water (hydroblasting, etc.)	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Steam Cleaning of Vehicles	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Composite Material Operations	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no

Table 2 Control, Collection and Treatment of Waste Water (continued)

Waste Stream		Process Modifications			Water Treatment Technologies			
Waste Stream	Does your shipyard deal with this waste stream?	If yes, have you modified processes to reduce this waste stream?	If you have modified processes, what process modifications have you made? Please describe the process modification, if applicable.	Would you recommend the process modification to to other shipyards? Please explain.	Do you treat this waste stream?	If you treat this waste stream, what collection and treatment methods do you use? Please describe what methods and provide vendor names, if applicable.	Would you recommend this treatment method to other shipyards? Please explain.	Is your shipyard currently considering any alternative technologies for this process or considering any water treatment methods? Please describe.
Storm Water Run-off	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Floating Dry Dock Ballast Tank Water	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Ship Bilge/Ballast Water	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Sewage & Grey Water from Ships	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no
Other* (Please Specify)	__yes__ no	__yes__ no		__yes__ no	__yes__ no		__yes__ no	__yes__ no

*any waste streams such as graving dock water that you may be treating. I did not have sufficient space to list all waste streams that might be generated from dock operations.

Appendix B Vendor Listing

This listing is not inclusive of all vendors for a given technology. It includes only those vendors which were directly contacted by The Applied Research Laboratory or who contacted us. Please check Section 2.2 for sources to find additional vendors for a given technology.

Vendor Listing

CLEANING OPERATIONS

Aqueous Cleaning

The Hotsy Aqueous Cleaning Corp.

Mailing Address: 21 Inverness Way E
Englewood, CO 80112-5796

Phone Number: (303) 792-5200

Simple Green

Mailing Address: P.O. Box 880135
El Paso, Texas 88588-0135

Phone Number: (800) 228-0709

Closed-Loop Cleaning Systems

Envirosolutions, Inc.

Mailing Address: 335 Post Road West
Westport, CT 06880

Phone Number: (203) 454-5902

Vector Environmental, Inc.

Mailing Address: 3374 West Hopkins Street
Milwaukee, WI 53216

Phone Number: (414) 444-4010

Unitech Industrial Inc.

Mailing Address: P.O.Box 330/ 16 South Ave.
Wappingers Falls, NY 12590

Phone Number: (800) 277-5522

Pressure Island

Mailing Address: 855 Oak Grove Ave., Suite 202
Menlo Park, CA 94025

Phone Number: (415) 473-4800

Vendor Listing

CLEANING OPERATIONS

Environmentally Friendly Solvents & Services

Safety-Kleen

Mailing Address:

Phone Number: (800) 323-5040

Petroleum Hydrocarbons

Inland Technology / ISO Prep

Mailing Address: 2612 Pacific Highway East Suite C
Tacoma, Washington 98424

Phone Number: (206) 922-8932

Supercritical Carbon Dioxide Cleaning

Liquid Carbonic Supercritical

Mailing Address: 966 Postal Road
Allentown, PA 18103

Phone Number: (215) 266-9693

Painter Design & Engineering

Mailing Address: 37230 20 Mile Rd.
New Baltimore, MI 48047

Phone Number: (810) 725-3330

CF Technologies

Mailing Address: 1 Westinghouse Plaza, Suite 200
Hyde Park, MA 02136-2059

Phone Number: (617) 364-2500

Terpene Blends

GLIDCO Organics

Mailing Address: P.O. Box 389
Jacksonville, FL 32201

Phone Number: (800) 231-6728

Vendor Listing

CLEANING OPERATIONS

Terpenes

Spectro-Chemical Lab Division / Coors Bio-T

Mailing Address: 600 Nineth Street
Golden, CO 80401

Phone Number: (303) 277-4254

SURFACE COATING/PREVENTION

Air-Assisted Airless Spray Gun

Graco Inc.

Mailing Address: P.O. Box 1441
Minneapolis, MN 55440-1441

Phone Number: (800) 367-4023

UNICARB System

Union Carbide

Mailing Address:

Phone Number: (203) 794-2522

SURFACE COATING/TREATMENT

Adsorption Systems

Metro-Pro Corp. Systems Division

Mailing Address: 160 Cassell Road
Harleysville, PA 19438

Phone Number: (215) 723-6751

Durr Industries, Inc.

Mailing Address: 40600 Plymouth Road
Plymouth, MI 48170

Phone Number: (313) 459-6800

SURFACE COATING/TREATMENT

FBCI

ARI Technologies, Inc.

Mailing Address: 600 N. 1st Bank Drive
Palatine, IL 60067

Phone Number: (708) 359-7810

Flameless Thermal Oxidizer

Thermatrix Inc. / Flameless Thermal Oxidizer

Mailing Address: 3590 N. First Street, Suite 30
San Jose, CA 95134

Phone Number: (408) 944-0220

Regenerative Thermal Oxidizer

United McGill Corporation / Thermagrid Regenerative Th

Mailing Address: One Mission Park, P.O. Box 7
Groveport, OH 43125

Phone Number: (614) 836-9981

Durr Industries, Inc.

Mailing Address: 40600 Plymouth Road
Plymouth, MI 48170

Phone Number: (313) 459-6800

Smith Engineering Company

Mailing Address: 2837 East Cedar Street
Ontario, CA 91761

Phone Number: (714) 923-3331

Tellkamp Systems, Inc./ Roxidizer

Mailing Address: 15520 Cornet Ave
Santa Fe Springs, CA 90670

Phone Number: (310) 802-1621

SURFACE PREPARATION

SURFACE PREPARATION

Abrasive Blasting

N.T. Ruddock Co. / ALUMAGLASS

Mailing Address: 600 Golden Oak Parkway
Cleveland, OH 44146

Phone Number: (216) 439-4976

The TDJ Group, Inc. / Blastox

Mailing Address: 760-K Industrial Drive
Cary, IL 60013

Phone Number: (847) 639-1113

Air Abrasive Wet Blast

Clemtex, Inc./ Clemtex WAB 60031

Mailing Address: P.O. Box 15214
Houston, TX 77020-5214

Phone Number: (713) 672-8251

Clemco Industries / Clemco Wet Blast Injector System

Mailing Address: P.O. Box 7680
San Francisco, CA 94120

Phone Number: (415) 282-7290

Air/water/abrasive Slurry Blast

Hydrair-America Company

Mailing Address: P.O. Box 1332
Roswell, GA 30077

Phone Number: (404) 476-4071

Williams Contracting

Mailing Address: 2076 West Park Place
Stone Mountain, GA 30087

Phone Number: (404) 498-2020

SURFACE PREPARATION

Carbon Dioxide Pellet Blast

Cold Jet, Inc.

Mailing Address: 455 Wards Corner Road Suite 100
Loveland, OH

Phone Number: (513) 831-3211

High and Low Pressure Water Abrasive Blast

American Aero Cranes & Water Blasting Systems

Mailing Address: P.O. Box 41249
Houston, TX

Phone Number: (713) 896-2002

High Pressure Water Abrasive Blast

Aqua-Dyne, Inc.

Mailing Address: 2208 Karbach Street
Houston, TX 77092-8096

Phone Number: (800) 231-9174

High Pressure Waterjet

NLB Corporation

Mailing Address: 29830 Beck Road
Wixom, MI 48393-2824

Phone Number: (810) 624-5555

Low Pressure Water Abrasive Blast

Hydrosander, Inc.

Mailing Address: 5617 Fairfield Road
Columbia, SC 29203

Phone Number:

SURFACE PREPARATION

Sodium Bicarbonate Blasting

Church and Dwight Specialty Co. / Accustrip System

Mailing Address: 469 N. Harrison Street
Princton, NJ 08540

Phone Number: (800) 221-0453

Sponge Blasting

Sponge-Jet and Trade

Mailing Address: 95C Dow Highway
Eliot, Maine 03903

Phone Number: (207) 439-0211

Ultra-high Pressure Water Blasting

Jet Edge

Mailing Address: 825 Rhode Island Avenue South
MInneapolis, MN 55426

Phone Number: (612) 545-1477

Flow International Corporation

Mailing Address:

Phone Number: (800) 446-3569

Butterworth, Inc. / Butterworth Liqua-Blaster

Mailing Address: P.O. Box 18312, 3721 Lapas Drive
Houston, TX 77223

Phone Number: (800) 231-3628

Woma Corporation

Mailing Address:

Phone Number: (800) 258-5530

SURFACE PREPARATION AND COATING

SURFACE PREPARATION AND COATING

Covers for Blasting and Painting Operations

Atlantic Supply Company / Monaflex Protection System

Mailing Address: P.O. Box 432, 93 Grove Street
Peterborough, New Hampshire 03458

Phone Number: (800) 225-7704

Indian Valley Industries, Inc. / Enviroscreen and Envirotar

Mailing Address: P.O. Box 810
Johnson City, New York 13790

Phone Number: (800) 659-5111

Hipp Plastic Wrap

Mailing Address: 7996 Armour St.
San Diego, CA 92111

Phone Number: (619) 541-2960

Fabric Building Systems, Inc.

Mailing Address: P.O. Box 673
San Leandro, CA 94577

Phone Number: (510) 562-5399

Reef Industries, Inc. / Armorlon

Mailing Address: P.O. Box 750218
Houston, Texas 77275-0218

Phone Number: (713) 943-7213

Eagle Industries of LA, Inc.

Mailing Address: P.O. Box 10652
New Orleans, LA 70181

Phone Number: (504) 733-3510

Enclosure for Painting and Blasting Operations

MMC Compliance Engineering, Inc. / CAPE

Mailing Address: P.O. Box 1860
Norfolk, VA 23501

Phone Number: (757) 494-0710

WASTEWATER TREATMENT

Wastewater Treatment Technologies

T2 Environmental Inc. / BOWTS

Mailing Address: 2596 North Star Cove
Port Hueneme, CA 93041

Phone Number: (805) 984-7260

AFL Industries

Mailing Address: 3661 W. Blue Heron Blvd
Riveria Beach, Florida 33404

Phone Number: (407) 844-5200

Clean Harbors Technology Corporation

Mailing Address: 1200 Crown Colony Drive/ P.O. Box 9137
Quincy, MA 02269-9137

Phone Number: (800) 533-5900

WELDING

Electrostatic Precipitators

United McGill Corporation

Mailing Address: One Mission Park, P.O. Box 7
Groveport, OH 43125

Phone Number: (614) 836-9981

Appendix C

Example of a Technology Summary
Joint Services P2 Handbook

Tri-Services'
Pollution Prevention Technical Library

Maintained by the Naval Facilities Engineering Service Center (NFESC)

Plastic Media Blasting (PMB) Paint Stripping

Methyl benzene, phenylmethane, C6H5CH3; dimethylbenzene, C6H4(CH3)2; ethyl methyl ketone, 2-butanone, MEK, CH3COCH2CH3; dimethylketone, 2-propanone, CH3COCH3; 1-butanol, butyric alcohol, CH3(CH2)2CH2OH; plumbum, Pb; Cr; carboxyic acid, phenylic acid, benzophenol, hydroxybenzene, C6H5OH; chloracetic acid, MCA, monochloroacetic acid, CH2ClCOOH; methylene dichloride, dichloromethane, CH2Cl2 Ketone, Acetone, n-Butyl Alcohol, Lead, Chromium, Zinc Compounds, Phenols, Chloroacetic Acids, and Methylene Chloride Methyl benzene, phenylmethane, C6H5CH3; dimethylbenzene, C6H4(CH3)2; ethyl methyl ketone, 2-butanone, MEK, CH3COCH2CH3; dimethylketone, 2-propanone, CH3COCH3; 1-butanol, butyric alcohol, CH3(CH2)2CH2OH; plumbum, Pb; Cr; carboxyic acid,

Revision: 9/96

Process Code: Navy: ID-01-99; Air Force: ST01; Army: DPT

Usage List: Navy: High; Army: High; Air Force: High

Substitute for: Chemical Paint Stripping/Sand Blasting

Applicable EPCRA Targeted Constituents: Toluene (CAS: 108-88-3), Xylenes (CAS: 1330-20-7), Methyl Ethyl Ketone (CAS: 78-93-3), Acetone (67-64-1), n-Butyl Alcohol (CAS: 71-36-3), Lead (CAS: 7439-92-1), Chromium (CAS: 7440-47-3), Zinc Compounds, Phenols (CAS: 108-95-2), Chloroacetic Acids (CAS: 79-11-8), Methylene Chloride (CAS: 75-09-2)

Overview:

Plastic Media Blasting (PMB) is a dry abrasive blasting process, designed to replace chemical paint stripping operations and conventional sand blasting. This process uses soft, angular plastic particles as the blasting medium.

PMB is performed in a ventilated enclosure such as a small cabinet (glove box), a walk-in booth, a large room, or airplane hanger. The PMB process blasts the plastic media at a much lower pressure (less than 40 psi) than conventional blasting. PMB is well suited for stripping paints, since the low pressure and relatively soft plastic medium have minimal effect on the surfaces beneath the paint.

After blasting, the media is passed through a reclamation system that consists of a cyclone centrifuge, a dual adjustable air wash, multiple vibrating classifier screen decks, and a magnetic separator. In addition, some manufacturers provide dense particle separators as a reclamation system. The denser particles, such as paint chips, are separated from the reusable blast media, and the reusable media is returned to the blast pot. Typically, media can be recycled ten to twelve times before it becomes too small to remove paint effectively. Waste material consists of blasting media and paint chips. The waste material may be classified as a RCRA hazardous waste because of the presence of metals. An alternative solution to handling a potential hazardous waste is to locate a vendor that would "lease" the blast media to the base and then recycle the media to recapture the metals.

Plastic media are manufactured in 6 types and a variety of sizes and hardnesses. A military specification (MIL-P-85891) has been developed for plastic media. The specification provides general information on the types and characteristics of plastic media. The plastic blasting media types are:

Type I Polyester (Thermoset)

Type II Urea formaldehyde (Thermoset)

Type III Melamine formaldehyde (Thermoset)

Type IV Phenol formaldehyde (Thermoset)

Type V Acrylic (Thermoplastic)

Type VI Poly(allyl diglycol carbonate) (Thermoset)

PMB facilities typically use a single type of plastic media which they use for all of their PMB work. The majority of DOD PMB facilities use either Type II or Type V media. Type V media is not as hard as Type II media and is gentler on substrates. Type V media is more commonly used on aircraft. Type II is better for steel-only surfaces.

An option with PMB is to lease the plastic media. Under the lease program, the used plastic media is picked up by the leasing company for recycling. This option eliminates media waste from the PMB facility wastestream.

The effect that this technology has on pollution prevention is that reusing the blasting media greatly reduces the volume of spent media generated as compared to sand blasting. When compared to chemical paint stripping, this technology eliminates the generation of waste solvent.

PMB is being used at Puget Sound, Charleston, and Portsmouth Naval shipyards; Naval Aviation depots (NADEPs) San Diego, Norfolk, and Cherry Point; and Naval Surface Warfare Center (NSWC) Indian Head, as well as other Navy activities and throughout the Army and Air Force. Plastic media glove boxes and enclosed blasting booths have been installed at aircraft maintenance activities to remove paint from support equipment and components. A blast media lease and recycle program is currently in place at NADEP Cherry Point. A more detailed list of organizations within the DOD depot maintenance community that have implemented PMB operations is provided in Appendix III of *Joint Paint Removal Study, Final Report Plastic Media Blast*, Joint Depot Maintenance Analysis Group, Technology Assessment Division, June 1994.

Materials Compatibility:

Storage and handling of plastic media and blast waste associated with this process pose no compatibility problems. Prior to using plastic media for depainting operations, personnel should check applicable military specifications [such as (MIL-P-85891)] and operations manuals for the PMB systems. Plastic media cannot be used with a system designed for other types of media. Some military specifications do not allow PMB for depainting certain types of materials (i.e. fiberglass, certain composites, honeycomb sandwich structures, and some applications with thin-skinned aircraft components). In certain cases, PMB can inhibit crack detection on some of the softer alloys used for aircraft components (i.e. magnesium).

Safety and Health:

As with any blasting operations, airborne dust is a major safety and health concern. Proper precautions should be taken to ensure that personnel do not inhale dust/particulate matter. Additional protective measures should be taken when stripping lead chromate- or zinc chromate-based paints, as these compounds may be hazardous. Inhalation of l and zinc compounds can irritate the respiratory tract, and some compounds are known to be carcinogenic. Inhalation of paint solvents can irritate the lungs and mucous membranes. Prolonged exposure can affect respiration and the central nervous system. Operators must wear continuous flow airline respirators in accordance with OSHA requirements as specified in 29 CFR 1910.94 when blasting operations are in progress.

Consult your local industrial health specialist, your local health and safety personnel, and the appropriate MSDS prior to implementing this technology.

Benefits:

Media can be recycled for use (10-12 recycling events)
Wastewater disposal costs (typical in chemical paint stripping operations) are virtually eliminated with PMB
Eliminates the production of waste solvents when compared to chemical paint stripping

Disadvantages:

Substantial capital equipment investment is required
Solid wastes may have to be disposed as a hazardous waste
Operator time, maintenance requirements, handling and disposal of waste varies upon material to be stripped
Quality of stripping is dependent on skill and experience level of the operator
Military specifications do not allow PMB for depainting certain types of materials
May not remove corrosion

Economic Analysis:

PMB systems can range in cost from $7,000 for a small portable unit to $1,400,000 for a major facility for aircraft stripping. The following information on investment costs and costs/payback for PMB systems at Hill AFB, Utah, was provided in *Joint Paint Removal Study; Final Report; Plastic Media Blast*, Joint Depot Maintenance Analysis Group, Technology Assessment Division, June 1994.

In 1987, Hill AFB gathered data during the stripping of F-4 aircraft using chemical stripping and PMB.

Assumptions:

Labor rate: $45/hr
Work load = 75 aircraft/yr
Labor per airplane: 183 hrs for blasting, 364 hrs for chemical stripping
Chemical procurement cost: $11.40/gallon
Chemical use per airplane: 468 gallons
Plastic media procurement cost: $1.76/lb
Plastic media used per airplane: 1,500 lbs
Water treatment/disposal: $8.24/1000 gallons
Water usage per airplane: 200,000 gallons
Electricity usage costs per airplane: PMB = $173; chemical stripping = $333
Paint and solvent waste disposal: 0.51 ton per airplane at $200/ton
Spent media and blast waste disposal: 0.85 ton per airplane at $260/ton
Water purchase costs: $0.43/1000 gallons

Maintenance costs per airplane: PMB = $1,333; chemical stripping = $667
Cost per airplane to strip parts which can't be done using PMB: $667

Annual Operating Cost Comparison for

PMB and Chemical Stripping

	PMB	Chemical Stripping
Operational Costs:		
Labor:	$617,600	$1,228,500
Chemical:	$0	$400,100
Plastic Media:	$198,000	$0
Water Treatment/ Disposal:	$0	$123,600
Electricity:	$13,000	$25,000
Hazardous Waste Disposal:	$16,600	$7,700
Water:	$0	$6,500
Maintenance Cost:	$100,000	$50,000
Cost of parts not done by PMB:	$50,000	$0
Total Operational Costs:	$995,200	$1,841,400
Total Recovered Income:	$0	$0
Net Annual Cost/Benefit:	-$995,200	-$1,841,400

Economic Analysis Summary

Annual Savings for PMB: $846,200
Capital Cost for Diversion Equipment/Process: $1,400,000
Payback Period for Investment in Equipment/Process: < 2 years

Approving Authority:

y: PMB is not authorized for use on aluminum and magnesium components that require a fluorescent penetrant inspection. NAVAIR has authorized PMB use on metal substrates under specific process control parameters at depot activities. NAVAIR has not authorized PMB for depainting composites, other non-metal substrates, or honeycomb sandwich structures. This recommendation should be implemented only after engineering approval has

been granted by cognizant authority.

Points of Contact:

Charles Tittle
S . 00TB
Naval Sea Systems Command
2531 Jefferson Davis Highway
Arlington, VA 22242-5160
Phone: (703) 602-3594, DSN: 332-3594
Fax: (703) 602-7213

Greg Piner
Code 342
Naval Aviation Depot
PSC Box 8021
Cherry Point, NC 28533-0021
Phone: (919) 466-7343, DSN: 582-8108
Fax: (919) 466-8108

Butch Green
LMTCE Code 343
Naval Aviation Depot
Naval Air Station Jacksonville
Jacksonville, FL 32212-0016
Phone: (904) 772-2469, DSN: 942-2481

Vendors:

The following is a list of PMB manufacturers. This is not meant to be a complete list, as there may be other manufacturers of this type of equipment.

Pauli & Griffin
907 Cotting Lane
Vacaville, CA 95688
Phone: (800) 666-1115
Fax: (707) 447-7036

Schlick-America Inc.
P.O. Box 374
Randallstown, MD 21133
Phone: (410) 655-0770
Fax: (410) 521-0483

Leasing Services:

Solidstrip, Inc.,
601 Interchange Blvd.
Neward, Delaware 19711
Phone: (800) 677-4568
Fax: (302) 292-8340

Composition Materials
1375 Kings Highway East
Fairfield, CT 06430

Phone: (800) 262-7763
Fax: (203) 335-9728

L.S. Solutions, Incorporated
P.O. Box 309
[illegible] Park, TX 77536
Phone: (713) 478-6522
Fax: (713) 478-6531

Sources:

Joint Paint Removal Study; Final Report; Plastic Media Blast, Joint Depot Maintenance Analysis Group, Technology Assessment Division, Dayton, Ohio; June 1994; (513) 296-8296.

N.E. Wasson, Jr., P.E., "Dry Stripping the C-5 and B-52 in the World's Largest Dry Stripping Installation", Proceedings of the Second Annual AF Worldwide Pollution Prevention Conference, June 2, 1993.

Butch Green, LMTCE Code 343, Naval Aviation Depot, Naval Air Station Jacksonville, June 1996.

Mark Meno, NADEP Cherry Point, July 1996.

Brian Lund, Solidstrip, Inc., June 1996.

Return to Depainting

lhill@nfesc.navy.mil
Last Updated: October 28, 1996

Appendix D Example of SAGE Cleaning Process Summaries

SAGE

Solvent Substitution Tools

Tools	Description
SAGE Expert System	The Expert System evaluates a process based on the user's responses to a set of questions. It then provides a list of ranked alternatives with links to more information about those alternatives.
Solvent and Process Alternatives Index	The hypertext index includes descriptions of alternatives, case studies, economic and environmental information, references, etc.
NESHAP for Degreasers Decision Tree	The decision tree will help users determine their requirements under The National Emission Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning.
State Information Page	The State information page provides links to and information on various State environmental and technical assistance contacts.
Glossary	The glossary includes terms found in SAGE and common to cleaning and degreasing applications.
Process Conversion Checklist	The checklist contains a listing of items that should be considered by shop supervisors or anyone involved with implementing or converting cleaning processes.
EPA Documents	Documents from the U.S. EPA available in Adobe PDF format.
Integrated Solvent Substitution Data System	The ISSDS allows users to query multiple information sources, including SAGE, for information on solvent substitution.

Homepage EnviroSense Expert System

sagemaster@clean.rti.org
Last Update: 18 February 1997
Submit Comments

URL: http://clean.rti.org/tools.htm

N-METHYLPYRROLIDONE (NMP)

NMP is an organic solvent. It is a volatile organic compound (VOC) and has a low vapor pressure of 0.29 mm Hg at 68 °F (0.39 mbar at 20 °C). It is combustible, with a flash point of 199 °F (93 °C). Its threshold limit value (TLV) is 100 ppm.

NMP cleans heavy oil and carbon deposits from engine parts. It is an excellent solvent for many coatings, including polyurethanes, printing inks, epoxy resins, polyamidimide-based wire enamels, and water-based coatings. Many plastics, including polystyrene, polyesters, and polyvinyl chloride are soluble in NMP. NMP also can strip paint.

NMP is acceptable for use in both immersion and ultrasonic processes. Pure NMP is commonly used, but it is available blended with surfactants or other solvents. It is also combined with a water rinse in semiaqueous processes.

Many oils become soluble in NMP only when the solvent is above 145 °F (63 °C). The oils can be separated from the solvent after the cleaning step by lowering the NMP temperature. The solvent can then be reused and the oil can be recycled.

NMP is listed under SARA 313 Title III (EPCRA), section 313(d)(2)(B), serious or irreversible chronic health effects. The effective date was January 1, 1995. First reports are due July 1, 1996. The full discussion can be found in the Federal Register dated November 30, 1994, Vol. 59, No. 229, pp. 61432-61485

PROCESS UNIQUE INFORMATION

 Environmental information concerning regulations and disposal.

 General information concerning the process and its uses.

 Representative MSDS summaries

 References containing information related to this alternative.

 Safety information on operator/process issues.

OTHER INFORMATION

GLOSSARY || STATE INFORMATION || PROCESS CONVERSION CHECKLIST